

Low Back Pain and Injury in Athletes

Wayne Hoskins

*Department of Orthopaedic Surgery, Royal Melbourne Hospital,
Grattan St, Parkville Victoria,
Australia*

1. Introduction

Low back pain is an extremely common entity in the general population. Athletes are no different in their affliction for suffering low back pain and injuries, particularly in sports that carry specific low back demands. Whilst traditionally low back pain in the non-athletic population has been thought of in terms of being acute or chronic in nature, recent long-term epidemiological studies have suggested there is a need to revise views regarding the natural history of low back pain. Low back pain is not simply either acute or chronic but fluctuates over time with frequent recurrences or exacerbations and should not be considered self-limiting. The natural history of low back pain in athletes is most probably no different. The very nature of athletic preparation requires mechanical overload. Athletic manoeuvres produce significant compressive forces directed at the lumbar spine. A trade-off is likely to exist between athletic demands and injury, with greater duration of training, training intensity and a lack of relative rest occurring at the expense of tissue overload and ongoing injury. This may explain why some athletes tend to have more persistent, chronic and recurrent low back symptoms, frequently associated with early degenerative joint disease.

Although most low back pain in both the athletic and non-athletic population is non-specific and mechanical in nature, athletes are often at special risk of more serious causes of back pain that are often sport specific in their aetiology. This is a result of the repetitive mechanical loading and often specific and unique motion imposed on the spines of athletes through various sporting requirements in training and competition. Furthermore, the paediatric sporting population carries a special risk for injury given they have less musculoskeletal maturity and they may be at a heightened risk for more severe and permanent skeletal damage, structural abnormalities and chronic pain.

The initial differential diagnosis list for athletic low back pain should be broad. Diagnosis should include a thorough history excluding red flag conditions, examination and a focussed evidence based approach to imaging. Attention should be paid to the mechanism of injury or the inciting event to assist in predicting the potential injury, implementing preventative measures and in developing a management and rehabilitation program. Consideration of the athlete's age and an understanding of the sports specific biomechanics of an athlete is required. It is unclear about the relevance of yellow flags in the development of low back injuries and chronic pain in athletic populations. A lack of research exists

investigating the management of low back pain in athletic populations. Elite level competitors are likely more willing to train and compete with pain and injury as a result of the financial commitments they receive from competition as well as their drive for competitive success, making the management of athletes with low back injury a challenge for the sports clinician. It is likely that management should mirror published guidelines designed for the non-athletic population and incorporate a period of relative rest, avoiding aggravating activities, changes to training and technique along with appropriate rehabilitation therapy.

The coming chapter will discuss the prevalence of low back pain and injury in sport, identify risk factors that athletes have for low back pain, highlight some of the consequences that back pain carries, discuss the diagnosis and management of back pain in athletes and identify areas for future research.

2. Prevalence of low back pain in sporting populations

The anatomical boundaries of the low back being a shaded area between the last ribs and the gluteal folds (Figure 1) has been found to be the most commonly used in a review of methodologically sound low back pain prevalence studies (Walker, 2000). The prevalence of low back pain in the general, non-sporting population has been well described with numerous well designed, long term epidemiological studies and systematic reviews existing

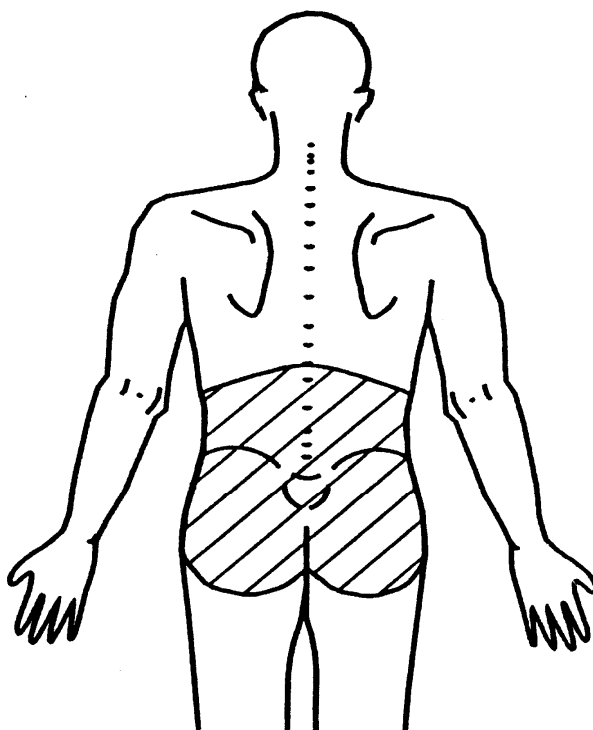


Fig. 1. The anatomical boundaries representing the low back

in the published scientific literature databases (Lebouef-Yde & Lauritsen 1995, Walker 2000). Evidence from this literature has clearly documented that low back is a very common entity and is responsible for substantial economic burden to society (Druss et al., 2002). However, most low back pain that people experience is low-intensity and low-disability in nature (Walker et al., 2004). Figures documenting lifetime prevalence have been as high as 84% with a point-prevalence between 12% and 33% recorded in a systematic review (Walker, 2000).

Despite the amount and quality of literature investigating low back pain in the general, non-athletic population, less interest has been afforded to investigating the prevalence, severity and epidemiology of low back pain in athletic populations. In particular there are very few large, long term epidemiological studies assessing low back pain amongst active competing athletes, especially at the elite and professional level of competition. Of the literature that exists, studies have documented that low back pain prevalence and severity can vary between sports, with, not surprisingly, an increase in pain noted in those sports that carry with them significant low back demands (Sward et al., 1990; Bahr et al., 2004). Noteworthy is the reported lack of significant difference in low back injury rates between contact and non-contact sports (Greene et al., 2001), suggesting that other factors may be more important in the development of most cases of low back pain and injury. However, the true prevalence, severity and natural history of low back pain in sporting populations remains unclear due to a lack of well designed, large-scale prospective and longitudinal scientific literature.

When comparing the literature that exists, it is not entirely clear whether competing athletes are at a risk of a higher prevalence or increased severity of low back pain compared with the non-athletic population. This is largely due to a lack of homogeneity in study design and methodology. It also has not been investigated whether low back pain prevalence or severity varies at different levels of athletic competition. Evidence suggests that sporting participation in the general population, regardless of activity, contributes to less frequent low back pain (Jacob et al., 2004). However, once low back pain is established, participation in sporting activities may indirectly contribute to increased severity of pain (Jacob et al., 2004). Bahr et al. analysed low back pain prevalence between elite athletes competing in endurance based sports: cross-country skiing (n=257), rowing (n=199), orienteering (n=278) as well as a non-athletic group (n=197) (Bahr et al., 2004). Low back pain lifetime (51-65%), year (48-63%) and seven day prevalence (20-25%) was similar between groups although lower in non-athletes. As far as the author is aware, despite smaller studies existing (Sward et al., 1991; Kujala et al., 1996), no other large study has used homogeneity in study design and methodology to make direct comparisons between active athletes and non-athletes. One difficulty in measuring low back pain in an athletic population is the lack of validated questionnaires to quantify the functional disability associated with low back pain. Whilst the validated questionnaires measuring pain severity and quality are likely to be useful, the validated questionnaires in use asking about functional limitations are unlikely to be useful as the parameters asked about are not created for sporting populations and questions asked are likely to be irrelevant to the high functional demands of athletes. The development of a validated sports specific, functional low back pain questionnaire is encouraged.

