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The sacroiliac joint − Victim or culprit

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A B S T R A C T

It is estimated that 10−30% of all low back pain is attributed to the sacroiliac joints. There are many challenges to diagnosing and treating the sacroiliac joints. Central to this challenge is determining whether the sacroiliac joint is the primary source of pain or dysfunction. This paper considers the complexities of diagnosis and management of sacroiliac joint dysfunction by providing a best evidence informed overview of the mechanics of the sacroiliac joint, the aetiology of sacroiliac joint dysfunction and the most current diagnostic strategies and management options for dysfunctions of these joints from a biopsychosocial perspective. This comprehensive chapter aims to shed light on the challenges of managing sport and exercise-related sacroiliac joint pain, and in so doing highlight the paucity of high quality research investigation of the joint, and the clinical uncertainty that is an unavoidable feature of addressing dysfunction of this joint.

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Introduction

It is widely accepted that the sacroiliac joints (SIJs) are a pain generator in 10−30% of axial low back pain cases [1,2]. It has been reported that approximately 44% of cases of SIJ pain are associated with trauma onset but in the majority, aetiology is unclear [3]. While theories of causative factors for SIJ pain are plentiful, evidence is sparse. In fact, it has been argued that clinicians and patients alike may be suffering from the confusion generated by an over-abundance of theoretical models upon which to rationalise treatment of these joints [4].

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In this review, the current knowledge regarding SIJ anatomy, function, aetiology, examination and treatment will be presented with a view to assisting a clinical approach. Central to this understanding lies the question: when pain is perceived at the SIJ, is it most rational to direct treatment at local tissues, or at factors remote to the joint? Is the SIJ the primary cause of pain in this region, or is it merely the victim of other factors acting on and around the joint?

Anatomy and function of the sacroiliac joints

In bipeds, the pelvis acts as a platform to the three largest levers of the body: the spine and the two lower limbs. Accordingly, the SIJ play a pivotal role in transferring loads between the spine and lower limbs by acting as stress relievers in the force-motion relationship between the spine and limbs [5]. In vivo motion studies have demonstrated small amounts of motion occurring in the SIJ [6]. This motion is considered essential to dissipate torsional stresses resulting from repeated force or sudden trauma that would otherwise lead to mechanical failure (fracture) in a solid pelvic ring [5]. In the sacroiliac region, those forces are considerably amplified by the large, dynamic levers acting upon the joint. Simultaneously, any amount of free motion within the pelvic girdle, no matter how small, necessitates the capacity for orchestrated control of the forces that act upon the mobile region.

Vleeming et al. [7,8] introduced the concepts of 'form closure' and 'force closure' to describe how the structures and muscles of the SIJ control load transfer through the joint. These terms have gained popularity and are in common clinical usage. The form/force closure concepts build from the previous work of Panjabi [9] that described a system of dynamic joint stability dependant on the structural and functional interaction of passive bony tissue and active musculotendinous and ligamentous structures. While Panjabi's model relates to dynamic vertebral stability, Vleeming et al. presented a model that relates to the dynamic stability of the SIJs.

Form closure

Form closure refers to how the bony and cartilaginous morphology of the SIJs contribute to joint stability [5]. All joints have a variable amount of form closure and the extent of form closure dictates how much added force (force closure) is required to control the joint when it is loaded. In the SIJs, where small degrees of motion are available, there are two main morphological adaptations that contribute to form closure: the shape of the sacrum and the contoured and corrugated joint surfaces. Specifically, Vleeming et al. highlight the fact that as the sacrum is wider superiorly than inferiorly, and anteriorly than posteriorly, it is 'wedged' cranially and dorsally between the ilia of the bony pelvic ring [7] enabling it to resist both vertical and anterior shearing forces [5]. Similarly, the joint surfaces of the ilia and sacrum are multiplanar and exhibit interdigitating symmetrical grooves and ridges that not only increase the area of contiguous contact, but increase the friction co-efficient between the two joint surfaces to resist shearing forces [7,10].

Force closure

Force closure refers to how muscles (acting through their ligamentous and facial attachments to the bony pelvis) contribute to SIJ stability by generating compressive joint forces that are adaptable to changes in loading conditions [11]. The ideal combination of SIJ control is achieved through a complex interaction of form closure and orchestrated force closure. Force closure can be thought of as an adaptive force which is directed perpendicularly to the SIJ in order to resist any potential non-physiological motion caused by internal force (e.g. locomotion) and external force (e.g. gravity) [8]. As such, force closure is used to control the degree of stiffness at the SIJ in a constantly adapting response to forces which are principally vertical in direction. Larger vertical forces result in increased activation of the myofascial force closure system and a consequent stiffening of the SIJ [12].

