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The musculoskeletal contribution to the evolution of chronic lumbopelvic pain: 2. Sporting activities and chronic pelvic pain

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Abstract

Where there is no proven infection or obvious local pathology, the occurrence of chronic pelvic pain (CPP) syndrome may involve contributions from the musculoskeletal, neurological, urological, gynaecological and immune systems. Part 2 of this article discusses the general effect of aerobic activity on CPP and then specific groin injuries, and includes a classification of movement-impairment syndromes of the hip to aid assessment and rehabilitation. This is followed by a discussion of cycling and other sporting activities associated with CPP.

Keywords: chronic pelvic pain syndrome, movement, musculoskeletal pain.

Introduction

Where there is no proven infection or obvious local pathology, the occurrence of chronic pelvic pain (CPP) syndrome (CPPS) may involve contributions from the musculoskeletal, neurological, urological, gynaecological and immune systems. In part 1 of this article, the potential musculoskeletal contributions of the lumbar spine and pelvis to CPPS were described (Jones *et al.* 2013). This provided the practitioner with a systematic assessment to identify the postural alignment strategies, habitual movement patterns and interactions of the lumbopelvic cylinder that may be contributing to an individual's presenting condition. However, persistent pain is also associated with changes in the central nervous and immune systems, and therefore, we need to be reminded that the purely structural-pathology-based model for explaining CPPS is outdated. Furthermore, since CPPS is often associated with negative cognitive, sexual and emotional consequences, these may also need to be addressed in order to provide optimum care for the patient.

Part 2 of this article discusses the general effect of aerobic activity on CPP and then specific groin injuries, and includes a classification of movement-impairment syndromes of the hip to aid assessment and rehabilitation. This is followed by a discussion of cycling and other sporting activities associated with CPP.

The effect of aerobic exercise on chronic pelvic pain

Orsini *et al.* (2006) showed that a sedentary lifestyle is a risk factor for CPP. These authors analysed surveys of 30 000 Swedish men aged between 45 and 70 years, and concluded that those who were physically active at work and pursued an active lifestyle in their leisure time showed a 50% reduction in their risk of severe lower urinary tract symptoms compared to inactive men. Inactivity of greater than 5 h a day (at plus 30 years of age) was associated with a twofold increased risk in developing

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symptoms. Orsini *et al.* (2006) concluded that physical activity in young and late adulthood appears to be associated with a lower risk of moderate and severe urinary tract symptoms.

In a double-blind, randomized controlled trial, Giubilei *et al.* (2007) compared the effects of an aerobic exercise programme ($n=52$) versus placebo/stretching and motion exercises ($n=51$) on a group of previously sedentary men. The cohort was recruited from a volunteer sample of 231 men who had at least a 12-month diagnosis of chronic prostatitis/CPP syndrome, who had not responded to conventional treatment for CPP and who had no contraindications to moderately intense physical exercise. The aerobic exercise protocol included:

- a warm-up and cool-down regimen of slow-paced walking;
- postural muscle isometric strengthening; and
- 40 min of fast-paced outdoor walking, at 70–80% of maximum heart rate.

The control group performed flexibility and motion exercises for the same length of time and frequency, but exercised at a level of a steady heart rate of 100 beats per minute. The results showed improvement in both groups at the end of the 18-week exercise period; however, the improvements in the aerobic exercise group were significantly better compared to those in the placebo/stretching group. Despite the small numbers in the study and the short length of the follow-up, the above authors recommended aerobic exercise as a valid treatment option in the treatment of CPP until further studies could confirm or repudiate their findings.

Specific groin injuries

Sports that include kicking, side-to-side cutting, interval sprinting, rapid or sudden changes of direction, quick accelerations and decelerations, and repetitive hip and pelvic girdle rotation with axial loading, such as running, golfing, ice hockey, figure skating, football, baseball, ballet, martial arts and gymnastics, have a high incidence of groin injuries (Verral *et al.* 2002; Cowan *et al.* 2003; Shindle *et al.* 2007; Pizzari *et al.* 2008). According to Lovell (1995, cited in Nam & Brody 2008), determining a differential diagnosis is essential, since 27–90% of patients who present with groin pain manifest more than one injury. These coexisting problems are thought to arise as a result of an initial injury altering the complicated biomechanics of the hip and groin, leading to secondary overuse injuries and/or the close proximity of anatomical elements in the region, predisposing one insult to involve adjacent structures (Morelli & Weaver 2005). Furthermore, in the sporting arena, the primary source of specialist consultation is the orthopaedic surgeon, who may perform a wide-ranging assessment of the musculoskeletal system with no real evaluation of pelvic girdle mobility or pelvic floor musculature. The patient is unlikely to be asked about urinary, bowel or sexual dysfunction, and often does not volunteer this information unless prompted. Likewise, the urological specialist will provide a thorough assessment and examination of the pelvic floor, bladder and bowel, but there will be no musculoskeletal component to the assessment. As described previously, many patients with CPP have a complex presentation and may well fit into more than one diagnostic category, resulting in a "best fit" diagnosis. If the signs and symptoms do not fit neatly into a diagnostic category, then a more creative approach to the assessment of the patient's condition is warranted.

The common types of groin injuries are listed below (see also Table 2):

- ligament and muscle strains/tendonitis/tendonosis/bursitis:
  - iliopsoas;
  - piriformis/obturator internus/obturator externus/gemelli;
  - sartorius/gracilis;
  - adductor magnus/brevis/longus/pectineus/gracilis; and
  - hamstring insertional injuries;
- acetabular tears;
- osteitis pubis (OP);
- athletic pubalgia or sports hernias;
- avulsion and stress fractures:
  - anterior inferior iliac spine – rectus femoris and gracilis;
  - adductors at the pubic rami;
  - hamstrings at the ischial tuberosity;
  - femoral neck; and
  - pubic rami;
- nerve compression injuries:
  - obturator nerve;
  - femoral nerve;
  - iliohypogastric nerve;
  - genitofemoral nerve;
  - ilioinguinal nerve;
  - lateral femoral cutaneous nerve of the thigh; and
  - pudendal nerve.

Ligament and muscle strain

The most common site of strain is the musculotendinous junction of the adductor longus or gracilis muscle, and this is also the most common cause of groin pain in the athlete (Reid 1992). The incidence among soccer players is between 10% and 18% (Nielsen & Yde 1989).

Muscular and tendinous assessment can be performed using Cyriax's soft-tissue tension differentiation tests, which involve palpation of the muscle over the area of strain, and the elicitation of pain on resisted adduction and passive stretch into abduction (Ombregt *et al.* 2002). The history of the injury usually provides information about the biomechanical forces and the likely tissues involved, and the use of real-time ultrasound imaging can help to confirm or exclude the diagnosis of tendonosis/tendonitis or muscle tear (Heyde *et al.* 2005). Care must be taken to differentiate muscle strains and tendonoses/tendonitis from OP, sports hernias and nerve entrapment (described below), which can present with similar symptoms (Morelli & Weaver 2005). In cases where athletes recall a traumatic event that results in the acute onset of symptoms, the diagnosis is more straightforward (Reid 1992).

When the onset of symptoms is insidious, a definitive diagnosis is hard to make, and patients in this category are often difficult to treat with orthodox protocols for adductor strains. It is these patients who present with ambiguous signs and symptoms who appear to fit into the CPP category since soft-tissue differentiation tests can often be equivocal. For example, during active contraction of the adductors, which insert directly into the ramus of the pubis, stress on the symphyseal tissue can reproduce the patient's symptoms and produce a false-positive test. This is usually confirmed by a lack of insertional tenderness and the absence of pain on passive stretch (Ombregt *et al.* 2002). If an adductor strain is suspected, the tear has to be accurately located, and this requires accurate and precise knowledge of functional anatomy (Fig. 1). There is a need to know whether the strain has occurred in the belly of the muscle or the musculotendinous junction rather than the insertion into the pubic bone. This will in part determine how aggressive the treatment programme can be (Fricker 1997), since insertional strains will require an initial period of rest before active rehabilitation can begin (Reid 1992). Decreased abductor range of motion and decreased adductor strength are associated with an increased incidence of adductor strains (Ekstrand & Gillquist 1983; Tyler *et al.* 2001). Biomechanical abnormalities of the lower limb, imbalance of the surrounding hip musculature and muscular fatigue have also been hypothesized to increase the risk of adductor strain (Hölmich *et al.* 1999). Prevention programmes focused on eliminating some of these abnormalities have been shown to be effective in professional hockey players, although there have been no controlled clinical studies proving these latter elements to be causative (Tyler *et al.* 2002).

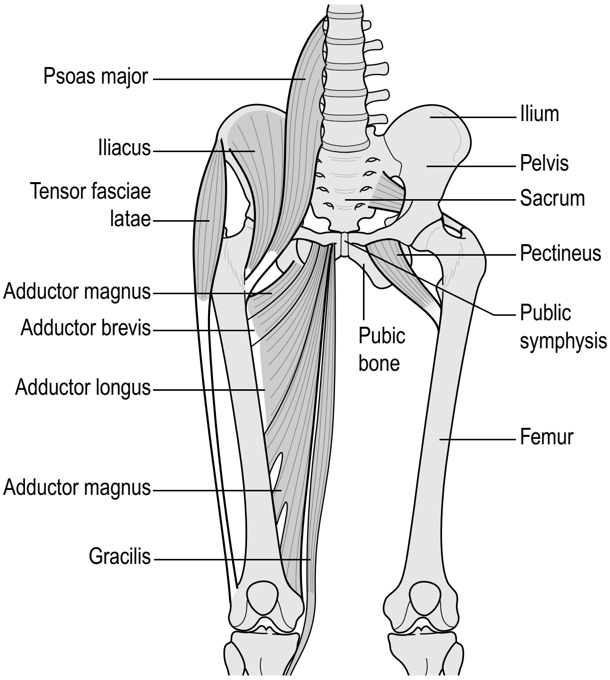

Figure 1. Diagram of the bony pelvis showing the insertion of the adductor group of muscles.

The iliopsoas originates from the transverse processes and anterior vertebral bodies of the lumbar vertebrae, passing inferiorly to insert on the lesser trochanter of the femur. It traverses the pelvic rim and crosses the hip joint, and it is at this point that the iliopsoas bursa is interposed between the muscle and the underlying bone. The iliopsoas bursa (Fig. 2) is the largest bursa in the body and has a direct communication with the hip joint in 15% of patients (Standring 2008); it is best visualized on a magnetic resonance imaging (MRI) scan (Reid 1992). The bursa and tendon can become irritated as they rub over the iliopectineal eminence of the pubis, particularly in sports requiring a significant use of the hip flexors, so this problem is common among football players, ballet dancers, hurdlers and martial arts experts (Hackney 1993). Bursitis can be characterized by a deep groin pain that is difficult for patients to localize and reproduce, and occasionally radiates to the

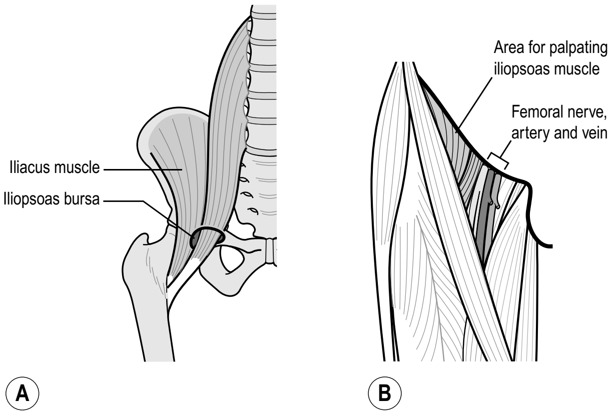

Figure 2. Location of (A) the iliopsoas and bursa, and (B) the area of palpation.

anterior hip. Because of the poor localization and reproducibility of the pain, the average time from the onset of symptoms to diagnosis is 32–41 months (Johnston *et al.* 1998). There is tenderness below the lateral inguinal ligament over the femoral triangle, adjacent to the femoral artery, where the musculotendinous junction of the iliopsoas muscle can be palpated (Fig. 3). The pain can be reproduced by stretching the iliopsoas; however, care must be taken to differentiate pain in psoas bursitis from femoral nerve irritation and conditions of the hip such as anterior hip impingement syndrome. Pain may also be reproduced when the flexed, abducted, externally rotated hip is extended and brought back into a neutral position (the extension test), or when the supine athlete raises his or her heels off the table to about 15° (Morelli & Weaver 2005).