Much of the current sporting literature on low back pain and injury has tended to focus on sports with specific low back demands such as rowing (O'Kane et al., 2003; Teitz et al., 2003; Bahr et al., 2004), skiing (Mahlamaki et al., 1988; Eriksson et al., 1996; Ogon et al., 2001; Bahr

et al., 2004), gymnastics (Sward et al., 1990; Hutchinson, 1999; Cupisti et al., 2004), diving (Baranto et al., 2006), wrestling (Lundin et al., 2001; Iwai et al., 2004), golf (McHardy & Pollard, 2005), cricket fast bowling (Elliott & Khangure, 2002; Ranson et al., 2010), tennis (Lundin et al., 2001) and American football (Iwamoto et al., 2004). Elite sporting activity in these sports is known to produce significant compressive forces directed at the lumbar spine (Hosea et al., 1989). The repetitive mechanical loading on the spines of athletes in these sports, often in positions involving end range of motion and the increased volume of training required for elite athletic performance is likely to result in tissue overload and subsequent injury. This, combined with a lack of full recovery between episodes of pain and injury due to many athletes not wanting to miss time off training or competition, may explain why athletes may have more persistent, chronic and recurrent low back symptoms, frequently associated with degenerative joint disease (Ong et al., 2003).

The knowledge surrounding the prevalence and magnitude of low back pain in sports that are not known for having specific low back demands, including the various highly popular football codes, remains largely unknown. Research has tended not to focus on low back pain as an area of interest in these sport, likely for a variety of reasons. Firstly, there are other well known more common and more serious injuries that tend to impact the functional demands of these athletes, resulting in loss of competition match play. Secondly, unlike other injuries that athletes experience, it is uncommon that low back pain is severe enough to prevent a professional footballer from competing or from relinquishing his place in team selection. This is particularly true when medical management frequently incorporates epidural steroid injections (Bono, 2004) and local anaesthetic agents (Orchard, 2004a), considered 'part of the game' in professional football (Orchard, 2001). Despite this, injury surveillances have documented that low back injury if present can be severe and have high recurrence rates. In one study on elite soccer, low back pain was reported as the most common overuse injury (Walden et al., 2005). In elite rugby league, 'back injuries' have been shown to have the highest rates of recurrence for all injuries (Orchard, 2004b), whilst in retired elite rugby league players, chronic low back pain has been the third most common complaint, reported by 39 % (Meir et al., 1997). In elite Australian Rules football, the Australian Football League's (AFL) long running injury surveillance has documented that five per cent of all players will miss a match each season with a 'lumbar or thoracic spine' injury, causing them to miss on average four weeks or matches per injury (Orchard & Seward, 2002). In amateur Australian Rules football players, 27% of player report a long term or recurrent back problem (McManus et al., 2004). In school children playing rugby union, low back pain has been shown to afflict over 40% of participants (Iwamoto et al., 2005).

Whilst there are many potential pain generators for low back pain, in reality most pain that both the general public and sporting population will experience, despite the use of advanced imaging techniques, can not be attributed to a tissue diagnosis and remain 'non-specific' and mechanical in diagnosis. However, there are several examples of where it is apparent that certain sports and activities have a clear association between the development of certain injuries and the mechanical demands associated with these sports and activities. Examples of this include spondylolisthesis in cricket bowlers (Ranson et al., 2010) and gymnasts (Toueg et al., 2010), herniated discs in weight lifters (Mundt et al., 1993) and traumatic injuries in body contact sports (Tewes et al. 1995). This will be discussed in further detail later in the chapter.

2.1 Prevalence of low back pain in adolescent sporting populations

There has been an increased awareness of low back pain in children and adolescents with several studies showing that low back pain is highly prevalent in the early years of life (Burton et al., 1996; Balague et al., 2003). Low back pain is known to increase with age during the first decades of life (Salminen et al., 1995), with prevalence increasing significantly following sexual maturity (LeResche et al., 2005). It has been theorized that low back pain in childhood may have important consequences for chronic low back pain in adulthood (Watson et al., 2002). This theory has more recently been validated with clear correlations now existing between low back pain in childhood and adolescence and in adulthood (Hestbaek et al., 2006). Hestbaek et al. in a large longitudinal study found low back pain in adolescence to be a significant risk factor for low back pain in adulthood with odds ratios as high as four (Hestbaek et al., 2006). A dose-response association was also demonstrated: the more days with low back pain the adolescent experienced, the higher the risk of future low back pain that they were more likely to experience. These findings are supported by other well conducted, long term research which has demonstrated that 90% of schoolchildren with low back pain will suffer from low back pain 25 years later (Harreby et al., 1996).

Questions have been raised regarding low back pain at the junior level of sporting competition, given that participation in adolescent sports has been found to be a risk factor for low back pain in one large, well conducted study (Kujala et al., 1997). Furthermore, sporting participation at an adolescent level has also been linked with higher low back pain prevalence than in adolescents who are non-athletes (Kujala et al., 1996). This is particularly true in the male sporting population (Burton et al., 1996). It is believed that adolescent athletes with less musculoskeletal maturity may be at a heightened risk for more severe and permanent skeletal damage and structural abnormalities, particularly when exposed to years of intense athletic training (Wojtys et al., 2000). However, there is a paucity of research documenting the true prevalence and severity of back pain in junior athletes and whether low back pain at a junior level predisposes increased prevalence of back pain later in a career. Like the adult literature, of the literature that does exist, it is extremely difficult to compare results due to a lack of homogeneity in study design. There is also a lack of literature comparing the prevalence and severity of back pain at varying levels of adolescent competition.

3. Risk factors for low back pain in sporting populations

Risk factors for the development of low back pain in the general population have been extensively researched in the published literature. Epidemiological studies into the prevalence of low back pain have identified that there are many individual, psychosocial and occupational risk factors for the onset of low back pain (Manek & MacGregor, 2005). A growing body of literature also exists implicating the role of genetic factors in back pain, in particular the development of disc injuries (Videman et al., 2005). Of the occupational factors there is evidence for a causal relationship between low back injuries and exposure to forceful exertions, awkward postures and vibration (Keyserling, 2000). Although not specifically targeted in research of athletic populations, it is probable that a combination of these 'occupational' factors is responsible for the development of most low back pain in athletic populations given many of the sports with low back demands are well known for

their awkward posturing, forceful exertions and high mechanical loading of the lumbar spine (Hosea et al., 1989; Hosea & Boland, 1989; Cholewicki et al., 1991; Gatt et al., 1997).