Every joint has a position where there is maximal congruency of the articular surfaces and maximum tension of the majority of its major ligaments. For the SIJs, this position is when the sacrum is nutated relative to the ilia (e.g., the sacral promontory moves anterior and inferior on the SIJ articular surface) [5]. Sacral nutation results in an increase in the compressive forces across the SIJs as the

posterior parts of the ilia approximate and an increase in the tension of the majority of the SIJ ligaments including the interosseous, short dorsal, sacrotuberous and sacroiliac ligaments [13]. In contrast to the sacrotuberous ligament, which increases in tension and therefore limits nutation [14,15], the long dorsal sacroiliac ligament increases in tension and limits counternutation [16]. It is theorised that tension in the long dorsal SI ligament also increases with tensioning of the ipsilateral sacrotuberous ligament and contraction of the erector spinae and muscles. In contrast, it is theorised that tension of the long dorsal ligament decreases with contraction of the gluteus maximus muscle or tensioning of the posterior layer of the thoracolumbar fascia resulting from a latissimus dorsi contraction [17]. Further, anatomical studies suggest that tension in the sacrotuberous ligament can also be increased with contraction of the biceps femoris or gluteus maximus muscles [5]. The relationships between the long dorsal and sacrotuberous ligaments, and between the long dorsal ligament and the erector spinae muscles provide protection against excessive slackening of the long dorsal ligament, which would leave the SIJs particularly susceptible to vertical shear forces [18].

Optimal control of the SIJs is situation specific and is achieved when there is an appropriate balance of mobility and stiffness to control shear of the joint surfaces resulting from the most economical use of muscular forces [5]. Cholewicki et al. [19] have shown that in persons without SIJ pain lumbopelvic stability during trunk perturbation is achieved with modest amounts of co-activation of the paraspinal and abdominal wall muscles. It is hypothesized that the deeper muscles (e.g., transverses abdominis, pelvic floor, diaphragm, lumbar multifidus) of this region are capable of exerting higher compressive forces across the SIJs compared with the more superficial muscles (e.g., and external oblique) due to the fact that they are closer to the axis of rotation of the spine and SIJs and have a more extensive attachment to the ligaments and fascia of the region [11]. Therefore, along with the muscles overlying the SIJ, contraction of these deeper muscles is reported to be an important component of the force closure mechanism of the SIJs [5,20].

Understanding the relationship between mobility and stiffness has implications in the athlete where load transfer between the lumbar spine and pelvis is an essential element of sporting activity. While stiffness in the joint may be essential to some extent, this needs to be balanced against the requirements for flexibility and fluid movement. Consequently, the biomechanical demands in sport need to be considered in the context of understanding how to achieve optimum control of the SIJ. While any athlete can develop SIJ dysfunction, sports with the highest prevalence appear to include football, basketball, powerlifting, gymnastics, golf, cross country skiing, and rowing [21].

Aetiology of sacroiliac joint dysfunction

Two contemporary views of SIJ dysfunctions that may lead to SIJ pain include impairments in SIJ force closure and maladaptation resulting from lumbar and lumbosacral joint fusion.

Impairments in force closure

The primary causes of impairment to the force closure mechanism of the SIJs are considered to be trauma, laxity of the pelvic ligaments, biomechanical asymmetry and suboptimal motor control of associated muscles [3,4,20,22]. Altered joint stiffness and impaired motor control of deep muscles have been associated with lumbopelvic pain [20,23]. It is theorised that traumatic damage to the SIJ ligaments results in aberrant motion of the joint and incompetence in the dynamic system of proprioceptive feedback and co-ordinated motor control [5]. Over time, reduced joint stiffness may result in recurrent microtrauma of ligaments and joint cartilage, leading to degenerative change [5]. Despite these associations, the explanation for the correlation of SIJ pain and impaired force closure is unlikely to be simple or direct [23].

Sports that challenge the force closure mechanism often do so through repeated single leg stance with torsion [24]. In this way, the repeated demands of sports such as skating, cricket, racket sports, rowing, and bowling (as well as others) are thought to increase risk of SIJ pain in athletes. Further important features in the presentation of sports and exercise-related persistent SIJ pain are likely to be similar to those in low back pain, including: increased or asymmetrical muscle bulk of the lumbopelvic muscles due to training practices [25,26], altered lumbopelvic movement patterns and muscle fatigue

[27]. While clinically relevant, such asymmetries are likely to be the product of sport specific demands and resulting muscle bulk and movement habits rather than isolated movement pathology of the SIJ.

Peripartum women are by far the most studied patient group in SIJ pain. The effect of sex hormones on collagen synthesis and ligamentous tension has been associated with reduced joint stiffness at the SIJ, although the association with pain is less clear [28]. Damen et al. [23,29] demonstrated that reduced SIJ stiffness and pelvic girdle pain in pregnant women are only correlated when the degree of laxity is asymmetrical across the SIJs. The existence of a patient group with SIJ pain due purely to impaired motor control in the absence of pregnancy or trauma is poorly supported in the current literature. Nevertheless, there appears to be considerable variance of expert opinion, leaving opportunity for misinterpretation.