Trigger points associated with the muscles around the pelvis and hip were discussed by Seffinger *et al.* (2012).

Acetabular tears and impingements of the hip

Acetabular labral tears are a recently recognized source of hip pain, particularly in the anterior hip or groin region (Lewis & Sahrmann 2006). Femoroacetabular impingement of the hip is a soft-tissue impingement of the acetabular–labrum complex, which may or may not include the capsule, psoas tendon or bursa. Upon further evaluation, studies have indicated that 22% of athletes with groin pain (Narvani *et al.* 2003) and 55% of patients with mechanical hip pain of unknown aetiology (McCarthy *et al.* 2001) have a labral tear. Except in cases of specific trauma, the aetiology of labral tears is often difficult to determine and can evade detection by non-invasive means. The pain and disability can be severe, with a sudden onset of symptoms, but an acetabular labral tear should also be suspected when a patient with normal radiographs complains of a long duration of anterior hip pain and clicking, with minimal to no restriction in range of movement (ROM). A wide range of provocative tests have been reported, but typically, it is confirmed with pain on passive hip flexion combined with adduction and medial (internal) rotation, and pain with a resisted active straight-leg raise (Farjo *et al.* 1999; Hase & Ueo 1999; McCarthy *et al.* 2001; Mason 2001; Binningsley 2003). Other reported tests are:

- flexion with medial rotation alone, or combined with adduction or axial compression;
- flexion with lateral (external) rotation; and
- hip extension alone or combined with medial rotation.

Whether these other tests were performed actively or passively was not specified, and the sensitivity and specificity of these tests have yet to be published. In six professional soccer players with anterior labral tears, Saw & Villar (2004) found that all of the players had significant pain with combined hip flexion, medial rotation and adduction. Mitchell *et al.* (2003) reported that the Flexion, Abduction and External Rotation (FABER) test elicited pain in 88% of patients (15 of 17) with intra-articular pathology, but they did not find any correlation between a positive FABER test result and different types of hip joint pathology.

The wide range of provocative tests may be attributable to differences in the location of the tear. In 56 hips of 55 patients, Fitzgerald (1995) used two different clinical tests that provoked symptoms in 54 patients, depending on tear location. To identify an anterior labral tear, the patient's leg was brought into full flexion, lateral rotation and full abduction, and then extended with medial rotation and adduction. To identify a posterior labral tear, the patient's leg was brought into extension, abduction and lateral rotation, and then flexed with medial rotation and adduction. If a labral tear is present, these manoeuvres will result in sharp pain with or without a click (Fitzgerald 1995).

To date, conservative medical treatment has not proven to be effective once a labral tear is diagnosed, and the appropriate physical therapy intervention has yet to be established. Surgical treatment results in short-term improvement, but the long-term outcomes are still unknown (Tyler & Slattery 2010). Since labral tears have

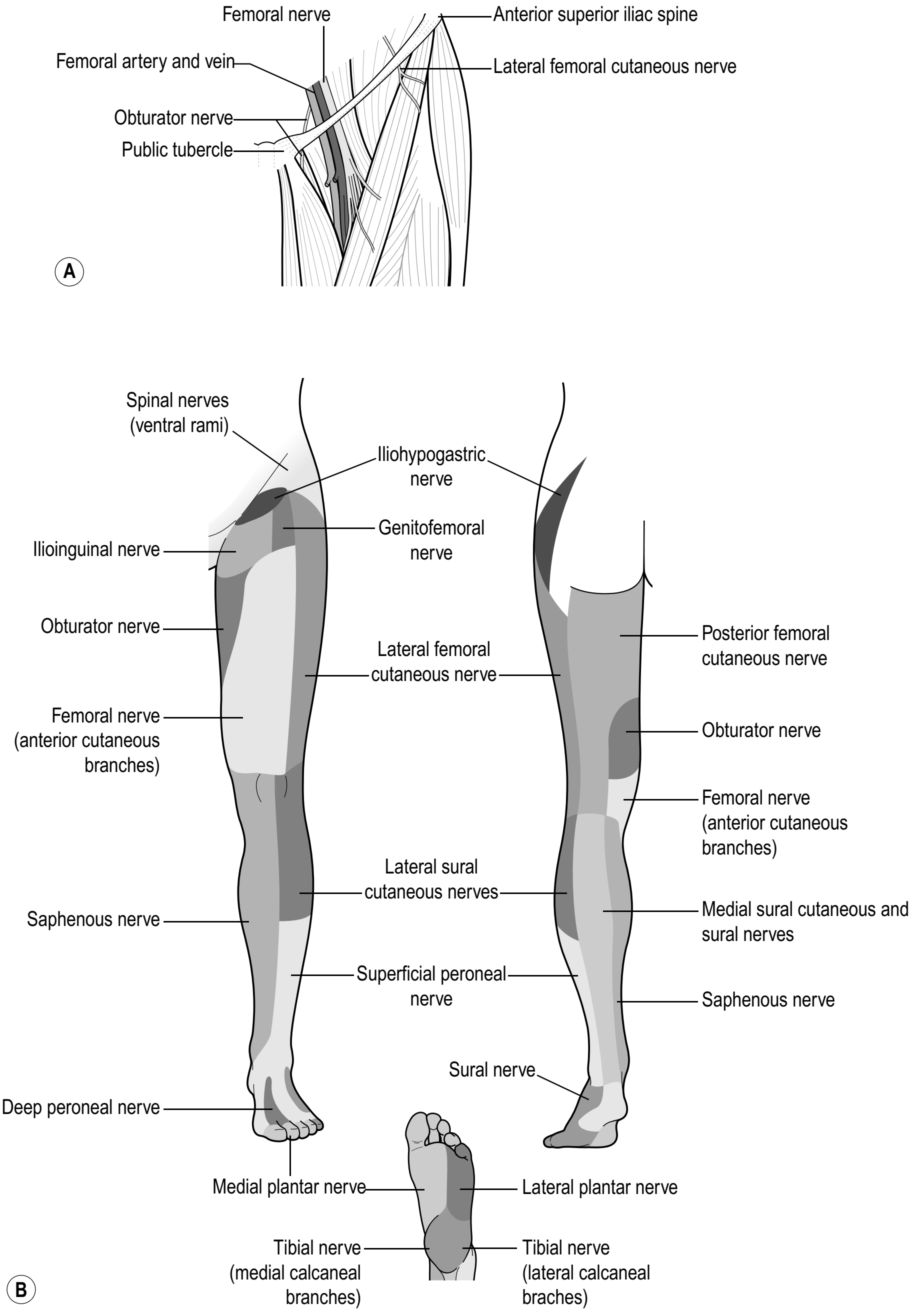

Figure 3. (A) Nerves of the thigh and (B) their distribution.

been associated with a higher risk for joint degeneration, this area warrants further investigation, especially with regard to prevention, early detection, appropriate physical therapy and medical treatment (Lewis & Sahrmann 2006).

Osteitis pubis

The name OP suggests inflammation; however, it appears to involve a degenerative rather than an inflammatory process, characterized by symphysis pubis pain, with occasional referral along the adductor muscles to the hip, superiorly to the lower abdominal region and posteriorly towards the perineum and scrotum in men (Hackney 1993). Osteitis pubis can produce symptoms of exercise-induced pain in the inner thigh and abdominal area, which come on gradually and worsen as the activity progresses. Examination reveals tenderness over the symphysis pubis and this usually needs to be present to confirm a diagnosis (Reid 1992). Confusingly, resisted hip adduction or trunk flexion may also reproduce the symptoms, which is usually indicative of muscular lesions. Plain-film radiographs commonly reveal sclerosis of the pubic bones, with occasional widening of the symphysis, with laxity on stork views >2 mm (Harris & Murray 1974). However, X-rays have poor construct validity since changes on X-ray often do not correlate with symptoms and there are positive radiographic findings found in asymptomatic individuals (Hackney 1993). Bone and MRI scans correlate better with symptoms than radiographic appearance, with the ability of MRI scans to show bone marrow oedema into the pubic bones and detachment of the anterior fascial layer, which is continuous with fascia overlying adductor muscles and the inguinal ligament (Karlsson & Jerre 1997). Osteitis pubis is generally thought of as the end result of an overuse continuum resulting in excessive and repetitive strain of the symphysis pubis and pelvis (Cunningham *et al.* 2007; Pizzari *et al.* 2008). There is limited evidence of proven risk factors for OP in the literature, although greater hip abductor to adductor muscle strength ratios and decreased total rotation range of hip motion have been implicated (Verrall *et al.* 2002; Maffey & Emery 2007).

Lower-quadrant biomechanical abnormalities such as hypermobility, intrapelvic asymmetry and technique deficits are also said to play a role in the onset of OP, but to date, there are no published trials to support this clinical observation (Reid 1992; Pizzari *et al.* 2008). Some authors also cite mechanical traction of the pelvic muscles (Ashby 1994). Although there is no convincing evidence that steroid injections are of any benefit (Hackney 1993), treatment typically includes general modified activity, physiotherapy in the form of correction of biomechanical abnormalities and muscle stretching, and non-steroidal anti-inflammatory drugs (NSAIDs) and corticosteroid injections (Holt *et al.* 1995). It occurs commonly in runners, footballers and in grass hockey goalkeepers, and can be difficult to distinguish from adductor strains, with the two conditions frequently occurring simultaneously.

Athletic pubalgia or sports hernias

The diagnosis of a sports hernia or athletic pubalgia is controversial since there is frequently no clinically detectable inguinal hernia on physical examination, and there is currently no consensus as to what specifically constitutes this diagnosis (Swan & Wolcott 2007; Caudill *et al.* 2008). It has been defined as a set of pelvic injuries involving the abdominal and pelvic musculature outside the ball-and-socket hip joint and on both sides of the pubic symphysis (Meyers *et al.* 2008; Omar *et al.* 2008). Athletic pubalgia occurs more often in men, although the female proportion, age, numbers of sports and soft-tissue structures involved have all increased recently (Meyers *et al.* 2008). Provocative sports usually include activities that involve quick turns while the foot is planted, cutting, pivoting, kicking and sharp turns, such as those that occur during soccer, ice hockey, rugby or football, or high knee-lift action, such as in the martial arts, sprinting and hurdling.

Although a specific inciting incident may be identified with focused questioning (Caudill *et al.* 2008), it usually has no specific traumatic cause and comes on insidiously, with some correlation with OP, weakness of the posterior inguinal wall, a stretched external ring and generalized distension of the anterior abdominal wall (Nam & Brody 2008). Posterior inguinal wall weakening is said to occur from excessive or high repetition shear forces applied through the pelvic attachments of poorly balanced hip adductor and abdominal muscle activation (Caudill *et al.* 2008). The pain is felt deep in the groin, gradually worsens over time, and may spread along the inguinal ligament into the perineum, rectus abdominis muscles and testicles in about 30% of symptomatic individuals (Zimmerman 1988).