Regardless of the sport in question, as Bono states, the low back is an important but under-recognized source of great dynamic power during a golf or baseball swing, a gymnast's landing, a power lifter's heavy squat, or a boxer's knockout punch. In static mode, it functions to help maintain an infielder's stand, a cyclist's tuck, or a ballerina's arabesque (Bono, 2006). These same sources of power and static control are likely to fail with fatigue, excess force and repetitive micro-trauma and result in low back injury. There are a few examples where a specific action or activity has been implicated in back injuries such as the fast bowling action in cricket, hyper-extension in gymnastics, prolonged flexion in skiing and cycling and repetitive lumbar flexion and loading in weight lifting pursuits. Despite this, there is a lack of literature investigating risk factors for the development of low back pain in athletic populations. Laboratory based studies exist demonstrating the high mechanical forces directed at the lumbar spine during a golfer's swing (Hosea et al., 1989), the rowing action (Hosea & Boland, 1989), American football blocking (Gatt et al., 1997) and weight lifting (Cholewicki et al., 1991). Low back pain is also likely be related to the type, intensity, duration and/or amount of athletic activity performed. In endurance based sports with low back demands a dose response relationship appears to exist with low back pain (Bahr et al., 2004). Causes of low back injury have also received much discussion in the large body of literature documenting changes in lumbar-pelvic muscle activation and recruitment due to low back pain, producing altered neuromuscular control strategies (Hungerford et al. 2003). This will be discussed later in the chapter.

What is less clear in athletic populations is the role that psychosocial factors have in both the development of low back injuries and also in the transition from acute to chronic pain. Multiple systematic reviews of the general population have shown that psychological factors have an important role in the transition from acute to chronic pain (Manek & MacGregor, 2005). In a recent systematic review of the literature, depression, psychological distress, passive coping strategies and fear-avoidance beliefs were sometimes found to be independently linked with poor outcome, whereas most social and socio-occupational factors were not (Ramond et al., 2011).

How this literature relates to athletic populations is unclear. Psychosocial factors may be more important for the professional and semi-professional athlete who has financial, contractual and performance concerns. These athletes generate a meaningful income and employment from their sporting endeavours. It has been suggested that a well motivated athlete may under-report pain in order to improve performance, their chances of team selection and for a positive mind frame (Lundin et al., 2001). Alternatively, pain may be over-reported as it may be provoked easily by intense training and competition requirements and hinder athletic performance (Lundin et al., 2001). The athlete may therefore place a greater impact on pain than may be appreciated. This situation is potentially more of a concern as exaggeration of self-reported low back pain and disability may be a predictor for low back pain chronicity (Gatchel et al., 1995). However, previous research on amateur athletes has found psychosocial issues such as level of satisfaction with coaches or team-mates not to be related to the development of low back pain (Greene et al., 2001). Despite this, it has been shown that low back pain in former elite athletes is predicted by psychosocial issues such as life dissatisfaction, neuroticism,

hostility, extroversion and poor sleep quality (Videman et al., 1995). Future research is required to more broadly investigate psychosocial factors in athletes and their impact and relevance, if any, to the development of low back injuries and chronic pain during play and after a career has ended.

3.1 Risk factors for low back pain in adolescent sporting populations

As opposed to the adult population, literature investigating risk factors for the development of low back pain in adolescent populations is not as conclusive in its findings. A recent systematic review of the literature included five studies (Hill & Keating, 2010). The included studies varied considerably in the methods used to gather data, definitions of low back pain, and recall periods for an episode of low back pain. Inconsistency in definitions of low back pain, pre-defined recall periods, and methods used to collect and analyse data limit conclusions that can be drawn about factors that identify children at risk of developing low back pain. As no risk factor has been validated in independent investigation, the authors concluded that there is no certainty that any factor places children at risk of developing low back pain (Hill & Keating, 2010).

Looking at studies investigating risk factors for low back pain in adolescent sporting populations, a large cross sectional survey has found that adolescents are at a greater risk of low back pain if they have low isometric muscle endurance in the back extensors, with no associations found for aerobic fitness, functional strength, flexibility, or physical activity level after adjustment for muscle endurance (Bo Anderson et al., 2006). It may be that the junior sporting population is initially protected from low back pain due to their increased physical fitness, but this could be lost following excessive spinal loading (Kujala et al., 1996) and high training duration (Kujala et al., 1992) that many become exposed to. This is more likely to be the case with the advanced professionalism and training commitments junior athletes face when they reach the transition to increased sporting specialization in elite junior and adult professional sporting competitions. This would be particularly the case if the athlete is allowed to progress with poor techniques that would predispose injury. Junior athletes at the elite level of competition also face pressure to play and train with low back pain (and other injuries) given non-participation or obvious injury history can affect future selection to professional adult level competition. This again makes management difficult.

Another potential reason for an increased incidence of low back pain in elite level adolescent athletes includes the likely increased prevalence of weight lifting training into the typical training programs of most athletes. The effects of the mechanical loading that weight lifting may have on the developing spine, particularly when poor lifting techniques and sub-optimal training programs focusing on body building exercises rather than more functional exercises, combined with the effects of increased loading and training volume has been discussed by other authors (Wotjys et al., 2000).

4. Consequences of low back injury

The development of low back injury when occurring in athletes has several potential consequences. This includes the development of future, recurrent and repeated episodes of low back pain and injury which may be related to the neuro-physiological changes to lumbar-pelvic stability that is known to occur secondary to low back pain, issues associated

with current and future playing performance, potential associations with the occurrence of other injuries and pain and disability to the player in the post career stage.

4.1 Recurrent pain and neuro-physiological changes of back pain

Without a doubt the biggest risk factor for future occurrences of low back pain in athletes are a previous or a current history of low back pain (Greene et al., 2001; O'Kane et al., 2003). It may be reasonable to conjecture that regardless of the aetiology of the initial low back pain, that once an athlete has experienced significant low back injury, that they remain susceptible to future pain and aggravation or exacerbation of pain. This fits with the natural history of low back pain in the non-athletic population (Hestbaek et al., 2006).

Low back pain is known to result in clinical instability of the lumbar-pelvic spine (Kaigle et al., 1995). Panjabi states that clinical instability occurs when segmental control around the physiological neutral zone cannot be accomplished (Panjabi 1992a). It results in a loss of the normal pattern of spinal motion as the neural control system alters the timing of muscular contraction patterns and reflex responses (Panjabi, 1992b; O'Sullivan et al. 1997a). With this loss of segmental stability, there is evidence to support the concept of increased compensatory substitution of the global system (Edgerton et al. 1996; O'Sullivan et al., 1997b), including earlier activation of various muscles involved with lumbar-pelvic motor control (Hungerford et al., 2003).

The lumbar-pelvic spine is preferably supported by an intricate arrangement of deep local muscles, including the multifidus and transversus abdominus, which provide a stabilising base on which the global muscles can act. The local muscles support the individual spinal segments during continuous full-body movements and allow the powerful activation of more global muscles acting across larger joints without spinal injury occurring (Wilke et al., 1995). Coordination of local muscle contraction to provide ongoing spinal stability and prevent injury is a complicated neurological process. Proprioceptive sensory feedback is necessary to permit the correct series, quantity and timing of muscular contraction (O'Sullivan et al., 1997a, Panjabi, 2003), a property lost with lumbar-pelvic pain and dysfunction (O'Sullivan et al., 1997b).