The SIJ continues to be discussed both as a source of neuromotor abnormalities causing pain in neighbouring structures and as a source of pain caused by neuromotor abnormalities in the same neighbouring structures [4,30]. Vleeming et al. [11] suggest that innominate (ilium) rotation may be adversely influenced by myofascial structures, causing a relative counternutation of the sacrum to the adjacent innominate and reducing the ability of muscular contraction to influence joint stiffness. In principle, this renders the SIJ vulnerable to shear force and the considerable leverages of the spine and lower limbs, with strain and risk of injury in surrounding connective tissue and myofascial structures. Conversely, Sole et al. [30,31] theorise that altered tone in the hamstring muscle may, in some cases, be interpreted as a neuromuscular response to mechanical instability in the SIJ. Thus, two interpretations appear to suggest that SIJ pain is both secondary to motor control adaptations and the cause of such adaptations, hence 'victim and culprit'. While the two scenarios are not exclusive of one another, this serves to demonstrate the difficulties in scientific study of this region of the musculoskeletal system. Moreover, it is also possible that the force transmitted across the SIJ is also considerably amplified by internal and external factors. There is some evidence from finite element modelling that standing spinal movements in the presence of lower limb length inequality can produce asymmetrical and highly amplified forces across the SIJ [32], although these findings should not be extrapolated to more 'functional' human movement such as walking or running.

Much attention has been paid to reduced force closure resulting from insufficient muscle activity and ligamentous laxity. It is also suggested that, for some patients, excessive activation of the motor control system may result in excessive force closure [4]. It is known that certain patients demonstrate sacroiliac pain associated with increased pelvic floor activation [33] while others demonstrate reduced activity [20]. O'Sullivan and Beales have described patients in whom adopted, antalgic postures are associated with a picture of excessive contraction and inhibition in myofascial structures of force closure [34]. These motor control responses are considered secondary to maladaptive cognitive processes based around misguided beliefs that their spine and pelvis is unstable or displaced and demonstrate maladaptive movement patterns [4]. Thus, the difference between this approach and those previously described is the suggestion that altered motor control may be cognitively driven and therefore there are further implications for practice.

Clinical assessment of the sacro-iliac joints

The clinical assessment of the SIJ aimed at informing treatment should include a thorough examination including consideration of a the pain presentation, tests to determine whether the SIJs are the source of pain and the possible mechanisms underlying this pain (i.e., altered SIJ motion or impaired force closure).

Assessment of sacro-iliac joint pain

While the SIJ has long been recognised as a potential pain generator, accurate diagnosis has been associated with complex, poorly validated and confusing theories about how this is best achieved. Despite the fact that the clinical diagnosis of a symptomatic SIJ is challenging, the primary focus of any physical examination is to consider and assess all of the structures that may give rise to pain (see Table 1). SIJ pain is characterised by increasing difficulty with load-bearing through the joint. Consequently, endurance capacity for standing, walking and sitting is reduced. In the athletic population this may result

Table 1
Structures which may give rise to SIJ pain [36–38].

Lumbar spine	Hip	Pelvic structures
Disc	Avascular necrosis	Myofascia
Facet joint	Osteoarthritis	Viscera – prostate, colon, gynaecological structures
Myofascia	Labral tear	
Nerve compression	Chondral damage	
Instability	Femoroacetabular impingement	
Stenosis		

in marked reduction in ability to perform activities which require load transfer through the SIJ. In addition, lower lumbar rotation can be painful, as in turning over in bed. Importantly, pain presents below the level of the lumbar spine, in the buttock and groin of the affected side with non-dermatomal referral into the postero-lateral lower extremity [35].

It has been suggested that identifying the SIJ as the source of pain can only be verified with the observation of substantial pain relief following an intra-articular injection of local anaesthetic into the joint space [39]. However even this procedure is prone to false positive responses and is not without risks. Therefore this procedure, along with subsequent management decisions should only be employed when there is good clinical reason, such as positive case history and clinical findings [39].

Described by Fortin in 1991, the Fortin sign suggests that when a patient localises the site of their pelvic pain to within 1 cm of the PSIS the source of their pain is the SIJ [40]. A 2008 study by Murakami et al. [41] demonstrated that only 18 out of the 38 patients presenting at an outpatient clinic who had this sign responded to a periarticular SIJ block suggesting an accuracy of 47%.

In 2005, Laslett et al. [42] proposed that the most effective means of implicating the SIJ as the source of pain by physical examination was through the use of a battery of five pain provocation tests after assessing their diagnostic accuracy against an intra-articular anaesthetic block in a sample of 48 persons aged 20–79. The five provocation tests include;

1 Distraction Test – The patient lies supine and the examiner applies a vertically orientated, posteriorly directed force to both the anterior superior iliac spines (ASIS). The test specifically stresses the anterior sacroiliac ligaments, and of all the tests used in the cluster, has the highest positive predictive value (0.6; 95%CI = 0.36–0.80) [43]. When performed in isolation, the test has sensitivity of 0.60 (0.36–80) and specificity 0.81 (0.65–0.91) [42].