Further investigations such as MRI, diagnostic ultrasonography and isotope scans are said not to provide any useful data in the assessment of sports hernias except to exclude other conditions (Caudill *et al.* 2008; Nam & Brody 2008). However, a recent review concluded that a large-field-of-view MRI survey of the pelvis, combined with high-resolution MRI of the pubic symphysis, provides excellent information about the location, causes and severity of the condition (Omar *et al.* 2008). Magnetic resonance imaging depicts patterns of findings in patients with athletic pubalgia, including rectus abdominis insertional injury, thigh adductor injury and OP (Zoga *et al.* 2008).

The range of possible pathologies or injuries is very wide, and an in-depth knowledge of the pelvic regional anatomy is essential in the diagnosis of this condition. Conservative management consisting of soft tissue and joint mobilization and manipulation, neuromuscular re-education, manual stretching, and therapeutic exercise is a viable option (Kachingwe & Grech 2008). A final course of action is surgical exploration of the posterior abdominal wall for defects, which are subsequently repaired. Surgery seems to be more effective than conservative treatment, and laparoscopic techniques generally enable a quicker recovery time than open repair (Brown *et al.* 2008).

Stress fractures

Although stress fractures are not common, if they do occur, the two most frequent sites for these to arise are the femoral neck and the pubic ramus (Morelli & Smith 2001). Stress fractures can be caused by overtraining, which can cause repetitive strain on the underlying bone structure. They are often seen in long-distance runners and military recruits, who may be required in their training to cover long distances with less-than-adequate footwear (Morelli & Smith 2001). Dancers are also subject to stress fractures, especially classical ballet dancers, who concurrently may also present with nutritional imbalances (Howse & Hancock 1992). In addition, there are risk factors that predispose individuals to stress fractures: osteoporosis, muscle fatigue, an excessive increase in training intensity or duration, as well as running on cambered or uneven surfaces (Reid 1992). The pain associated with stress fractures is exacerbated by activity and diminished by rest; however, pain at rest is indicative of advanced disease. Confirmation of a stress fracture is usually made by MRI scan, which has been shown to be accurate and reliable in the imaging of these injuries (Ahovuo *et al.* 2002).

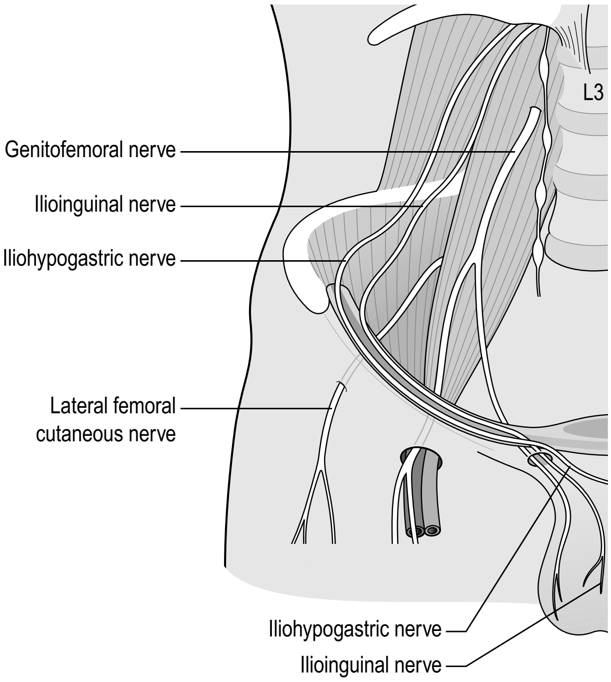

Figure 4. Schematic drawing of the iliohypogastric, ilioinguinal, genitofemoral and lateral femoral cutaneous nerves of the thigh: (L3) third lumbar nerve.

Nerve compression

Several nerves around the groin and pelvis are vulnerable to compression: the ilioinguinal nerve; the iliohypogastric nerve; the lateral femoral cutaneous nerve of the thigh; the genitofemoral nerve; the obturator nerve (Fig. 4); and the pudendal nerve.

The hip joint itself is supplied by: the femoral nerve, which also innervates the iliofemoral ligament and the superior capsule; the obturator nerve, also supplying the pubofemoral ligament; the superior gluteal nerve, which supplies the superior and lateral part of the joint capsule, and also the gluteus medius and minimus; and the nerve to the quadratus lumborum, which supplies the posterior capsule and the ischiofemoral ligament (O'Brien & Delaney 1997). The L2, L3 and L4 spinal nerves can also refer pain to the groin or anterior thigh (Morelli & Weaver 2005).

The ilioinguinal, iliohypogastric and genitofemoral nerves originate from the first lumbar nerve (L1), but the genitofemoral nerve receives additional input from L2 or L3. There is considerable anatomical variation in the origin and course of these nerves, as well as an overlap of their cutaneous distributions (Aszmann *et al.* 1997; Akita *et al.* 1999; Rab *et al.* 2001). The ilioinguinal branch passes through the inguinal canal, becoming fairly superficial near the superficial inguinal ring, and continues to supply the root of the penis (or labia majora), anterior scrotum and medial thigh, as does the genitofemoral nerve. The iliohypogastric nerve further divides into two branches: the anterior cutaneous branch, which carries cutaneous sensation from the lower abdominal and groin region medial to the anterior superior iliac spine (ASIS); and the lateral cutaneous branch, which receives sensation from the lateral thigh and gluteal region (Morelli & Weaver 2005). In addition to these sensory distributions, the ilioinguinal and iliohypogastric nerves provide motor innervations to the lower abdominal musculature.

Entrapment of the ilioinguinal, iliohypogastric and genitofemoral nerves may result in groin pain or lower abdominal pain that can radiate to the genitals. These nerves can be injured by direct trauma, including abdominal surgery such as Caesarean section, transvaginal tape for stress incontinence surgery and hernia repairs for overzealous training of the abdominals (Starling & Harms 1989; Al-dabbagh 2002; Murovic *et al.* 2005; Whiteside & Barber 2005; Vervest *et al.* 2006; van Ramshorst *et al.* 2009). Tenderness is often noted 2–3 cm inferiorly and medially to the ASIS, and hip extension usually produces increased pain or hypoaesthesia in the nerve's distribution (Morelli & Weaver 2005).

Compression of the lateral femoral cutaneous nerve of the thigh or meralgia paraesthetica can occur as it passes under or through the inguinal ligament, resulting in a persistent burning sensation, tingling or aching pain, and hypersensitivity or hyposensitivity in the anterolateral aspect of the thigh (Moucharafieh *et al.* 2008). In addition to sportsmen such as squatting rifle team members and athletes who sustain acute trauma to the area, it has been noted in women who sit for prolonged periods with the involved leg underneath the body (Morelli & Weaver 2005), and more recently, in wearers of tight low-cut trousers (Moucharafieh *et al.* 2008).

The obturator nerve supplies the adductor muscles and the skin over the inner thigh, and is increasingly being reported as a source of chronic groin pain in athletes, normally by becoming entrapped in the obturator foramen or the thickened fascia surrounding the adductor muscles – usually the adductor brevis (Morelli & Weaver 2005). Symptoms can include deep aching over the adductors or at the pubic bone, but its anatomy makes it difficult to distinguish between adductor strain and obturator nerve entrapment (Morelli & Weaver 2005). Classically, the deep ache near the adductor origin of the pubic bone is exacerbated by exercise, subsides with rest, but often resumes with activity, and may radiate down the medial thigh toward the knee. Spasm, weakness and paraesthesia may also occur in the area (Brukner *et al.* 1999).

Conservative management of nerve compressions, including changes in training regimens, ice, NSAIDs, pharmacological management, local corticosteroid injections and nerve blocks, have been suggested, along with surgical referral in resistant cases (Brown *et al.* 2008; Suresh *et al.* 2008).

The pudendal nerve is commonly seen as a source of CPP because of its course through the levator ani muscle. The treatment and evaluation of pudendal nerve entrapment is dealt with by De las Peñas & Pilat (2012) and Prendergast & Rummer (2012).

Similar to the classification of mechanical lumbopelvic pain described in the first part of this paper (Jones *et al.* 2013), classification of movement impairment syndromes of the hip provides a systematic process with which to examine and select exercises to provide appropriate prescription and pathology-specific modification of exercise for hip pain (Lewis & Sahrmann 2006). A summary of hip classifications organized by test position, symptom behaviour with variations of the test position or movements within the test position, and clinical judgements of quality of alignment or movement is presented in Table 1.

As discussed previously, differentiation of any neural components associated with the limitation-of-length testing of muscles needs to be evaluated to ensure that the perceived length changes are not caused by neural irritation. The next section of the present paper discusses specific sports and CPP, including genitourinary symptoms in cycling.

Cycling and genitourinary symptoms in men and women

The reported incidence of cycling-related urogenital symptoms varies considerably (Leibovitch & Mor 2005), and some authors question the existence of a relationship between bicycle riding and urogenital symptoms, suggesting that larger case-control studies are required before conclusions can be drawn (Taylor *et al.* 2004; Brock 2005). Nevertheless, in a recent comprehensive review of the literature, Sommer *et al.* (2010) concluded that there is a significant risk in relation to cycling-related urogenital symptoms in both men and women, emphasizing the requirement for further research on bicycle and bicycle seat design. Rather than discourage cycling as an activity, the present section aims to describe the urogenital symptoms most commonly attributed to cycling, including the hypothesized mechanisms, and inform the reader of the potential adjustable bicycle factors in order to assist the rider who complains of cycling-related urogenital dysfunction.

Symptoms

The most common cycling-associated urogenital problems are genital numbness, followed by erectile dysfunction (ED) (Ricchiuti *et al.* 1999; Leibovitch & Mor 2005; Sommer *et al.* 2010). Other, less-common symptoms include CPP, priapism, penile thrombosis, infertility, haematuria, dysuria, difficulty in achieving orgasm, lymphoedema of the labia majora or "bicyclist's vulva", torsion of the spermatic cord, prostatitis, hardened perineal nodules, and elevated serum prostate-specific antigen (Doursounian *et al.* 1998; LaSalle *et al.* 1999; Baeyens *et al.* 2002; Leibovitch & Mor 2005; Sommer *et al.* 2010). A summary of important epidemiological studies assessing the impact of bicycle riding on sexual function is shown in Table 2.