Several authors have suggested that of the local lumbar-pelvic stabilisation muscles, the multifidus and transversus abdominus are key stabilisers (Wilke et al., 1995, Hodges & Richardson, 1996). The multifidus muscles are the deepest of the posterior stabilising muscles having predominantly vertebrae-vertebrae attachments, attaching to the zygapophyseal joint capsules and being segmentally innervated (Macintosh et al., 1986). They function to finely control lumbar vertebral movements about the neutral zone, with their anatomical arrangement, joint attachments and neurological innervation making them the principal muscle for this function (McGill, 1991; Wilke et al., 1995). The transversus abdominus is the deepest of the abdominal muscles. It has extensive attachments to the thoracolumbar fascia and with its advantageous line of attachment, is the most capable of all muscles in tensioning the thoracolumbar fascia, thereby having a major effect on lumbar-pelvic stability by restricting vertebral displacement (Hodges & Richardson, 1996) and controlling rotational and lateral stability of the spine via the thoracolumbar fascia (Cresswell, 1993). In normal participants both the multifidus and transversus abdominus have a large cross sectional area of type one, or slow twitch muscle fibres, which allows

them to provide a tonic contraction to assist with their responsibility of providing constant lumbar-pelvic stability (Jorgensen et al., 1993). Activity of the multifidus and transversus abdominus should occur in advance of the muscles required to provide body movement and action in a feed forward mechanism (Hodges & Richardson, 1996). This occurs regardless of the direction of reactive forces (Hodges & Richardson, 1996).

In those with low back pain, significant changes to the multifidus and transversus abdominus have been recognised to occur which changes lumbar-pelvic stabilisation strategies (Biedermann et al., 1991; Hides et al., 1996; Hodges & Richardson, 1998; Hodges et al., 2003). This, in addition to the compensatory action of the global system, may produce altered muscle response patterns required for lumbar-pelvic stabilisation during sudden trunk loading in athletes following their clinical recovery from low back pain (Cholewicki et al., 2002). After the first episode of low back pain, selective atrophy of the multifidus can occur rapidly within days of pain occurrence, which can be as high as 31% in 24 hours (Hides et al., 1996), a temporal pattern suggestive of a neurogenic mechanism. This atrophy may not be restored following pain remission, which has been linked to a high rate of recurrent low back pain (Hides et al., 1996). In biomechanical research models, loss of even one segment of multifidus muscular control has been shown to significantly reduce the overall stability of the spine, particularly in controlling buckling when load on the spine is increased (Crisco & Panjabi, 1991). Multifidus also shows less endurance and greater fatigability after pain syndromes (Biedermann et al., 1991). This loss in endurance has enabled significant identification of athletes with existing low back pain (Roy et al., 1990). Changes to the internal structure of the type one fibres of the multifidus including a decrease in fibres can also occur following the onset of low back pain (Ford et al., 1983). This may result in reduction of neuromuscular control in fatigue situations and subsequent lumbar-pelvic clinical instability, as the multifidus cannot hold the contraction or the repetitive nature of contractions for the required time frame.

Low back pain is known to increase the threshold of transversus abdominus activation and cause a loss of its tonic activity so that it becomes phasic (Hodges et al., 2003). This suggests that the background stabilisation property provided by transversus abdominus is lost. In participants with a chronic history of low back pain, whilst in remission of pain, a delay in the activity of transversus abdominus has been found, regardless of the direction of imposed force (Hodges & Richardson, 1998). Importantly, this demonstrates that even with the absence of pain, there are alterations to the coordinated firing pattern, which predisposes injury. A lack of feed forward activation will have joints unprepared to take load at the point of loading so there is a higher risk of injury. Importantly this can occur in the absence of pain and may be related to performance deficit in the athlete. Other research has shown that imbalanced patterns of erector spinae activity and reduced trunk extension strength which results from low back pain remains present if low back pain does not resolve (Renkawitz et al., 2006).

Although likely to be multi-factorial, one explanation for recurrent low back pain in athletes could be that athletes who demonstrate neuromuscular control alterations to sudden trunk loading have an increased risk of sustaining a low back injury (Cholewicki et al., 2005). Previously it has been shown that athletes with a recent acute low back injury exhibit altered neuromuscular control strategies for sudden trunk loading (Cholewicki et al., 2002). These findings are relevant to the unexpected and expected contact nature of sports such as the

various body contact football codes and related other sports but also for the agility, change of direction and sudden stop-start nature of many running based ball sports.

Lumbar muscle activity during gait functions to control trunk movements (Carlson et al., 1988). In a non-athletic population, low back pain has been shown to produce poorly coordinated activity of the lumbar muscles during gait (Lamonth et al., 2005). This situation occurring in athletes in running based sports may lead to forces being directed at unprotected spinal structures producing subsequent mechanical stress and injury. Greater and more frequent mechanical spinal loading could contribute to both injury and delayed healing response. Similar to the non-athletic population, a situation may exist where low back pain fluctuates over time with recurrences or exacerbations and temporary remissions (Hestbaek et al., 2003; van Tulder et al., 2002). In support of this mechanism for repetitive and recurrent injury, Green et al. documented that athletes with a history of low back injury with current low back pain have a six times greater risk for future injury (Greene et al., 2001). For athletes with a previous history of low back injury who are now asymptomatic, approximately a three times greater risk of injury exists (Greene et al., 2001; Cholewicki et al., 2005).

4.2 Consequences to athletic performance

Low back injury in athletes may be of further significance as Nadler et al. documented that athletes with resolved low back pain from a history of low back injury demonstrate significantly diminished athletic performance in a 20m shuttle run test compared with a healthy group (Nadler et al., 2002). Despite this study, there is very little scientific literature investigating the consequences of current or resolved low back pain and injury on athletic performance. Research findings have demonstrated that weak hip extensors have been associated with the presence of low back pain, and in female athletes, the presence of hip weakness identified at the time of the pre-participation physical has been shown to be predictive of the subsequent development of low back pain (Kankaanpaa et al., 1998; Leinonen et al. 2000; Nadler et al., 2001; Nadler et al., 2002). Gluteus maximus should be the primary hip extensor during sprinting (Simonsen et al. 1985). During sprinting, the hamstrings should act as a transducer of power between the knee and hip joint and contribute little to hip extension (Jacobs et al., 1996). This transfer of power is essential in the execution of explosive movements like sprinting (Gregoire et al., 1984).