2 Thigh Thrust Test – The patient lies supine with affected side hip flexed to 90°. The pelvis is stabilised at the opposite ASIS with the hand of the examiner, while providing steady increasing pressure through the axis of the femur. The test specifically examines the posterior tissues on the joint, and has a high inter-rater reliability (Kappa = 0.94, 0.64–0.82 p < 0.001), sensitivity (0.36–0.88) and specificity (0.50–0.69) in studies of moderate to high methodological quality [42,44].

3 FABER (Patrick's) Test - The patient lies supine as the examiner crosses the affected-side foot over the opposite-side thigh. The pelvis is stabilised at the opposite ASIS with the hand of the examiner. A gentle downward force is applied to the affected-side knee of the patient and is steadily increased, exaggerating the motion of hip flexion, abduction, and external rotation. The test is primarily used to identify pathology of the hip joint. However, it can be useful in identifying SIJ pain when clustered alongside the other tests. The test creates a horizontal abduction force through the femur, creating tension through the soft tissues and transferring the forces through to the SIJ. Intra-rater reliability is high, and improved with the use of inclinometry (ICC 0.86, 0.86, and 0.91 with sensitivity 0.69–0.77 and specificity 0.16–1.0 (Kappa = 0.83), albeit with variable pain relief criteria [44].

4 Compression Test – The patient is placed in a side-lying position, with the affected side up, facing away from the examiner, with a pillow between the knees. The examiner places a steady downward pressure through the anterior aspect of the lateral ilium, between the greater trochanter and iliac crest. This test is a pain provocation test which is believed to stress the SIJ structures, and in particular the posterior SIJ ligament, to attempt to replicate patient's symptoms [42]. A systematic review of the reliability of pain provocation tests of the SIJ undertaken in 2000 concluded based on the synthesis of four studies that the Compression test is not reliable (Kappa = 0.63) [45].

5 Gaenslen's Manoeuvre - The patient lies supine with the affected side leg near the edge of the table while the patient's shoulders are positioned towards the middle of the table. The patient then draws the non-affected side leg into full flexion and holds the flexed knee while the examiner holds the leg with their hand placed over the patient's hand. This action keeps the ilium on the non-tested side in a slightly posterior and stable position during the manoeuvre. This test can indicate the presence or absence of SIJ Pain but can also indicate pubic symphysis instability, hip pathology or an L4 nerve root lesion [46].

The Distraction, Thigh Thrust and Compression Tests were found to be the best cluster of tests as the Thigh Thrust is the most sensitive test (0.88), the Distraction Test is most specific (0.81), and the Compression Test was found to have the highest positive likelihood ratio (2.20) [47]. Further, according to Laslett and Szadek, three or more positive tests had high levels of sensitivity (91% & 85%) and specificity (78% & 76%) [39,42,48], and specificity increases to 87% in patients whose pain doesn't centralise into the lumbar spine on provocation [39].

While diagnosing the painful SIJ involves primarily establishing whether the joint itself is a pain source, it is also important to establish if any of the local myofascial structures are generating pain. This can be either as a primary pain source or secondary to pain in an associated structure. Primary pain in myofascial tissue would result from injury to the affected tissue, whereas secondary pain may emerge from altered myofascial loading due to antalgic or protective movement patterns [34]. Despite the available clinical tests that can be used to establish SIJ pain, the exact cause of pain in the pelvis may remain elusive. To that end, the gold standard diagnostic procedure for establishing SIJ pain is a 75–100% relief of pain [49] following an intra-articular injection of local anaesthetic under fluoroscopic guidance [1].

Along with physical examination, consideration should be given to psychosocial, hormonal and neurophysiological factors, which may be implicated in the overall clinical presentation of SIJ dysfunction [4]. Along with the potential nociceptive drivers for pain around the SIJ, it is understood that chronic pain can also be centrally mediated, and it is therefore reasonable to consider that SIJ pain could be both peripherally and centrally produced and maintained [4]. When assessing the patient with SIJ pain it is worth considering the importance of recognising the need to evaluate the patient in relation to risk factors for centrally mediated pain [50,51]. These include but are not limited to: a negative attitude that back pain is harmful or potentially severely disabling; fear avoidance behaviour and reduced activity levels; an expectation that passive, rather than active, treatment will be beneficial; a tendency to depression, low morale, and social withdrawal and; social or financial problems [52].