Table 1. Items for hip classification organized by test position, symptom behaviour with variations of the test position or movements within it, and clinical judgements of quality of alignment or movement (taken from Sahrmann 2002): (TFL) tensor fascia latae muscle; (ROM) range of movement; (ITB) iliotibial band; (SLR) straight-leg raise; (GT) greater trochanter; and (AOR) axis of rotation

Test position	Symptom behaviour with variations	Judgement of femoral alignment or movement
Standing	Standing	*Normal femoral alignment*: Long axis of femur orientated 10° lateral to the sagittal plane with patellae orientated in the frontal plane (facing forward) *Hip flexed*: Hip angle flexion >10°; suggests short hip flexors *Hip extended*: Hip angle extension >10°; suggests long iliopsoas, short hamstrings
	Bilateral hip/knee flexion (partial squat)	*Normal*: Knee flexion 45° with heel staying in contact with floor; knee in line with second toe; foot pronates (Fig. 5A) *Hip medial rotation*: Knee moves in line medial to big toe; suggests poor stability of posterior gluteus medius or overactivity of TFL (Fig. 5B) *Hip lateral rotation*: Knee moves in line lateral to fourth toe
	Single-leg stance, other leg flexed to 70°	*Normal*: No change in hip joint rotation *Hip adduction*: Downward tilting of opposite side of pelvis; suggests stance-side hip abductors weak/long (Fig. 6) *Pelvic rotation*: Towards stance leg; suggests short hip medial rotators *Hip rotation*: Femur rotates medially; suggests long/weak hip lateral rotators
	Forward bending	*Hip flexion*: Men <75°, women <85°; suggests short stiff hip extensors (Fig. 7B) *Hip flexion*: If >100° or >70° during a standing bow (forward bend with straight back), this suggests long hamstrings and potential for anterior hip impingement (Fig. 7C)
Sitting	Sitting knee extension with ankle dorsiflexion	*Knee extends*: If <75° with hip flexed to 90°, this suggests short hamstrings (differentiate neural component with trunk and cervical flexion) *Hip medially rotates*: Suggests short medial hamstrings and/or overactivity of TFL (Fig. 8)
	Sitting hip flexion	*Normal*: Hip flexed to 120°, maximum resistance to iliopsoas is tolerated; muscle long if it can resist between 105° and 110°, but not 120°; weak if unable to tolerate resistance at any point in range
	Hip rotation	*Normal*: Hip medial and lateral rotation symmetrical and approximately 30° *Medial rotation*: ROM>lateral rotation; suggests structural variation hip antetorsion when also observed in hip extension *Lateral rotation*: ROM>medial rotation; suggests structural variation hip retrotorsion when also observed in hip extension
Supine	Hip flexor length test (modified Thomas test)	*Normal*: Extended thigh lies on table with lumbar spine flat; femur in midline without hip rotation or abduction; knee flexed to 80° without abduction of tibia or lateral tibial rotation; hip extended 10° *Short hip flexors*: Thigh does not reach table (Fig. 9); abduct hip and extension range increases, suggests TFL/ITB short; passive extension knee range increases, suggests rectus femoris short; iliopsoas short if hip abducted, knee extended and thigh does not lie on table *Femoral head glides anteriorly*: Suggests iliopsoas long and/or anterior capsule stretched
	Straight-leg raise	*Normal*: GT maintains constant AOR during passive and active SLR, hip flexes to 80° *Femoral anterior glide*: GT moves anteriorly and superiorly (medial rotation and insufficient posterior glide) during active SLR; suggests stiff posterior structures and/or hamstrings short (Fig. 10); during passive SLR, the GT maintains a relatively constant position, but the examiner needs to control AOR with a thumb placed in the inguinal crease; active SLR may produce anterior hip pain, while passive SLR is pain-free *Femoral medial rotation*: Long iliopsoas and/or long stiff hip lateral rotators
	Hip abduction/lateral rotation with hip flexed	*Limited hip ROM*: With groin pain
	Unilateral hip flexion, passive and active	*Femoral anterior glide*: Pain in groin, and the GT moves anteriorly/superiorly; restriction of GT movement with pressure at inguinal crease, increases resistance to hip flexion *Limited hip ROM*: If flexion <115°, this suggests short gluteus maximus/piriformis/posterior hip joint structures

Continued/

Potential mechanisms

Compression of the pudendal nerve between the symphysis pubis and the bicycle seat (Goodson 1981), or at its course through Alcock's canal (Amarenco *et al.* 1987), have been proposed as potential mechanisms, although several authors have attributed numbness to transient ischaemia caused by pressure on the vascular supply of the

Table 1. (*Continued*)

Test position	Symptom behaviour with variations	Judgement of femoral alignment or movement
Side-lying	Hip abduction, other hip positions neutral	*Normal-strength hip abductors (gluteus medius/minimus, TFL)*: Resisted hip abduction with pressure above ankle, able to tolerate maximum end of range; long if able to resist after 10–15° adduction; weak if unable to tolerate any resistance
	Hip abduction with lateral rotation and extension	*Normal-strength posterior gluteus medius*: Able to tolerate maximum end-of-range resistance; long if able to resist after 10–15° adduction; weak if unable to tolerate any resistance *Hip flexes when maximum resistance applied*: Suggests TFL overactivity
	Hip adduction (uppermost leg); starting position: hip abduction, lateral rotation, slight extension with knee extended	*Normal*: Hip adducts 10°; *Hip adducts <5°*: Suggests short hip abductors (Fig. 11) *Hip flexes and/or medially rotates*: Suggests short TFL and/or anterior gluteus medius/minimus *Femoral lateral glide*: Excessive hip adduction with anterior distal portion of the GT, suggests long hip abductors
	Hip adduction (lowermost leg); starting position: hip adduction, neutral rotation, flexion/extension knee extended	*Normal*: Able to tolerate maximum resistance when applied to lower thigh; weak adductors if unable
Prone	Hip medial rotation	*Normal*: 35° medial rotation without pelvic rotation; hip ROM is very variable and does not necessarily imply muscle shortness; however, if <30°, check obturators, quadratus femoris, gracilis, piriformis, gemelli, posterior gluteus medius *Structural variation*: <10° medial rotation suggests retroversion of femur; >50° medial rotation suggests antetorsion of femur (Fig. 12A); check range in supine to confirm
	Hip lateral rotation	*Normal*: 35° lateral rotation without pelvic rotation; hip ROM is very variable and does not necessarily imply muscle shortness; however, if <30°, check medial rotators; TFL/ITB, anterior gluteus medius, gluteus minimus *Structural variation*: <10° lateral rotation suggests antetorsion of femur; >50° lateral rotation suggests retroversion of femur (Fig. 12B); check range in supine to confirm *Femoral anterior glide*: GT moves anteriolateral, making wide arc of movement; suggests TFL/ITB short
	Hip extension with knee extended	*Normal*: 10° hip extension with slight lumbar knee extension and simultaneous contraction of gluteus maximus and hamstrings *Femoral anterior glide*: GT moves anteriorly; suggests overactivity of hamstrings, and/or short and stiff TFL and stretched anterior capsule (Fig. 13)
	Hip extension with knee flexed	*Normal*: 10° hip extension with slight lumbar extension; short rectus femoris/TFL if hip extension <5°; if unable to maintain hip extension when maximum resistance applied, implies weak/long gluteus *Femoral anterior glide*: GT moves anteriorly; suggests overactivity of hamstrings and/or stretched anterior capsule
Quadruped	Quadruped	*Normal*: 90° angle between femur and pelvis; neutral rotation, abduction/adduction <90° or hip lateral rotation suggests short/stiff posterior hip joint capsule, gluteus maximus/piriformis (Fig. 14A)
	Backward rocking towards heels	*Normal*: Hips flex to heels, no pain; decreased hip flexion or pelvic rotation implies short/stiff gluteus maximus/piriformis (rotation implies asymmetric stiffness) (Fig. 14B); confirm by abducting and/or lateral rotating hips, which increases hip flexion

perineum (Oberpenning *et al.* 1994; Ricchiuti *et al.* 1999; Ramsden *et al.* 2003; Gemery *et al.* 2007).

As discussed by Lovegrove Jones (2012a, b), Vleeming (2012), De las Peñas & Pilat (2012) and Prendergast & Rummer (2012), Alcock's canal is bordered laterally by the ischial spine and medially by the fascial layer of obturator internus muscle. The pudendal nerve leaves the canal ventrally below the ischiopubic ramus, and it is thought that pressure on the ramus compresses neural and vascular tissue in Alcock's canal, resulting in penile and perineal paraesthesia, which is often called Alcock's syndrome (Amarenco *et al.* 1987; Oberpenning *et al.* 1994). Oberpenning *et al.* (1994) hypothesized that the onset of temporary perineal numbness, which can last for 10–20 min or more, is a result of compression of the perineum, which in turn causes compression on the pudendal nerve and artery. Ricchiuti *et al.* (1999) reported electromyographic evidence of bilateral pudendal nerve

Table 2. Important epidemiological studies assessing the impact of bicycle riding on erectile function/sexual function (Sommer *et al.* 2010): (MMAS) Massachusetts Male Aging Study; (OR) odds ratio; and (ED) erectile dysfunction*

Reference	Study population, type of study	Number of subjects	Outcome measurement(s)	Results	Limitations of the study
Andersen & Brown (1997)	Cross-sectional, cyclists in a 540-km race	160	Questionnaire	2% had symptoms of pudendal or cavernosal nerves; 20.6% had penile numbness for >1 h and 6% for >1 week; 13% had impotence (7% for >1 week, 2% for >1 month)	No validated outcome measurement, just observational and descriptive study, self-report, small sample size, lack of longitudinal follow-up
Marceau *et al.* (2001)	Cross-sectional survey (MMAS)	1709	Questionnaire interview	OR for ED = 1.72, if bicycle riding >3 h week^{-1}	Self-report, small sample size of cyclists/sport cyclists, lack of longitudinal follow-up
Schrader *et al.* (2002)	Bicycle police officers (mean cycling time = 5.4 h day^{-1})	22	Rigiscan, pressure measurement	In cyclists, significantly lower erectile events in sleep, correlated with duration of biking and pressure of the nose of the saddle; 91% had groin numbness	Small sample size, lack of longitudinal follow-up
Schrader *et al.* (2008)	Bicycle police officers using a no-nose saddle for 6 months	90	Questionnaire, Rigiscan, pressure and biothesiometry	66% reduction in saddle contact pressure, significant improvement in tactile sensation and erectile function	No improvement in Rigiscan after 6 months no control group, small sample size
Guess *et al.* (2006)	Female premenopausal bicyclists, runners as controls	70	Biothesiometry, questionnaire	Significantly higher vibratory thresholds in bike riders at perineum, posterior vagina, and labia; no negative effect on sexual function	Questionnaire's validity is questionable, small sample size, no longitudinal follow-up, no statistical associations possible, no unathletic control group
Battaglia *et al.* (2009)	Female horseback and mountain bike riders	6	Ultrasonography, questionnaire	Disseminated microlithiasis of the clitoral body in five women	Small sample size, no longitudinal follow-up, no statistical associations possible, unclear clinical significance
Dettori *et al.* (2004)	Prospective cohort study, cyclists riding 320 km	463	Questionnaire	Cumulative incidence of ED after the ride was 4.2% and this was 1.8% one month after the event; mountain biking and relative height of handlebars were associated with a higher risk of ED; 31% experienced perineal numbness	Sample size too small for valid statistical conclusions (large confidence interval)

*A summary of the most important studies showing the impact of cycle riding on erectile function, nocturnal penile tumescence, clitoral structure and female sexual function.