Significant alterations to hip extensor recruitment have been shown to occur with chronic low back pain during walking, causing the gluteus maximus to be inhibited and hamstrings overactive (Vogt et al., 2003). Hypothetically, gluteus maximus inhibition during sprinting may impact power development and sprinting performance and may require the hamstrings to contribute more force to hip extension rather than acting in its transducer role, potentially predisposing hamstring injury. This fits with the often talked about, but poorly researched syndrome proposed by Janda, the lower crossed syndrome, where decreased hip joint range of motion leads to hypermobility of the lumbosacral region (Janda, 1996), which may be another potential mechanism for low back pain. It also fits with models of overactivity of the global muscle system and a compromise in the local spinal muscle system, predisposing excess force directed at unprotected spinal structures and further back injury.

Given the consequences of low back pain on the lumbar-pelvic muscular system discussed earlier in this chapter, it is highly likely that other measures of athletic ability may be reduced in athletes with a history of low back injury. If objective deficits are documented in research, further research is also required to document that rehabilitation and management protocols are successfully able to reverse the decline in athletic performance, not just resolve symptoms.

4.3 Association of low back pain with other injuries

Given that evidence exists documenting that low back pain produces changes in the neuromuscular control of the lumbopelvis (Demoulin et al., 2007) and in athletes, it produces altered muscle response patterns required for lumbar-pelvic stabilization during sudden trunk loading following clinical recovery from low back pain (Cholewicki et al., 2002), it is reasonable to hypothesize that low back pain could increase the risk an athlete has of suffering other injuries. A prospective study by Nadler et al. showed a correlation between the prevalence of low back pain in athletes and lower extremity overuse syndromes, through an unclear mechanism (Nadler et al., 1998). In community level Australian Rules footballers, a history of low back pain has been shown to be a risk factor for other injuries, producing a 19% increased risk of overall injury rates (McManus et al., 2004). Changes in lumbar-pelvic stabilisation and neuromuscular control could explain the high rates of injuries such as hamstring injuries, groin injuries and other lower limb muscle strains which occur in the various football codes, cricket and track and field to name a few sports.

Using magnetic resonance imaging to confirm diagnosis of hamstring injury, 14% to 19% of all hamstring injuries are without muscle damage (Verrall et al., 2001; Verrall et al., 2003; Woods et al., 2004), suggesting no local muscle pathology. A recent study found this figure could be as high as 45% (Gibbs et al., 2004). Injury in such cases could possibly be related to altered functional biomechanics or pain referral that does not appear on cross sectional imaging. It is known that referred myotomal pain from lumbar-pelvic structures, the sciatic nerve and the gluteal or piriformis muscles can mimic hamstring strains (Verrall et al., 2001). The term 'back related hamstring injury' has been coined and is used to classify injuries as having both local hamstring signs and positive lumbar signs (Bennell et al., 1998, Orchard, 2001).

The association between low back ailments and hamstring injuries has been recognised for some time (Baquie & Reid, 1999). However, this relationship has not received as much recognition in the scientific literature as what is suggested anecdotally. Verrall et al. have performed a prospective study which showed that a past history of low back injury approached significance for being a predictor for hamstring injury ($p=0.06$), without reaching the statistically significant level (Verrall et al., 2001). Further specific research has not followed on from this 114 participant study. A strong correlation between common lower limb soft tissue injuries, including hamstring and calf injuries, that involve L5 and S1 nerve supply, with increasing player age has been clearly demonstrated in the AFL's injury survey (Orchard & Seward, 2002). Orchard et al. suggest that on the basis that low back injuries are very common in elite athletes with increased levels of lumbar degenerative changes at the L4/L5 and L5/S1 levels (Ong et al., 2003), that subtle pathology may be present, which increases with age and which predisposes hamstring and calf injury

(Orchard et al., 2004). The association between low back injury and pathology and hamstring injury has extended into treatment approaches with authors documenting the use of mobilisation (Baquie & Reid, 1999) and slump stretching protocols (Kornberg & Lew, 1989; Turl & George, 1998) in the management of hamstring injured athletes with signs of lumbar injury.

4.4 Post career low back pain

Questions need to be raised regarding whether low back pain normalizes following a career of athletic participation. It is known that former elite athletes are more likely to receive hospital care suffering from musculoskeletal complaints in general (Kujala et al., 1996). However, in the largest study performed using self-reported questionnaires, it appears that low back pain is less common in former elite athletes (29.3% of 937) than in non-athletes (44% of 620) (Videman et al., 1995). This is despite an increase in degenerative radiological findings in former elite athletes (Videman et al., 1995; Lundin et al., 2001). It is unclear whether participation in certain sports will affect post career pain or the intensity of low back pain experienced (Lundin et al., 2001).

5. Diagnosis

Although most low back pain is non-specific and mechanical in nature (Burton et al., 1996), athletes presenting to a sports clinician with back pain may have a pathological cause. It is important to initially consider a broad differential diagnosis list. A sports clinician looking after athletic patients is responsible for performing a diagnostic triage to rule out red flag conditions, diagnose the condition and either referring out, or being responsible themselves for treating symptomatic tissues and recognising and evaluating functional deficiencies and aetiological factors responsible for factors causing the low back injury. Dealing with an athlete can often be a challenge when compared with the general population. A sports clinician must assimilate a large body of clinical information unique to the diagnosis and management of the special needs of those who participate in sport. This includes being highly familiar with the vast array of sports and the potential injury mechanisms for low back pain that could occur in a particular sport.

Whilst most back pain will be mechanical in nature it is important to exclude other diagnoses such as rheumatological or inflammatory conditions, infection, fracture and neoplasm. This is particularly the case when adolescent athletes present with low back pain as they are more likely to potentially have a pathologic cause for their symptoms (Micheli et al., 1995). For this reason, it is important for those caring for younger athletes to maintain a high index of suspicion for some of the more common pathologic causes of low back pain in this population. Sports-related diagnoses that have been said to be considered include disc-related back pain, atypical Scheuermann's kyphosis, spondylolysis, spondylolisthesis and other stress fractures of the pelvis, especially in female athletes (Waicus & Smith, 2002). Other research has documented that junior athletes with chronic low back pain form a population of adolescents who have degenerative disc disease identified on magnetic resonance imaging (Dimar et al., 2007). For adolescent athletes with degenerative disc disease, the relative risk of reporting recurrent low back pain up to the age of 23 years is 16 compared with those having no disc degeneration (McManus et al., 2004). Furthermore, disc protrusion and Scheuermann-type changes also contribute to the risk of persistently

recurrent low back pain at a later age (Salminen et al., 1999). How this should alter management approaches remains unclear as there is also a large proportion of adolescent athletes with signs of degeneration present on imaging who remain symptom free. Low back pain in adolescent athletes is a problem that should not be ignored but instead fully evaluated.

The challenge with diagnosis of back pain is that the tissue diagnosis model is mostly not relevant, despite advances in imaging techniques. Whether a sporting population or not, history must identify and eliminate potential red flag conditions that may be present that would indicate more serious pathology. Red flags are clinical indicators of possible serious underlying conditions requiring further medical intervention. Red flags were designed for use in acute low back pain, but the underlying concept can be applied more broadly in the search for serious underlying pathology in any pain presentation. Red flag conditions are listed in Table 1, and should be enquired about in all patients. The presence of red flags in acute low back pain suggests the need for further investigation and possible specialist referral as part of the overall strategy. If there are no red flags present it is safe to reassure the patient and move ahead with the diagnosis process.