Assessment of sacroiliac joint motion

In some fields (i.e., manual therapy) it is common to carry out motion testing as part of the examination of the SIJ. However, scrutiny of these tests, including the Standing Flexion Test, the Seated Flexion Test and Gillett's Test has demonstrated that they lack diagnostic value as approximately 20% of asymptomatic subjects were found to have positive findings [53]. To date there is insufficient evidence to suggest that intraarticular motion of the SIJ can be assessed by manual palpation [39]. Specifically, there is a paucity of studies that have employed valid instruments to measure SIJ motion that have identified positional faults of the SIJ—in fact the converse is true [54]. A study by Goode et al. [6] demonstrated that motion of the SIJ is limited to minute amounts of rotation and of translation suggesting that clinical palpation of SIJ motion have limited clinical utility. Furthermore, inter-examiner reliability of individual palpation tests is poor (kappa = < 0.20), though some pain provocation tests appear to have adequate reliability [39]. Palpation is therefore not a reliable means of assessing the joint, and alternative methods with greater clinical efficacy are required. Tulberg et al. [54] used roentgen stereophotogrammetric analysis of SIJ position in 10 symptomatic patients before and after joint manipulation of the SIJ. This was compared with clinical testing of the sacroiliac joints using 2 positional tests and 6 functional movement tests. While the clinical testing was uniformly positive before manipulation and uniformly negative after manipulation, there was no appreciable difference in position between ilium and sacrum in any plane using an imaging technique that was accurate to 1–1.5°.

Assessment of impaired force closure

The Active Straight Leg Raise Test (ASLR) has been advocated as a useful diagnostic test for assessing force closure in patients with pelvic girdle pain (PGP) [55]. The ASLR assesses the ability to transfer load between the spine and the legs via the pelvis [55], and can be used to differentiate PGP from hip or lumbar pain [56]. ASLR is performed in a supine position with legs straight and feet apart. The subject is instructed to raise their legs 5–20 cm above the bench, one after the other, without bending the knee and without pelvic movement relative to the trunk. A score is provided for each leg on a six-point Likert scale (0 = not difficult at all, 1 = minimally difficult, 2 = somewhat difficult, 3 = fairly difficult, 4 = very difficult, 5 = unable to do). The scores are added to give a total score out of 10. The clinician observes any compensatory motor strategies such as altered breathing patterns, pelvic tilt/rotation during the test. The test is repeated with manual compression applied through the ilia. The ASLR test is positive if the scores improve with pelvic compression [20]. Changes in pain and ability are believed to result from the reinforcement of the force closure mechanism. Failure to adequately perform the ASLR test may therefore result from failing force closure [57]. Clinically, a positive test may be useful in discriminating those who have SIJ pain from insufficient force closure compared with excessive force closure. Conversely subjects who report worsening SIJ pain with pelvic compression and local muscle activation might be considered to be troubled by excessive force closure [4]. However, the test should only be used along with the clinical cluster as described in order to avoid reaching erroneous diagnostic conclusions [57] as according to Bruno et al. [55] the ASLR test has sensitivity of 0.20–0.25 and specificity of 0.84–0.86.

Managing the painful SIJ

Manual therapy

It has been suggested that manual therapy techniques for treatment of SIJ dysfunction or pain are 'shrouded by an enormous amount of mystique' [4]. Techniques reported in the literature have often been aimed at treating either immobility/fixation of the joint [58,59]. As previously discussed, there is currently little evidence to support motion palpation examination of the sacroiliac joint, despite its widespread use in most manual therapy and rehabilitation disciplines.

Clinical opinion on the usefulness of manual therapy in the treatment of SIJP varies greatly. There are relatively few trials to elucidate the matter, and those that exist are uncontrolled or poorly controlled [60–63].

Wreje et al. [60] used clinical motion, position and pain testing to identify sacroiliac dysfunction and compared a treatment of SIJ mobilisation and muscle energy technique with a 'control', group who received massage. Both groups improved equally in pain, although the manipulation group used less analgesic medication and took fewer days off work. Shearar et al. [61] compared manual manipulation with mechanical force directed to the SIJ, finding no obvious difference between groups in pain and function at discharge. Kamali and Shokri [62], reported that one session of high velocity, low amplitude manipulation of the lumbar spine and sacroiliac region was superior to manipulation of the SIJ alone at 1 month follow up, but no control was provided and it should be noted that all patients had been receiving physical therapy prior to manipulation treatment. Kamali et al. [63] randomised patients to receive either SIJ manipulation or stabilisation exercises. Again, no significant between group differences were found.

It is perhaps most relevant that manual therapy has been shown to alter muscle tone and EMG activity in the muscles related to SIJ stabilisation: hamstrings, quadriceps and abdominal muscles [30,31]. Moreover, there is also supporting evidence to show an effect on segmental excitability of the central nervous system [64]. Such studies provide a useful science-based mechanism for understanding the potential role of manual therapy in the management SIJ pain. Now that it is established that there is no structural effect from the application of manual therapy, analgesic effects are more likely to be produced by inhibitory neurophysiological responses in the central and peripheral nervous

system [65] and via alterations in reflex motor activity [43]. However, questions remain regarding the duration of neurophysiological effects associated with manual therapy and the optimisation of multimodal treatment approaches combining manual therapy with other common approaches, exercise in particular.