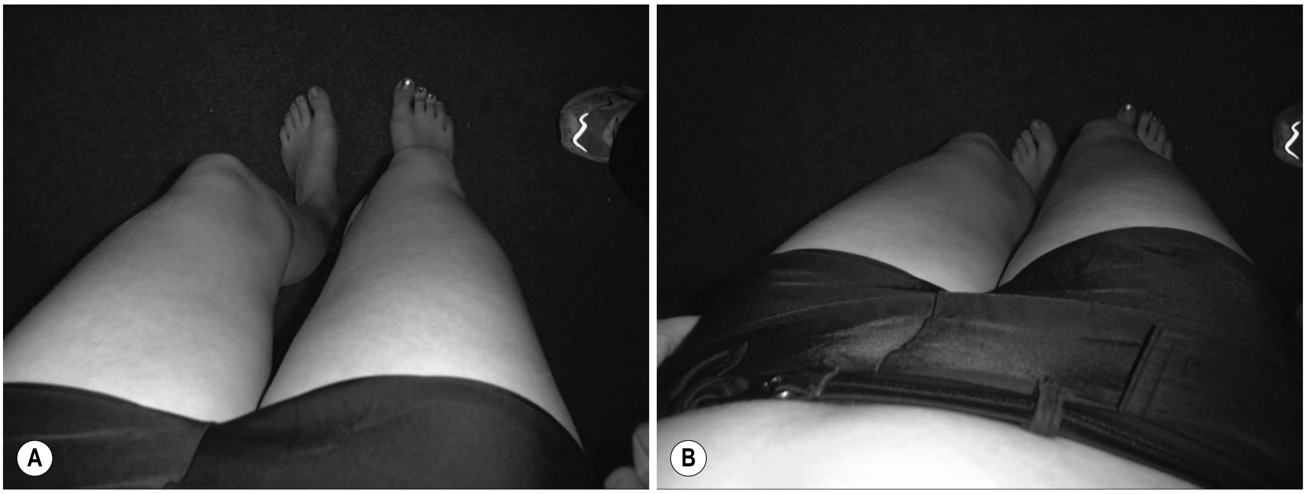

Figure 5. Small knee bend from above: (A) ideal alignment, knee in line with second toe; and (B) hip medial rotation, knee moves in a line medial to big toe (this suggests poor stability of the posterior gluteus medius or overactivity of the tensor fascia latae).

injury associated with excessive cycling. They reported that the transient ischaemic episodes involving the pudendal nerve and subsequent measurable delays in conduction were rapidly reversible if the ischaemia was of relatively short duration. However, ischaemia of longer than 8 h in duration resulted in a significant deterioration of nerve function and recovery would take several weeks. Although acknowledging that the cause of perineal numbness and ED resulting from bicycle riding is not fully understood, it is suggested to be a result of continuous compression and strain on the pudendal nerve and arteries, leading to nerve entrapment and vascular occlusion (Gemery *et al.* 2007; Sommer *et al.* 2010).

Leibovitch & Mor (2005) postulated that the movements of the pedalling legs in the forward sitting position could result in stretching of the pudendal nerves over the sacrospinal and sacrotuberous ligaments. This may cause increased tensile and compressive stress on the nerve trunk, and a loss of the normal gliding movement of the nerve relative to the adjacent soft tissue and bony structures of the pelvic floor. The gliding movement of nerves in general has been described by Shacklock (2005) as being an essential aspect of the mechanical function of neural tissue, which serves to disperse the tension applied at one point of a nerve to the whole length of a nerve, reducing the forces on the nerve tissue. Neural mechanosensitivity is discussed further in Seffinger *et al.* (2012).

Naňka *et al.* (2007) proposed an alternative mechanism of urogenital dysfunction in cyclists. They suggested that, because the pudendal nerve is protected by a thick layer of fatty tissue extending below the extent of the pubic body in the floor of Alcock's canal, compression of the posterior dorsal nerve of the penis (PDNP) in the sulcus nervi dorsalis penis is the main cause of Alcock's syndrome. They hypothesized that the position of the PDNP close to the pubic ramus, and its proximity to the fibres of the suspensory ligament of the penis and the ischiocavernosus body make it more vulnerable to mechanical insult (Naňka *et al.* 2007). Since a compression neuropathy depends upon mechanical and ischaemic insult, these authors suggested that the PDNP is the mostly likely nerve to be affected, particularly as it is the only one supplying the glans penis, and hence, it is able to be the cause of diminished glandular and penile sensitivity (Naňka *et al.* 2007).

Irrespective of the causative mechanisms, Labat *et al.* (2008) stated that, despite these examples of pudendal nerve compression, very few cyclists go on to develop pudendal neuralgia.

Therapeutic options regarding adjustable bicycle factors

As discussed above, there remains controversy as to whether alterations in riding habits actually change the prevalence of urogenital symptoms among cyclists (Taylor *et al.* 2004). However, in addition to modifying training schedules and periodically rising from the saddle for a brief time to relieve pressure and help re-establish blood flow (Huang *et al.* 2005), the factors that have been evaluated are adjustments of the saddle, bicycle and body position. There are areas of agreement and inconsistencies in the literature; these factors are addressed in turn.

Figure 6. Single-leg stance, other leg flexed, downward tilting of the opposite side of pelvis. This suggests that the stance-side hip abductors are weak and/or long.

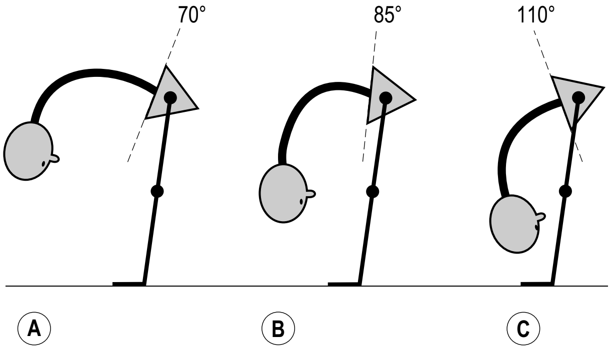

Figure 7. Forward bending: (A) normal, even flexion throughout the lumbar and thoracic regions with the hips flexing to approximately 70°; (B) hip flexion <75° (men) and <85° (women) suggests short, stiff hip extensors; and (C) hip flexion >100° suggests long hamstrings and the potential for anterior hip impingement.

Saddle design

The design of the bicycle saddle is thought by a number of authors to be a major factor in the aetiology of perineal compression (Jeong *et al.* 2002; Rodano *et al.* 2002; Sommer *et al.* 2010). Some saddles have a deep groove or hole connecting the anterior to the posterior part of the saddle, and there is disagreement as to whether this is more or less likely to cause neurovascular compression (Rodano *et al.* 2002; Gemery *et al.* 2007; Sommer *et al.* 2010) (Fig. 15). Saddles without a narrow protruding nose, or with a large hole and a shape that allows for proper seating of the ischial tuberosities significantly reduce pressure distributed in the perineal region of cyclists (Schrader *et al.* 2008; Sommer *et al.* 2010). However, Rodano *et al.* (2002) argued that there is a greater likelihood of perineal numbness with holed or deep-grooved saddles because the load is transferred from the ischiopubic ramus to the perineum, particularly as the edge of the groove frequently corresponds anatomically to the location of the pudendal nerve and artery. Holed saddles present edges in the region where the hole is projected, and these edges in saddle design can affect saddle pressure because of the contact of small areas under an elevated compressive load (Carpes *et al.* 2009). Gemery *et al.* (2007) stated that a grooved seat allows better preservation of the seat/symphysis space and reduces the compression on the

Figure 8. Sitting knee extension with hip flexed to 90°, hip rotates medially. This suggests short medial hamstrings and/or overactivity of the tensor fasciae latae muscle.

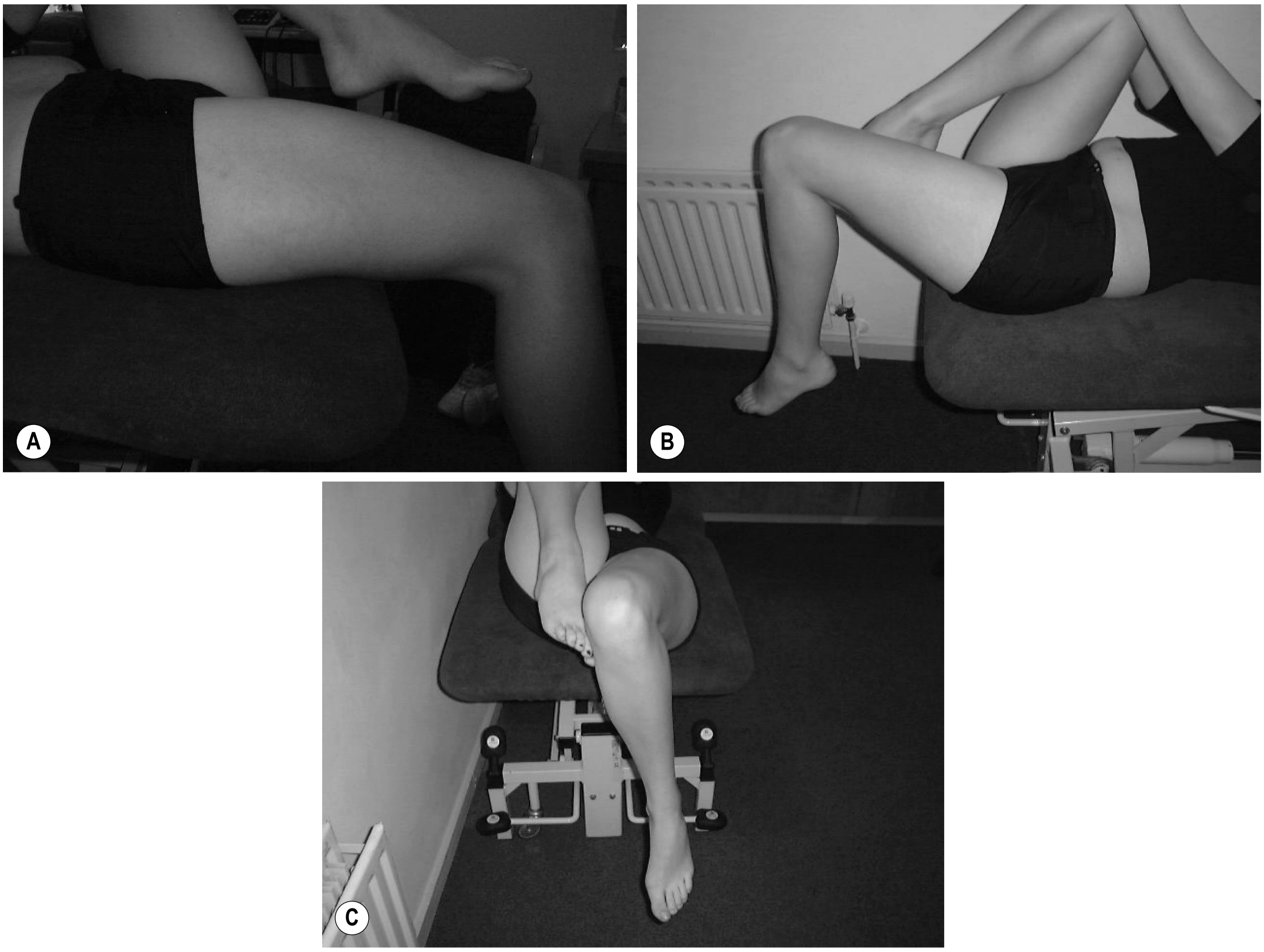

Figure 9. (A) Normal: extended thigh lies on table with lumbar spine flat; femur in midline without hip rotation or abduction; knee flexed to 80° without abduction of tibia or lateral rotation; and hip extended 100°. (B, C) Short hip flexors: thigh does not reach table, showing femoral medial rotation and lateral tibial rotation.

pudendal artery more than a standard saddle. They constructed three-dimensional models from computed tomography scans of one adult male pelvis (a healthy volunteer) and three bicycle seats to assess the influence of the rider's saddle position on vascular compression (Fig. 16). These models were correlated with lateral radiographs of a seated rider in order to determine potential