Red flag conditions	History or examination findings
Possible fracture	Major trauma Minor trauma in elderly, osteoporotic or those taking long term corticosteroids
Possible infection	Symptoms and signs of infection such as fever or chills Recent bacterial infection Risk factors for infection such as underlying disease process, immunosuppression or intravenous drug use
Possible tumour	Age >50 or <20 years History of cancer Constitutional symptoms such as weight loss Pain at multiple sites Pain worse at rest Pain worsening at night Failure to improve with treatment Pain persists for more than 4-6 weeks
Possible significant neurological deficit	Severe or progressive sensory alteration or weakness Bladder or bowel dysfunction Evidence of neurological deficit (in legs or perineum in the case of low back pain)

Table 1. Red flag conditions for back pain

A focus should be made on the patients age and the age related differential diagnoses prior to full characterisation of the symptoms in history taking. As with all medical diagnosis, it is important to find out key information including the site of pain, whether any pain referral or radiation exists, associated symptoms in particular neurological deficit and systemic

features of illness potentially leading to back pain, when the onset of pain began, the course of the pain, quality of pain, the severity, aggravating and relieving factors and movements, previous history of back pain and back injuries and treatment approaches used and their various success. History should also include questioning of the mechanism of injury or the inciting event. This mechanism of injury allows the clinician to predict what potential injuries may have occurred with the force transmitted and facilitates developing a rehabilitation program and implementing preventive measures through technique or training alterations if applicable.

Lawrence et al. state that the patient's athletic background should be explored (Lawrence et al., 2006). This includes types of sports played, duration of involvement, the level of competition along with what stage of the season the athlete is at, upcoming competition and future goals. This is relevant as it may impact upon the management approaches to be used and their success if an athlete is unwilling to miss a period of training or competition or is going to be uncooperative with management recommendations. It is also important to get an idea of what multidisciplinary management team and coaching staff the athlete has surrounding them as co-management is typically necessary and often mandatory when dealing with the high level elite and professional athlete. These multidisciplinary resources should be embraced and a good working relationship developed as cooperation is often required to implement management programs in an athlete centre approach to care.

In low back pain research performed on the general population, guidelines recommend early identification of psychosocial factors that could prevent recovery from acute low back pain (Ramond et al., 2011). As discussed earlier in this chapter it is unclear whether the yellow flag model is applicable to the sporting population. The presence of yellow flags may highlight the need to address specific psychosocial factors as part of a multimodal management approach. Yellow flags are psychosocial indicators suggesting increased risk of progression to long-term distress, disability and pain. Yellow flags were designed for use in acute low back pain. In principle they can be applied more broadly to assess the likelihood of development of persistent problems from any acute pain presentation. Yellow flags can relate to the patient's attitudes and beliefs, emotions, behaviors, family, and workplace. The behavior of health professionals can also have a major influence. Key factors in low back pain are: the belief that pain is harmful or severely disabling; fear-avoidance behavior (avoiding activity because of fear of pain); low mood and social withdrawal; and expectation that passive treatment rather than active participation will help (New Zealand Low Back Pain Guide, 1997). Future research is required to investigate the relevance of these factors in athletic populations.

Following history taking, physical examination should be equally as thorough and incorporate standard observations and structural analysis, range of motion assessment, palpation and traditional orthopaedic and neurological testing procedures to inform possible investigations if required. The single-leg hyperextension test has been described and is a useful provocative test when differential diagnosis includes spondylolysis (Jackson et al., 1976).

5.1 Imaging of injuries

Much controversy exists surrounding the utility of plain film, computed tomography, magnetic resonance imaging, and bone scintigraphy in the evaluation of sports-related spine

injuries (Hollenberg et al., 2003). Diagnostic imaging should be used in an evidence based and targeted fashion. The evidence to support the use of diagnostic imaging in non-specific, mechanical low back pain without red flags present is lacking and its use is often costly, time consuming and potentially harmful to the patient when radiation doses are considered. The topic of routine screening is also a dated process. In football code players, it is unclear whether they have a greater prevalence of radiographic lumbar spine abnormalities, including spondylolysis and spondylolisthesis, as age-matched controls (Jones et al., 1999).

In a large retrospective study of plain radiographs of the lumbar spine of 4243 athletic men and women with low back symptoms, 14% had a radiologic diagnosis of spondylolysis and 47% of these (or 7% of all athletes with back symptoms) had associated spondylolisthesis (Rossi & Dragoni, 2001). However, the diagnosis of spondylolysis and spondylolisthesis does not always equate to the symptoms present. The prevalence of spondylolysis in the general population has been estimated between 3% and 6% (Bono, 2006). Most commonly spondylolysis and spondylolisthesis occurs at L5 (85% to 95% of cases) and L4 (5% to 15%) (Standaert et al., 2000). Degenerative findings are known to be higher in athletes with low back demands on radiographic imaging (Sward et al., 1991). Again, their presence does not have to equate a source of symptoms in all cases.

When investigating spondylolysis, imaging should commence with plain radiographs, with anteroposterior, lateral and oblique views. Grading of the spondylolisthesis can be made on the lateral film using the Myerding system. Whilst plain films can be diagnostic, CT is superior in the diagnosis and is the imaging modality of choice for the diagnosis of spondylolysis (Teplick et al., 1986). SPECT is sensitive to metabolic bone changes and is positive in acute spondylolisthesis, however it can be normal in chronic pars defects (Lusins et al., 1994), helping to diagnose acute versus chronic injury and in attributing a source of symptoms. SPECT has been shown to have superior sensitivity to standard bone scans for detecting spondylolysis (Bellah et al., 1991). Magnetic resonance imaging can detect early changes in bone marrow oedema but not fracture, however marrow oedema is known to predate a frank pars defect (Gundry & Fritts., 1999). The use of magnetic resonance imaging in the evaluation of spondylosis has mixed opinions in the literature (Hollenburg et al., 2003), but given the lack of radiation its use is increasing particularly when repeated scanning is required for follow up of adolescent athletes.

Other injuries that require imaging to diagnose include disc herniations. Magnetic resonance imaging is the imaging of choice for the diagnosis of disc herniation, foraminal narrowing and other disc injuries. It can also demonstrate degenerative disc disease and facet arthropathy as causes of back pain (Hollenburg et al., 2003). However, the exact correlation between a degenerated disc and low back pain has been described as elusive as high rates of radiographic findings of degenerative discs are found in asymptomatic patients (Boden et al., 1990). Fatigue type sacral stress fractures are a potential cause of low back pain in athletically active premenopausal women (Johnson et al., 2001). Although plain films can be diagnostic, symptoms typically precede radiographic findings by weeks to months (Johnson et al., 2001). Additionally there is difficulty interpreting radiological findings in the sacral area. Bones scans are very sensitive for stress fractures, but non-specific: a normal scan virtually excludes the diagnosis. CT is sensitive and specific for most stress fractures (Hollenburg et al., 2003). More recently magnetic resonance imaging has been used for the diagnosis of stress fractures (Major et al., 2000) despite previously being thought of sensitive

but not specific. In the very early stages magnetic resonance imaging can detect medullary oedema but is insensitive for detecting a fracture line.