Exercise therapy

It must be remembered that a large number of muscles contribute to the dynamic, moment to moment adaptations required for optimal force closure of the SIJ [5]. These include the latissimus dorsi, quadratus lumborum, transversus abdominis, internal oblique, multifidi, erector spinae, piriformis, obturators, gluteal muscles, diaphragm, hamstrings, rectus femoris, sartorius and pelvic floor musculature [11]. By the same token, asymmetry or altered neuromuscular function of any of these muscles can theoretically be expected to affect the efficiency of force closure and load transfer through the SIJ. For example, asymmetrically increased activation of the lumbar multifidi, quadratus lumborum or hamstring muscles may produce a resultant strain on the SIJ [11].

Exercise approaches have been designed to improve the 'stabilising' effect of some or all of these muscles, meaning strengthening to produce stronger force closure across the SIJ. Overall, there is some conflict in the evidence. Stuge et al. [66] compared the efficacy of specific lumbopelvic stabilisation exercises with individualised physiotherapy treatment without the use of stabilisation exercises. In this study, which gives detailed examples of the exercise programs, the specific stabilisation exercises provided clinically important reductions in pain, pain related disability and quality of life, meanwhile the comparator group showed little change. At 2 year follow up, these treatment effects were sustained [66]. Since a substantial number of women do not recover from pelvic pain in the post partum period, these results are particularly interesting. However, contradictory evidence has shown little effect in specifically designed pelvic stabilisation programs [67]. Equally, little benefit was shown in a study of exercises specifically designed to address impaired function in diagonal trunk muscle systems thought to be active in force closure of the SIJ [68]. However, a Cochrane review [69] was able to conclude that strengthening exercises and sitting pelvic tilt exercises reduce pain intensity and back-pain related sick leave. Group exercise, led by a physical therapist, has also been shown to be effective in the antenatal period [70]. A more recent systematic review, Tseng et al. [71] suggest that possible reasons for poor outcome results include poor compliance and the potential for discomfort in some exercise programs.

External pelvic compression

External pelvic compression is the term used for any force produced outside of the body that creates a compressive effect on the pelvic girdle. This may be manual, as in the ASLR test, or more commonly via a pelvic compression belt. There is now over 25 years of accumulating evidence for the use of pelvic compression belts in the rehabilitation of pelvic pain in specific groups such as sports people and peripartum women [10]. In the athlete, they may be simply prescribed and fitted when pain provocation tests for the SIJ are positive without the belt and negative when it is fitted with adequate tension [5].

The mechanism by which external pelvic compression exerts an influence remains unclear. Studies have demonstrated that pelvic compression belts can reduce SIJ laxity [72] and improve neuromuscular performance in the stabilising muscles of the pelvis [30]. Pelvic compression belts have been shown to produce changes in electromyography activity in the abdominal muscles, gluteus maximus and latissimus dorsi, quadratus lumborum and gluteus medius. These changes were task specific and often studied in healthy subjects.

In patients with chronic low back pain, external pelvic compression results in a reduction of muscular exertion around the pelvis during prone hip extension [73]. This finding appears to support the notion that persistent pain may be associated with greater activation of the muscles involved in force closure, rather than instability of the SIJ. It is noted that the necessary tension to achieve these results in using a pelvic compressional belt is often relatively low (around 50 N) [74] and that additional tension may not confer greater benefit [72]. A systematic review [75], demonstrated moderate evidence for the role of external pelvic compression in influencing lumbopelvic kinematic motion, reducing pain, reducing SIJ laxity and augmenting neuromuscular control by reducing recruitment of

stabilising musculature in individuals with and without lumbopelvic dysfunction. However, the same review found limited evidence for the effect of external pelvic compression on decreasing mobility between the ilium and sacrum and improving strength in the stabilising musculature.

Injections

Though the SIJ block is seen as the gold standard for diagnosis of SIJ pain, the evidence for their use remains equivocal. Consideration must be given to target-specificity as an essential criterion in assessing the validity of a local anaesthetic block; otherwise any diagnostic inferences cannot be legitimately attributed to anaesthetisation of the purported target [76]. Rupert et al. [2] found the false-positive rate of single, uncontrolled, sacroiliac joint injections was 10%−62% with a pain relief threshold set at 75%−100%. The false positive rate ranged between 10% and 44% for dual anaesthetic blocks when the pain relief threshold was set at 75%−100%.

A systematic review of SIJ blocks by Kennedy et al. [76] found that when local anaesthetic alone is injected 35% (95% CI: 29−41%) of patients had at least 75% relief. When local anaesthetic and steroid were injected 49% (95% CI: 47−51%) of patients had at least 75% relief. The authors of this review concluded that the addition of steroid increased the rate of positive responses to SIJ injections.