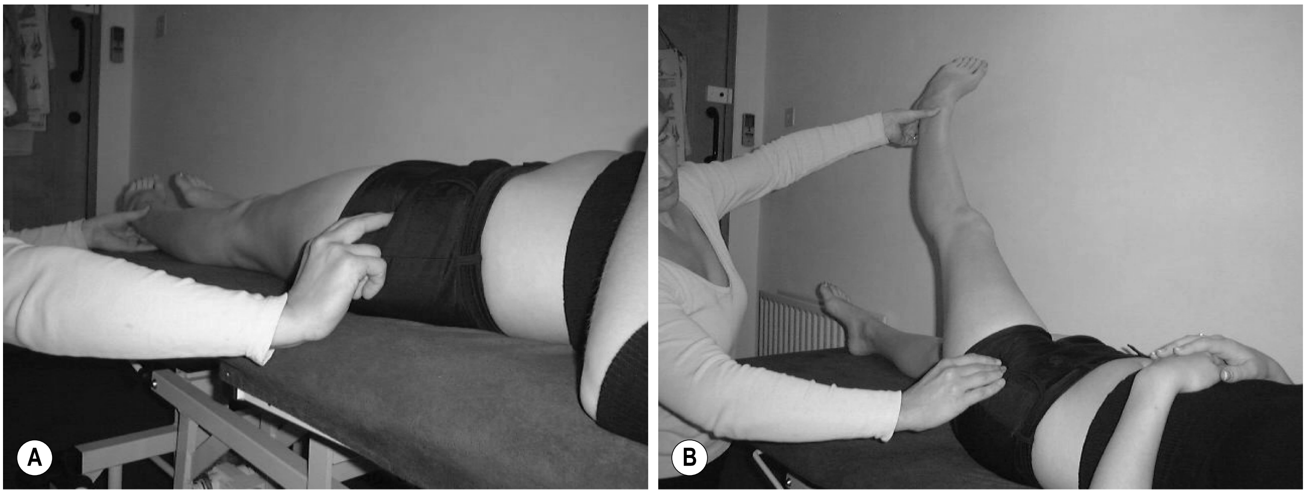

Figure 10. (A) Monitoring the greater trochanter. (B) The greater trochanter moves anteriorly and superiorly during active straight-leg raise (medial rotation and insufficient posterior glide); this suggests stiff posterior structures and/or short hamstrings.

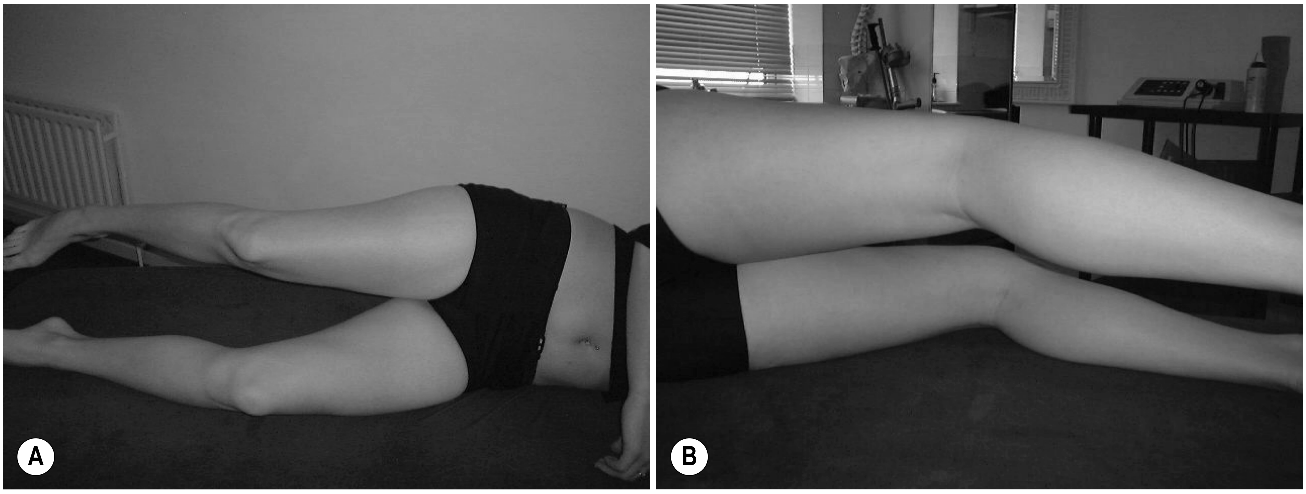

Figure 11. Side-lying hip adduction (uppermost leg) from (A) in front and (B) behind. Starting position: hip abduction, lateral rotation and slight extension with knee extended; hip adduction <5° suggests short hip abductors.

vascular compression between the bony pelvis and cycle seats at different angles of rider positioning as well as saddle type. They concluded that the rider's position is more important for reducing compression than seat design alone (see the section on postural adjustment below).

Posture and type of bike

Rodano *et al.* (2002) suggested that, in competitive road and mountain biking, 30–40% of a cyclist's body weight will be loaded through the saddle, but because the body weight is distributed through the pedals, handlebars and saddle, the combination of the position of the cyclist on the bicycle, the pedalling action and the body weight distribution will determine the effect on the muscles, ligaments and other structures around the pelvis, including the prostate and neurovascular bundle. Disagreement remains about whether the upright or forward lean posture is most suitable to minimize urogenital distress while cycling (Rodano *et al.* 2002; Gemery *et al.* 2007; Potter *et al.* 2008; Carpes *et al.* 2009; Sommer *et al.* 2010). Sommer *et al.* (2010) stated that, in the upright-seated position, a reduction in penile blood flow of up to 70% occurs as a result of compression of the dorsal penile arteries in the perineum. In contrast, Gemery *et al.* (2007) suggested that, with the rider leaning forward, greater compression of the internal pudendal artery occurs immediately below the pubic symphysis (Figs 15 & 17). Rodano *et al.* (2002) indicated that, when the cyclist is in the bent-forward race position (Fig. 16), the pudendal

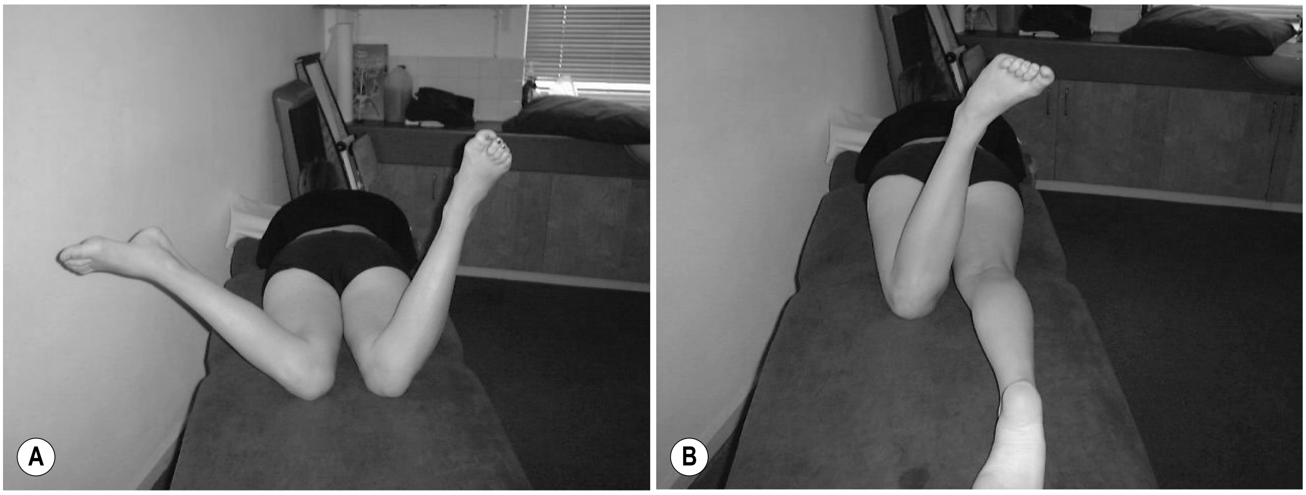

Figure 12. (A) Prone hip medial rotation: (left) >50° hip medial rotation suggests antetorsion/anteversion of the femur; and (right) hip just within normal range. (B) Prone hip lateral rotation: hip range of motion is very variable and does not necessarily imply muscle shortness; however, if <30°, check medial rotators, tensor fasciae latae/iliotibial band, anterior gluteus medius and gluteus minimus muscles; if <10° lateral rotation, this suggests antetorsion of the femur. Confirm similar ranges in supine.

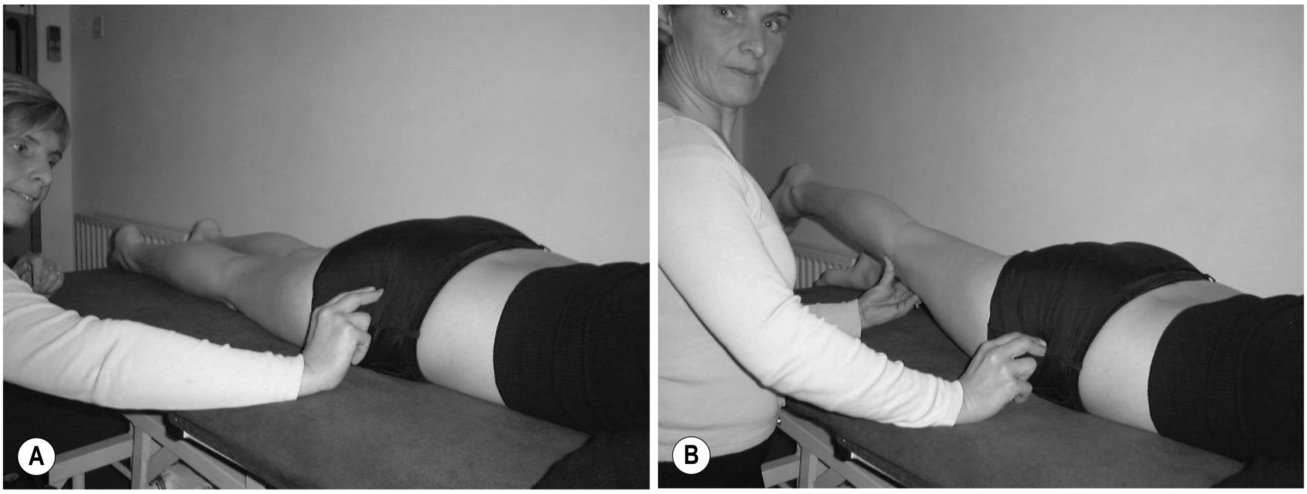

Figure 13. Prone hip extension with knee extended: (A) therapist monitoring the greater trochanter; and (B) femoral anterior glide, the greater trochanter moves anteriorly, which suggests overactivity of the hamstrings and/or a stretched anterior capsule.

nerve is more likely to be compromised since the greatest pressure is transferred to the anteroposterior section of the saddle.

A study to verify the effect of trunk position and saddle design on saddle pressure in both men and women concluded that it is the masculine anatomy that mainly influences saddle pressure during riding (Carpes *et al.* 2009). For men, the trunk-forwards position lowers the values of saddle pressure only for men using the ‘‘holed’’ saddle, whereas there were no statistical differences when comparing saddle pressure between the two trunk positions for women. Therefore, differences in the centre of gravity, perineal anatomy and pelvic bone shape of men and women may result in gender differences in pressure values from bicycle seats (Potter *et al.* 2008).