6. Management

Success in dealing with athletes with back injuries likely requires efforts to address both the cause of the injury and the most appropriate rehabilitation therapy (McGill, 2002). In many cases, addressing the cause of low back pain involves the athlete changing technique but without exception, they have to change the way they train (McGill, 2002). However, evidence to support risk factors for the development of athletic low back pain is lacking. Evidence exists showing that coaching aimed at improving technique in cricket fast bowlers decreases the prevalence and progression of disc degeneration measured with magnetic resonance imaging (Elliot & Khangure, 2002). Whether this translates to improved clinical results or to other sports remains unknown. Despite personal opinions that exist in the literature on the benefits of rehabilitation, there is lack of clinical research recruiting subjects with low back pain from athletic populations into randomised controlled trials investigating rehabilitation protocols or other treatment approaches. Apart from one short-term small study (Hanrahan et al., 2005), the author is not aware of other randomised controlled trials for the treatment or rehabilitation of low back pain with subjects drawn from an athletic population. It is not possible to produce evidence based guidelines for the management of back pain in different sports until an adequate literature base is established.

Current published evidence based guidelines for low back pain management for acute pain in non-athletic populations generally advocate an approach to management that includes advice to: remain active, modify activity, remove only those activities that specifically aggravate and potential replace with other non aggravating activity (relative rest) and to stay at work (Koes et al., 2001; Arnau et al., 2006). Simple analgesic pharmacological agents and exercise and manual therapies are often also advised in a multimodal approach. For chronic conditions various exercise-based protocols are often recommended. It may be for an athlete that a too aggressive active approach to management and the tissue loading from incorrectly prescribed 'stabilization exercises' (Callaghan et al., 1998; Kavcic et al., 2004) may be aetiological or aggravating factors. In support of this assertion, it has been shown that there is no significant advantage of additional core-strengthening in reducing low back pain occurrence in athletes (Nadler et al., 2002). Future research should investigate different rehabilitation protocols in a range of athletes from different sports.

The core principles of published guidelines should be used in the management of athletes with low back pain until they are replaced with athlete specific research and guidelines. The published guidelines in many ways mirror many of McGill's suggestions on how to reduce the risk of low back injuries in athletes, which include (McGill, 2002):

- Avoiding end range of spine motion during exertion. Examples of this include golfers sparing the spine from full lateral bend and near full rotation by reducing the back swing and grooving abdominal patterns that lock the rib cage to the pelvis on follow through.
- Use techniques to reduce reaction moments, such as tackling athletes directing force vectors through the lumbar spine to minimize resulting compressive forces.

- Avoid prolonged sitting (or sitting at all) on the bench, as prolonged flexion through sitting exacerbates discogenic back problems together with ligament based syndromes and results in decreased lumbar flexibility after a warm up period (Greene et al., 2002).
- Do not train shortly after rising from bed if a large amount of lumbar motion is required.
- Have athletes capable of stabilizing their lumbar spine irrespective of their phase of ventilation.
- Have the athlete contract musculature to stabilize the spine to more effectively transmit forces, particularly when an athlete might experience an unexpected load, when using combinations of simultaneous moments and after speed and acceleration of body segments are required.
- Practice spine sparing movement patterns and stabilizing motor patterns.

As most low back pain in athletes is likely to result from repetitive micro-trauma and fatigue from the often monotonous and repetitive overuse situations in training, management must include modifications in training (Baranto et al., 2009). Discussions should be made with coaching staff to ensure a period of relative rest, activity modification and if relevant, technique alteration is made to prevent the cycle of recurrent exacerbations and chronic pain.

Given the natural history of low back pain in adolescence involves a significantly increased risk of adult low back pain, it might be counterproductive to postpone treatment of adolescent athletes until the problems become more severe and chronic (Hestbaek et al., 2006). Hestbaek et al. have suggested a change in focus from the adult to the young population in relation to research, prevention, and treatment of low back pain (Hestbaek et al., 2006). However, it remains to be seen whether a greater focus on prevention and treatment can eliminate the risk and consequences of future low back pain episodes and minimise future chronicity.

A growing body of literature exists suggesting that classification of patients with non-specific, mechanical low back pain into subgroups for the purpose of directing treatment decision-making is important to improve prognosis, quality of care and patient outcomes (Borkan et al., 1998; Beaton et al., 2001). Various approaches are used to classify patients including the McKenzie or Mechanical Diagnosis and Therapy (MDT) technique and the Delitto or Treatment Based Classification (TBC). An important clinical symptom observed during the MDT examination process is centralization. This is where spinal and referred pain is abolished in a distal-to-proximal direction in response to therapeutic movement and positioning strategies (McKenzie & May., 2003; Aina et al., 2004). With the TBC patients are classified into three stages based on condition severity, ranging from the acute to subacute and advanced rehabilitation stage (Delitto et al., 1995). Stage 1, where the goal is symptomatic relief identifies four basic treatment subgroups, i.e. manipulation, exercise, stabilization, and traction, using specific clinical signs and symptoms, has been extensively researched and supported in the literature (Fritz et al., 2003; Fritz et al., 2000; Fritz et al., 2007).

An increased body of literature is also developing to support clinical prediction rules, which are prognostic models aiming to identify patient characteristics and clinical signs and symptoms to assign patients to treatment approaches to predict patient outcomes. Although

such models do not exist for athletic populations, their development is encouraged given the multitude of treatment modalities that currently exist for back pain. When looking at clinical prediction rules for low back pain, two separate models have been developed to identify patients who would respond best to manipulation (Flynn et al., 2002; Fritz et al., 2005). The original model used five criteria: no symptoms below the knee, recent onset of symptoms (<16 days), low fear avoidance belief questionnaire score for work, hypo-mobility of the lumbar spine, and hip internal rotation range of motion (>35 degrees for at least one hip) (Flynn et al., 2002). This was modified to two criteria that included no symptoms below the knee and recent onset of symptoms (<16 days), as a pragmatic alternative for identifying patients most likely to positively respond to manipulation (Fritz et al., 2005). The stabilization clinical prediction rule was developed to determine whether patients with low back pain are likely to favorably benefit from stabilization exercises (Hicks et al., 2005). It uses four classification criteria, which include: age <40, positive prone instability test, positive aberrant trunk movements, and average straight leg range of motion >91 degrees. Whether these clinical prediction rules can be applied to athletes or whether new rules are required to be developed for athletic populations remain to be seen.

When specifically looking at exercise based rehabilitation protocols McGill suggests several key principles that should be included when developing exercise programs (McGill, 2002):

- Muscle endurance, not strength is more important.
- Patients should be encouraged to maintain a neutral spine when under load and use abdominal contraction and bracing in a functional way.
- No single abdominal exercise challenges all of the abdominal musculature while sparing the back. Therefore more than one exercise is required and the 'big three' is recommended: curl ups, side bridge and leg and arm extensions in the bird dog position.