In terms of therapeutic SIJ injections, two randomized controlled trials provide categorical data for local anaesthetic with corticosteroid blocks in patients suffering predominantly from non-specific spondyloarthropathies and ankylosing spondylitis; the procedure led to pain relief of between 1 and 6 months in 60−88% of the patients [77,78].

According to Manchikanti [49] the evidence for therapeutic intraarticular sacroiliac joint injections is limited to moderate for short and long term pain relief. The Kennedy et al. [76] review considered studies which satisfied the essential criteria of effect, consistency, replication, and the use of controls. The authors found that based on these criteria the overall quality of evidence for therapeutic SIJ injections was moderate. It is not clear from the evidence if image-guided intra-articular diagnostic injections of a local anaesthetic predict a positive response to a therapeutic injection.

In terms of cooled radiofrequency neurotomy in managing chronic sacroiliac joint pain Stelzer [79] carried out an observational study on a case series of 126 patients, and found that when stratified by time to final follow-up (4−6, 6−12, and >12 months, respectively): 86%, 71%, and 48% of subjects experienced ≥50% reduction in VAS pain scores, 96%, 93%, and 85% reported their quality of life as much improved or improved, and 100%, 62%, and 67% of opioid users stopped or decreased use of opioids. A further study by Ho et al. [80] found that out of 20 cases, 16 found good benefit for up to 2 years following neurotomy. In addition, 2 randomized, double-blind placebo-controlled trials Chen et al. [81]; Patel et al. [82] found the evidence for managing SIJ pain using cooled neurotomy to be fair.

A retrospective cohort study by Hoffman and Agnish [83] considered the benefits of prolotherapy in a group diagnosed with SIJ instability. The authors concluded that as 23% of the 103 patients showed minimal clinically important improvement (>15 point reduction on ODI) that prolotherapy provided clinically meaningful benefit for this patient group. These findings are similar to those in smaller studies by Cusi et al. [84] and Kim et al. [85] but never the less there appears to be limited benefit for prolotherapy and the long term outcomes and complications rates are poorly reported.

Surgery

As recognition that the SIJ can be a source of low back pain increases, the demand for treatment strategies including surgical intervention has grown. Historically the consensus opinion has been to avoid surgery until all conservative means of management have been trialled, and failed [86,87].

According to NICE guidelines [88], SIJ stabilisation surgery is indicated for SIJ conditions including degenerative sacroiliitis, osteoarthritis, SI joint disruptions from trauma or pregnancy, problems after lumbar spinal fixation techniques, anatomical abnormalities such as scoliosis, infection, gout, tumour or idiopathic causes. The guidelines further state that patients being considered for surgery should have persistent chronic symptoms that are unresponsive to conservative treatment. SIJ surgery should only proceed once a positive diagnostic evaluation has been completed with SIJ injections, though as has been established, this process too is not without its challenges.

The traditional surgical approaches can be broadly categorised as open surgery and minimally invasive surgery (MIS) [89]. A study by Ledonio et al. [87] considered the safety and effectiveness of MIS vs open SIJ stabilisation. The authors concluded that based on estimated blood loss, surgery time and length of hospital stay, MIS outperformed open surgery. ODI scores were similar and fusion rates could not be assessed. Minimally invasive sacroiliac joint (SIJ) stabilisation has been shown to be safe and effective for the treatment of SIJ dysfunction. Though multiple devices are available to perform SIJ fixation or fusion, the surgical revision rates after these procedures had not been directly compared. A study by Spain and Holt [90] retrospectively identified all patients in their practice who underwent SIJ fixation or fusion between 2003 and 2015 and compared revision rates using Kaplan-Meier survival analysis. They found that 38 patients underwent SIJ fixation with screws and 274 patients underwent MIS stabilisation using triangular titanium implants. Four-year cumulative revision rates were 30.8% for fixation and 5.7% for stabilisation. They concluded that SIJ fixation with screws had a much higher revision rate compared to SIJ stabilisation with MIS.

An RCT by Polly [91] compared Minimally Invasive Surgery (MIS) with Non Surgical Management (NSM) in a cohort of patients with SIJ dysfunction and found the MIS group had better outcomes at 6 months, based on pain reduction, absence of complications and re-intervention. An RCT by Stureson and Dengler [92] compared MIS with NSM using ability to perform ASLR as the outcome measure. 71% of those undergoing MIS were able to perform the task compared with 32% in the NSM group. Zaidi [89] performed a systematic review and meta-analysis of 432 patients, and found significant improvements in pain and functional scores in those undergoing MIS stabilisation. Capobianco [93] carried out a systematic review and meta-analysis of 432 patients found significant improvements in quality of life scores at 6 and 12 month follow-up when compared with a NSM group.

On the basis of these results, NICE recommend the use of SIJ stabilisation performed as a minimally invasive procedure in the United Kingdom. While long term follow up studies are ongoing, currently little is known about the longer term consequences of SIJ stabilisation. Furthermore while stabilisation of the joint is achieved through this procedure, there is evidence that fusion of the joint does not occur in many patients.