Use of a recumbent cycle has also been shown to produce a smaller decrease in genital oxygen tension; however, in some situations, it can be a more difficult and less practical bike to ride (Schrader *et al.* 2002; Dettori & Norvell 2006). Mountain bicycles have been associated with a greater risk of ED as compared with road bicycles, according to Dettori *et al.* (2004); however, their study is weakened by a small cohort size of impotent bicyclists and a high non-responder rate (>20%).

Saddle width

It has been suggested that endothelial injury of the penile artery can occur as a result of the compressive trauma caused by the pressure of sitting on a bicycle saddle, either by chronic

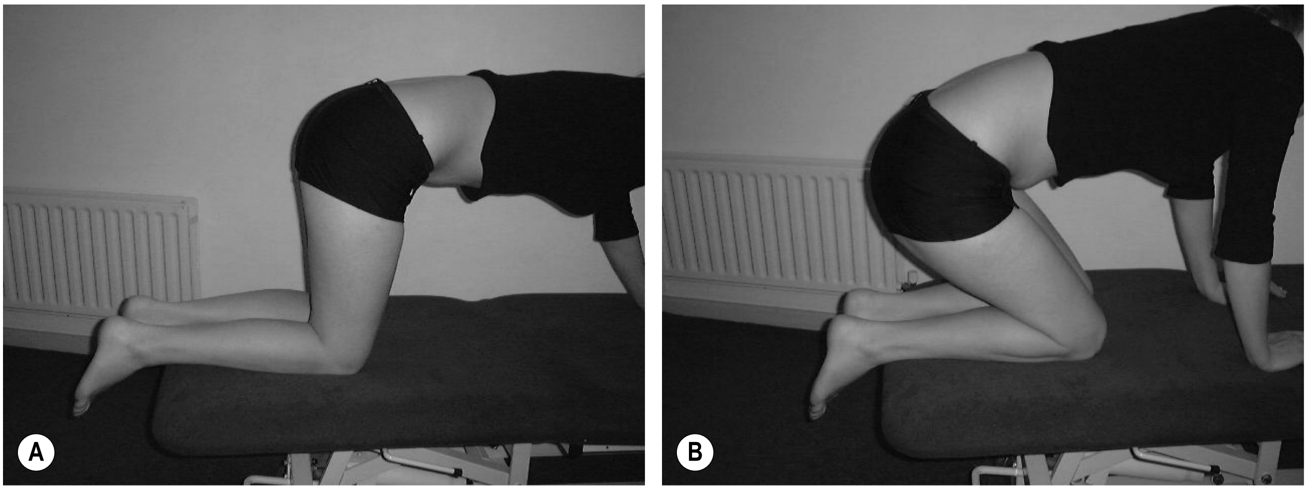

Figure 14. (A) Quadruped, a <90° angle between the femur and pelvis suggests a short/stiff posterior hip joint capsule and gluteus maximus/piriformis. (B) Backward rocking heels, hips do not flex to heels, which is suggestive of decreased hip flexion or pelvic rotation, and implies a short/stiff gluteus maximus/piriformis (rotation implies asymmetric stiffness).

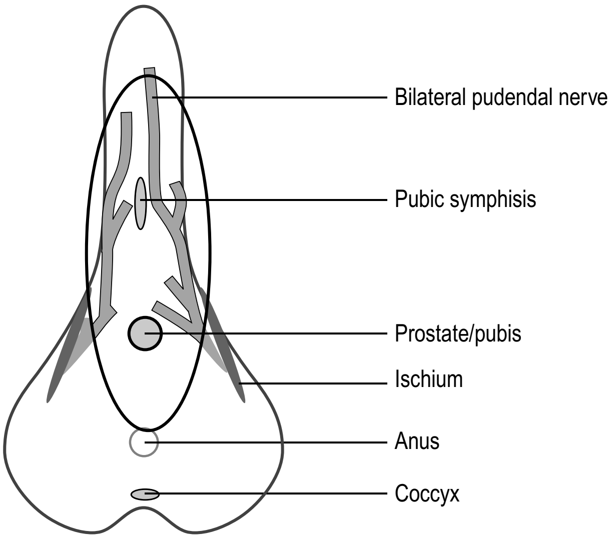

Figure 15. Estimation of the alignment of the human body in the cycle saddle. The helix shows the anatomical area that is most subject to injury during cycling (after Rodano *et al.* 2002).

compression of the neurovascular structures in the perineum or when a cyclist slips onto the top bar of a bicycle, and lands directly on the perineum or the ischiopubic ramus (Sommer *et al.* 2010). Most cyclists sit on a saddle that is narrower than the space between the ischial

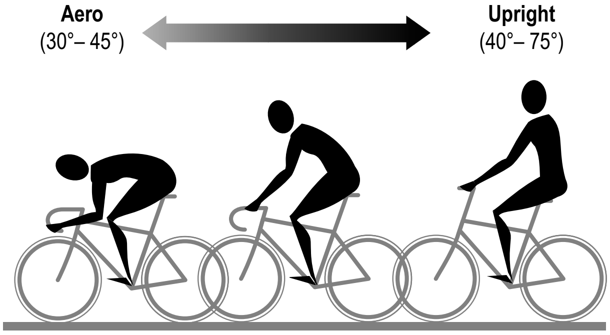

Figure 17. Different seating positions for a rider on a bicycle.

tuberosities, causing the load to be borne on the ischiopubic ramus, close to the Alcock's canal, which may lead to a compromised blood supply to the penis (Richiutti *et al.* 1999; Jeong *et al.* 2002; Rodano *et al.* 2002; Sommer *et al.* 2010). Jeong *et al.* (2002) also concluded that a narrower saddle significantly reduces penile blood flow and could be the cause of blunt trauma to the perineum, although the small number of subjects ($n = 20$) and the indirect method used to measure penile blood flow reduces the validity of the study. Weiss (1985) and Bond (1975) have both proposed that transient ischaemia can be

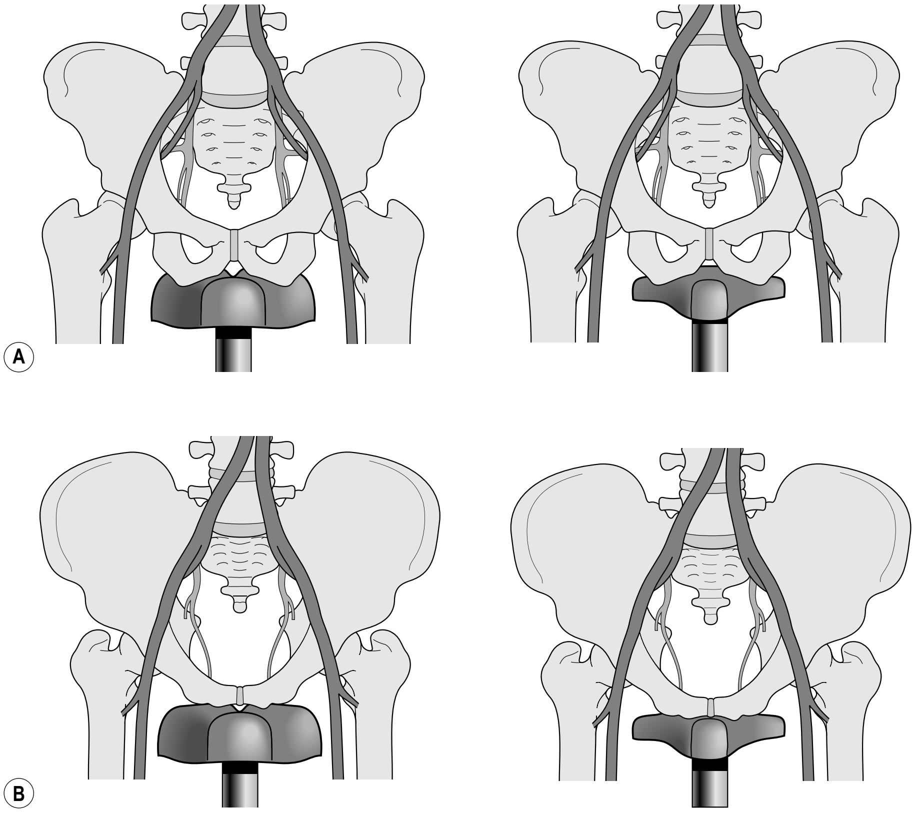

Figure 16. Frontal views with pelvis positions corresponding to: (A) a rider in a partial forward lean with arms extended; and (B) a rider in a full forward lean, as when using aerodynamic bars. The seats on the left have a central groove (preserving the seat–symphysis space), while the seats on the right are of a flat racing style. There appears to be greater compression during the forward lean when using a racing saddle.

caused by compression of structures between the saddle and the symphysis pubis.

Sommer *et al.* (2010) concluded that the width of the saddle must span at least the distance between the ischial tuberosities, and the saddle must be wide enough for the ischial tuberosities to be situated on the flat back region of the saddle so that they are positioned higher than the soft tissue.

Saddle padding

According to Sommer *et al.* (2010), cycling on a gel saddle resulted in 37% more loss of penile oxygenation than cycling on an unpadded saddle. They hypothesized that this was a result of the gel being pressed into the perineal region until the ischial tuberosities encounter resistance as the rider sinks into the saddle. Furthermore, the wider saddle showed 57% better penile oxygenation than the narrow saddle when comparing the same seat position and padding material.

Conclusions

Particularly given the cardiovascular benefits from this low-impact activity, practitioners are urged to balance the risk–benefit ratio of cycling, as they would any intervention in medicine (Brock 2005). Rather than discourage cycling, the present authors suggest that readers should emphasize to their patients with urogenital dysfunction strategies that may minimize the potential adverse effects of cycling, such as:

- periodically rising from the saddle for a brief time, which can relieve pressure and help to re-establish blood flow;
- modifying training schedules;
- adjusting posture on the bike or using a different type of bike; and
- modification of the saddle, such as an unpadded, wide, no-nosed saddle, but consideration must be taken regarding the location of the groove or hole.

Running

While running has many beneficial effects, such as improving cardiovascular health and improving bone density, there is a risk of injury to the musculoskeletal system as a result of poor training technique and overtraining (Harrast & Colonno 2010).

Geraci & Brown (2005) reported that the most common causes of hip pain in runners are muscle strains and tendinitis, which can be attributable to changes in running speed, sudden changes of direction, and a sudden increase in weekly or monthly mileage. The athlete presents with acute localized pain, which is found over the muscle–tendon unit on examination. Assessment reveals weakness on resisted testing and pain on passive stretching. There are underlying risk factors for the development of a stress fracture, including increases in frequency, duration or intensity (Harrast & Colonno 2010). Periodization of training is a coaching technique that includes rest days after higher-intensity training sessions in a training programme and reduces risk of injury. Training in running shoes older than 6 months is a risk factor for stress fracture (Gardner *et al.* 1988). Stress fractures of the pelvis account for approximately 1–7% of all such fractures, and the most common site for a fracture is the pubic ramus (Fredericson *et al.* 2006). Patients may present with pubic ramus stress fractures, which may be initially thought of as soft-tissue injuries to the adductors. The history of onset and analysis of the athlete's training programme should help to avoid this. Hreljac (2005) reported that up to 70% of runners sustain overuse injuries during any one year.

Football

Ekstrand & Gillquist (1983) reported that the incidence of groin pain in soccer players was 8% over a period of one year. Other authors have reported that the incidence of groin injuries in professional footballers is as high as 22% (Werner *et al.* 2009).

Werner *et al.* (2009) investigated the incidence, pattern and severity of hip and groin injuries in professional footballers over seven consecutive seasons. A total of 628 hip/groin injuries were recorded, accounting for 12–16% of all injuries per season. More than half of the injuries (53%) were classified as moderate or severe (involving an absence of more than one week), the mean absence per injury being 15 days. Re-injuries accounted for 15% of all registered injuries. In the 2005–2006 and 2007–2008 seasons, 41% of all diagnoses relied solely on clinical examination (Werner *et al.* 2009). These authors concluded that hip/groin injuries are common in professional football, and the incidence over consecutive seasons is consistent. They further noted that hip/groin injuries are associated with long absences and many hip/groin diagnoses are based only on clinical examination.

A qualitative study by Pizzari *et al.* (2008) looking at the prevention and management of OP in the Australian Football League reported that all clubs involved in the study showed a high awareness of the condition, and had identified a number of management strategies to combat it, such as rest-modified training, correction of predisposing factors as well as early detection of onset.

As discussed previously in part 1 of this paper, there is much debate about the aetiology of adductor-related groin pain (Jones *et al.* 2013).

Ice hockey

Ice hockey is an aggressive contact sport in which players have to move at great speed on the ice while displaying a very high level of skating ability. The combination of speed, rapid acceleration and deceleration, and contact makes for a significant potential for injury. Kai *et al.* (2010) stated that groin injuries in hockey make up for 5–7% of all hockey injuries, while National Hockey League data revealed that 13–20% of players would suffer a groin injury (Caudill *et al.* 2008).

As in other sports, groin pain in hockey players has multiple aetiologies, which often do not present with unequivocal signs and symptoms. Osteitis pubis is common because of the repetitive changes in direction in combination with bursts of acceleration and deceleration (Kai *et al.* 2010). While skating, the adductor muscles function in adduction and external rotation, and adductor pain is often reported as being worse on skating and shooting the puck (Kai *et al.* 2010). Repetitive motions during hockey (e.g. during a slap shot manoeuvre) involve ipsilateral hip extension with contralateral trunk rotation, and will also predispose the adductor muscles to injury. A slap shot manoeuvre requires rapid twisting motions of the body, and abdominal muscle tears occur during these rapid, torque-producing movements.

Sports involving repetitive flexion of the hip

Antolak *et al.* (2002) concluded that CPP may be explained in part by compression of the pudendal nerve, especially when the activities included continued flexion of the hip, as occurs during many sports such as American football, weight lifting and wrestling (Antolak *et al.* 2002). Antolak *et al.* (2002) hypothesized that, because many athletes begin participation in their sport as teenagers, hypertrophy of the muscles of the pelvic floor during these developmental years can cause elongation and remodelling of the ischial spine. This results in rotation of the sacrospinous ligament, causing the sacrotuberous and sacrospinous to be superimposed over each other. Furthermore, during squatting activities, or during sitting and rising activities, the pudendal nerve may be stretched over the sacrospinous ligament or the ischial spine, which may produce shearing force on the nerve (Antolak *et al.* 2002). This can be made worse by the actions of the gluteus maximus, and the abduction and extension of the hip; for example, rising from the squatting position of the baseball catcher, or in the rugby scrum or during a ruck.

The following two case studies look at examples of athletes who presented with chronic anterior pelvic girdle pain and chronic posterior thigh pain, respectively.

Case study 1

A 21-year-old female middle-distance runner who complained of a 3-year history of anterior hip and groin pain was diagnosed with chronic left-sided OP. She first noticed a gradual onset of anterior abdominal wall pain with running that increased in intensity over a number of weeks. This progressively restricted her running ability and finally completely prevented her from participating in training. As time progressed, the irritability and severity of the symptoms increased with her decreasing levels of activity, including the length of time it took for these symptoms to dissipate. Aggravating factors included pain while walking, sitting at a desk while studying or being in moving vehicles, which all resulted in a gradual decrease in the woman's physical activity along with a concurrent reduction in her conditioning.

Various physical assessments were performed and specialist consultations carried out, but no treatment resulted in an improvement in her signs and symptoms. The athlete eventually become so disabled by her groin pain that she found it difficult to attend university lectures, and travel on public transport or even in private motor vehicles. An MRI scan indicated some bone marrow oedema around the margins of the symphysis pubis, concurrent with findings of OP, but evaluation by a consultant with a special interest in groin problems concluded that, despite the changes on the MRI scan, there was a large cortical input into the athlete's symptoms. In view of the longevity of her symptoms, he suggested that she could not aggravate the situation any further, and should return to being as active as possible and disregard the pain.

Assessment revealed a significant shift of the pelvis to the left, with associated apparent leg length discrepancy. There was a visible rotoscoliosis to the right in the lumbar spine, with an apex at the L3 mobility segment. Forward flexion was limited by pain and stiffness in the lumbar spine. Left rotation was also limited by pain and stiffness in the lumbar spine. Right rotation reproduced the anterior pubic pain. Arthrokinematic assessment of the mobility segments in the lumbar spine revealed reduced neutral zone motion at the L5–S1 mobility segment, with a blocked articular end-feel. There were bony alignment changes in the pelvis with the left innominate positioned in anterior rotation. Arthrokinematic assessment of the sacroiliac joint (SIJ) revealed a significantly diminished neutral zone motion, especially in the left-sided SIJ (Lee 2004). There was associated diminished multifidus bulk and active voluntary recruitment. There was also delayed recruitment time in the left gluteus maximus and increased tone in the left hamstrings. Osteokinematic assessment of the hip revealed a fixed flexion deformity of the left hip flexors, and palpable hypertonicity in the hip flexor group and adductor group of muscles.

Treatment consisted of a high-velocity manipulation to L5–S1, myofascial release and deep tissue mobilization. Additionally, following treatment to reduce the hip flexor and adductor group hypertonicity, it was assessed that there was underlying diminished length of the flexor and adductor groups. These muscle groups were stretched passively and the athlete was prescribed a stretching programme that she was to follow independently. Trigger points were discovered in the proximal third of the adductor magnus and the distal third of the iliopsoas. These were treated using a modified protocol, as described by Travell & Simons (1993).

A unique aspect of the assessment of this athlete was the per rectal assessment of the pelvic floor. This involves a sophisticated digital analysis of the tone, length and function of the pelvic floor muscles (PFMs), and the mobility of the pudendal nerve. It is outlined in detail in De las Peñas & Pilat (2012), Prendergast & Rummer (2012) and Whelan (2012). In this case, the pubococcygeus and iliococcygeus muscles were both found to be hypertonic and short. Trigger points were found in the anterior third of both the pubococcygeus and iliococcygeus, which reproduced the anterior groin pain reported by the athlete. Assessment of the mobility of the three branches of the pudendal nerve was carried out, and diminished mobility was found in the anterior and perineal branches of the nerve (De las Peñas & Pilat 2012; Prendergast & Rummer 2012). Prolonged sustained pressure techniques including Thiele massage and trigger point techniques were applied to the hypertonic pubococcygeus and iliococcygeus muscles (Whelan 2012). Finally, mobilization of the pudendal nerve was carried out, with an emphasis on the perineal and anterior branches (De las Peñas & Pilat 2012; Prendergast & Rummer 2012).

On assessment of breathing patterns, the athlete had poor lateral expansion of her lower ribs and a hypertonic diaphragm. The importance of the assessment of an athlete's breathing is discussed fully in Chaitow *et al.* (2012). Breathing re-education included making her aware of and relaxing her upper thorax, lateral costal breathing, and teaching inhalation via nasopharyngeal breathing and exhalation via oropharyngeal breathing.

The assessment of the lumbopelvic cylinder using manual and visual assessment with real-time diagnostic ultrasound was discussed in the first part of this paper (Jones *et al.* 2013), and the same principles were applied with this athlete. She was found to have hypertonic and weak external and internal oblique muscles, poor contraction of the transversus abdominis and weakness of the PFM group. Re-education of her trunk overactivity was performed using the techniques described previously (Jones *et al.* 2013).

The athlete was instructed about self-treatment of the internal trigger points and hypertonic PFMs, as well as stretches to address shortened muscles as described above. Her treatment initially took place fortnightly, decreasing to monthly and then every 2 months. The treatment was continued for a period of 8 months.

Good outcomes were achieved with regard to improved function, reduced pain levels, and reduced hypertonicity in the global muscles and the PFMs. Improved pelvic floor function was observed using real-time diagnostic ultrasound imaging and correlated with digital manual examination. The athlete was able to return to a more normal life in terms of activities of daily living, recommenced recreational running, and was able to return to progressive weight training and conditioning in the gym. She remains active and symptom-free to date.

Case study 2

A 30-year-old male rugby player, a loose-head prop, complained of an acute onset of pain in the right hamstring insertion. A sudden tear was felt during a ruck, and although this was attended to pitchside, he returned to play for the remainder of the match. The hamstring tightened after the game and the player consulted the team physiotherapist the next day. A torn posterior medial right hamstring was diagnosed and the PRICE (Protect, Relative Rest, Ice and Elevation) protocol was instituted. Over the next few weeks, he attended for treatment by the team physiotherapists and this focused primarily on the soft-tissue lesion in his hamstring insertion. After an initial improvement in his pain and walking ability, his improvement seemed to plateau around week 6. He still experienced a significant restriction in his ability to run at even a slow pace. Further treatment over the following 3 months included steroid injections, deep-tissue massage to the hamstrings, a progressive strengthening programme and acupuncture, but this did not result in any further reduction in his pain or improvement in his running ability. Magnetic resonance imaging revealed an intact hamstring with no evidence of recent or previous tears.

Eight months post-injury, the rugby player was not making any progress, and was still experiencing pain localized to the medial aspect of the right ischial tuberosity that was aggravated by clenching his pelvic floor or gluteus maximus. He reported pain on rising from sitting, taking a wider than normal step, climbing stairs, getting out of a car, running and trying to kick a ball. Differential tissue tension testing revealed no indication of contractile or non-contractile lesions in the hamstrings or the adductors. Osteokinematic assessment of the pelvis revealed an upslip dysfunction of the innominate, with an associated anterior rotation. Arthrokinematic assessment of the sacroiliac joints revealed decreased neutral zone motion, with a fixed articular end-feel. There was a corresponding rotation of the L5 mobility segment to the left. Arthrokinematically, the L5 mobility segment revealed a compressed neutral zone, with a fixed articular end-feel. There was increased tone in the adductors and hamstrings, with associated tenderness on palpation in the proximal to middle third of the adductors and the proximal third of the medial hamstrings. Additionally, there was increased tone in the quadratus lumborum, piriformis and obturator internus. There were a significant number of trigger points in these muscles, which revealed underlying muscle length changes when released. Per rectal assessment revealed increased tone in the posterior PFMs, specifically the iliococcygeus and the posterior third of the pubococcygeus, with trigger points in the belly of these muscles. Pressure on these trigger points produced pain locally and referred the pain to the site of the medial hamstring pain.

Treatment consisted of high-velocity traction manipulation to the right SIJ and high-velocity thrust manipulation to the L5–S1 mobility segment. Soft-tissue release, via myofascial techniques and trigger point techniques, as described in De las Peñas & Pilat (2012) and Prendergast & Rummer (2012), was performed on the hamstrings, adductors, quadratus lumborum, piriformis obturator internus and PFMs. The athlete was instructed about self-treatment of the external hypertonic muscles and the external trigger points. He was also taught techniques to lengthen the adductors and hamstrings, and the piriformis and quadratus lumborum muscles.

After three treatments, he reported no pain in the hamstring and was able to return to a graduated weight-training and conditioning programme. He was fit for rugby by the end of one month and was able to return to his place on the first team.

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