Biopsychosocial assessment and treatment

Sports clinicians are recognised for expertise in the assessment and treatment within a biomechanical model of musculoskeletal medicine. However, it has been argued that management of athletes with low back and pelvic girdle pain syndromes should be delivered according to a biopsychosocial model [94,95]. The suggested benefits of this approach include reduced reliance on poorly evidenced biomechanical theories and reduced usage of injections and surgical interventions [94]. O'Sullivan and Beales [4] propose that SIJ dysfunction and pain are more likely to be multifactorial in aetiology. Further, numerous investigators have identified that patients with persistent spinal and lumbopelvic pain exhibit elevated muscle activation during motion and in static postures [20,33]. Therefore, it is important to consider that SIJ dysfunction and pain may be the result of excessive or insufficient force closure [4]. Accordingly, clinical attention to altered patterns of muscle activation and inhibition (rather than simply weakness, strength and flexibility) may prove to be important in the prescription of individualised exercise. Moreover, it is important to consider the link between elevated muscle activation and 'maladaptive' cognitions [4] and persistent pain conditions in general [94]. This view is in keeping with the 'fear avoidance' model of chronic pain in which pain persists due to an individual's loss of confidence in body resilience and tendency to avoid activity, which is perceived as threatening [96].

The implications of cognitive maladaptation in lumbopelvic pain are, in fact, much more far-reaching than described above. More recently, Beales et al. [97] showed that altered body perception, sleep disturbance and kinesiophobia were more prevalent in patients with moderate disability due to pregnancy-related pelvic pain than in controls without pain. Similarly, psychological factors have long been known to play an active role in the progression of low back pain and are considered opportunities for treatment interventions [98]. Certainly, the perpetuating influence exerted by psychological factors on persistent lumbopelvic pain helps to explain the modest effects of physical treatments in patients with chronic symptoms.

SIJ joint 'instability' has never been reliably demonstrated or associated with SIJ pain in the athletic population. For that reason, sports clinicians should consider the potential impact of using such terms with sports people. It has been suggested that the term 'instability' should be reserved for unstable spondylolisthesis and unstable fractures [94], due to the implicit associations of this word with weakness and vulnerability to injury. It is now widely suggested that the inappropriate diagnosis of SIJ 'instability' may not only lead to unnecessary interventions but also potentially fosters hypervigilance and altered movement behaviours in otherwise healthy athletes. Any harm arising from such effects must be considered entirely iatrogenic and potentially avoidable. In athletes with persistent SIJ pain, these effects should therefore be considered in addition to sport specific concerns as part of a bio-psychosocial assessment.

Summary

Sacroiliac pain, stability and dysfunction are separate clinical concepts that should not be conflated. The association of altered sacroiliac stability and pain has been demonstrated in peripartum women where joint stiffness is asymmetrical. This finding has not been adequately reproduced in any other population with SIJ pain, including sportspeople. Further studies in the aetiology of SIJ pain are required to address this conspicuously absent knowledge. Potential causes of SIJ pain in athletes may be both extrinsic (e.g. training practices causing loading asymmetries in the axial skeleton) and intrinsic (e.g. post-traumatic ligament incompetence or persistent altered lumbopelvic muscle tone following injury to local and neighbouring tissues). Due to the highly integrated nature of SIJ function, intrinsic influences on the force closure mechanism may include the lumbar spine, the hip, the knee, the rib cage and even the shoulder. In this complex and dynamic system, the question of 'victim' and 'culprit' is perhaps less important. Extrinsic influences include sport specific movements and adverse or asymmetric loading patterns in the pelvis. Biopsychosocial assessment is recommended to further consider the possible influence of cognitive and behavioural influences in producing maladaptive movement patterns, excess muscle contraction and dysfunctional attitudes towards pain and recovery. Currently, there is a paucity of studies assessing the causative influences of SIJ pain in sports people, therefore these clinical concepts must be considered unproven.

Practice points

- SIJ pain in the athlete may be associated with trauma or repeated training activities.
- Clinical evaluation should include clustered pain provocation testing. Palpation and mobility testing are of unproven value.
- A biopsychosocial approach is essential in cases of persistent pain. Statements regarding instability' of the joint may have unintended negative effects, particularly in the athletic population.
- Evidence based treatments include exercise, manipulation, pelvic compression belts, corticosteroid injection and surgery.

Research agenda

Future research efforts should strengthen understanding of the aetiology, assessment and management of SIJ pain in athletic populations. Much of the current research has focussed on SIJ pain in peri-partum women and has limited utility to clinicians in sports and exercise. Sport specific prevalence of SIJ injury is yet to be established in almost all sports, as are risk factors and mechanisms of injury. In order to progress toward high quality intervention studies, there must first be consensus over diagnostic criteria that allow reliable assessment of SIJ injury and pain in athletic populations.

Conflicts of interest

None of the authors has any potential conflict of interest.

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