Once the basics are developed, then higher challenges and advanced exercises can be incorporated. When specifically looking at athletes, McGill suggests a five stage paradigm based around an adequate foundation of stabilizing motion/motor patterns (McGill, 2002):

1. Identifying the essential motions and grooving appropriate motion/motor patterns.
2. Ensuring joint and whole body stabilizing patterns.
3. Develop muscle endurance around these patterns.
4. Enhance strength.
5. Establish power.

Non-operative management is the mainstay for athletes with low back injuries. If simple conservative approaches to management fail, therapeutic epidural spinal injections are often the next line of therapy recommended in a trial of therapy. However, there are conditions which will require early surgical opinion and management, whilst failed non-operative management of severe, chronic low back pain may also require surgical management. Typical conditions for surgical referral include spondylolisthesis, disc herniation and traumatic fracture. The natural history and risk of progression and the non-operative and operative treatment of spondylolysis has been extensively covered by Bono (Bono 2006) and other authors (Lennard TA & Crabtree M, 2005). Bono states that indications for early surgical management for spondylolysis are a neurological deficit related to spondylolisthesis, a progressive slip or a grade III or high grade slip at presentation. Other

literature also exists discussing the management of disc degeneration and disc herniation (Lennard TA & Crabtree M, 2005; Bono, 2006; Lawrence et al., 2006).

7. Future research

Further high quality research into low back pain in athletic populations is required. A list of research projects identified in this chapter include:

- Conducting long term longitudinal studies assessing the true prevalence, severity and epidemiology of low back pain in junior and senior athletic populations, across different sports and different grades of competition. Ideally with homogeneity in study design and methodology to allow direct comparisons with data from non-athletic populations.
- Development of a validated sports specific functional based outcome measure for athletic populations for use in both research and in clinical settings.
- Identifying risk factors for the development of low back pain and injuries in junior and adult levels athletes
- Determine if these risk factors are reversed, that it results in reduced low back pain and injuries.
- Assess the role that psychosocial variables or yellow flags have in the development of low back injury and chronic pain during play and after a career has ended.
- Determine whether a current or previous history of low back injury renders athletes susceptible to developing other injuries and whether management approaches incorporating the low back can subsequently prevent injury.
- Identify deficits in athletic ability occurring secondary to low back pain and injury and whether rehabilitation protocols or other management approaches can reverse these changes.
- Conduct randomised controlled trials to determine optimal management approaches for the prevention and treatment of acute and chronic low back pain from subjects recruited from an athletic population
- Assess whether current clinical prediction rules for the management of low back pain can be used on athletic populations or whether new prediction rules recruiting subjects from a sporting background are required.

8. References

- Aina A, May S, Clare H. The centralization phenomenon of spinal symptoms: a systematic review. *Man Ther* 2004;9:134- 43.
- Arnau JM, Vallano A, Lopez A, Pellise F, Delgado MJ, Prat N. A critical review of guidelines for low back pain treatment. *Eur Spine J* 2006, 15:543-53.
- Bahr R, Andersen SO, Loken S, Fossan B, Hansen T, Holme I. Low back pain among endurance athletes with and without specific back loading--a cross-sectional survey of cross-country skiers, rowers, orienteers, and nonathletic controls. *Spine* 2004, 29:449-54.
- Balagué F, Dudler J, Nordin M. Low-back pain in children. *Lancet* 2003, 361:1403-4.

- Baquie P, Brukner P. Injuries presenting to an Australian sports medicine centre: a 12-month study. *Clin J Sport Med.* 1997;7:28-31.
- Baranto A, Hellström M, Nyman R, Lundin O, Swärd L. Back pain and degenerative abnormalities in the spine of young elite divers: a 5-year follow-up magnetic resonance imaging study. *Knee Surg Sports Traumatol Arthrosc.* 2006;14(9):907-14.
- Baranto A, Andersen TI, Sward L. Preventing low back pain. In: Bahr R, Engebretsen L (Eds). *Sports Injury Prevention*. Chapter 8, Blackwell Publishing, 2009.
- Beaton DE, Bombardier C, Katz JN, Wright JG. A taxonomy for responsiveness. *J Clin Epidemiol* 2001;54:1204-17.
- Bellah RD, Summerville DA, Treves ST, Micheli LJ. Low-back pain in adolescent athletes: detection of stress injury to the pars interarticularis with SPECT. *Radiology.* 1991;180:509-12.
- Bennell K, Wajswelner H, Lew P, Schall-Riauour A, Leslie S, Plant D, Cirone J. Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers. *Br J Sports Med.* 1998;32(4):309-14.
- Biedermann HJ, Shanks GL, Forrest WJ, Inglis J. Power spectrum analyses of electromyographic activity. Discriminators in the differential assessment of patients with chronic low-back pain. *Spine.* 1991;16(10):1179-84.
- Bo Andersen L, Wedderkopp N, Leboeuf-Yde C. Association between back pain and physical fitness in adolescents. *Spine* 2006, 31(15):1740-4.
- Boden SD, Davis DO, Dina TS, Patronas NJ, Wisel SW. Abnormal magnetic resonance scans of the lumbar spine in asymptomatic individuals. A prospective investigation. *J Bone Joint Surg Am.* 1990; 72:403-408.
- Bono CM. Low-back pain in athletes. *J Bone Joint Surg Am.* 2004, 86-A:382-96.
- Borkan JM, Koes B, Reis S, Cherkin DC. A report from the Second International Forum for Primary Care Research on Low Back Pain. Reexamining priorities. *Spine* 1998;23:1992-6.
- Burton AK, Clarke RD, McClune TD, Tillotson KM. The natural history of low back pain in adolescents. *Spine* 1996, 21(20):2323-8.
- Callaghan JP, Gunning JL, McGill SM. The relationship between lumbar spine load and muscle activity during extensor exercises. *Phys Ther* 1998, 78:8-18.
- Carlson H, Thorstensson A, Nilsson J. Lumbar back muscle activity during locomotion: effects of voluntary modifications of normal trunk movements. *Acta Physiol Scand* 1988, 133:343-53.
- Carragee E, Alamin T, Cheng I, Franklin T, Hurwitz E. Does minor trauma cause serious low back illness? *Spine* 2006, 31:2942-9.
- Cholewicki J, McGill SM, Norman RW. Lumbar spine loads during the lifting of extremely heavy weights. *Med Sci Sports Exerc.* 1991;23:1179-86.
- Cholewicki J, Greene HS, Polzhofer GK, Galloway MT, Shah RA, Radebold A. Neuromuscular function in athletes following recovery from a recent acute low back injury. *J Orthop Sports Phys Ther* 2002, 32:568-75.
- Cholewicki J, Silfies SP, Shah RA, Greene HS, Reeves NP, Alvi K, Goldberg B. Delayed trunk muscle reflex responses increase the risk of low back injuries. *Spine* 2005, 30:2614-20.

- Cupisti A, D'Alessandro C, Evangelisti I, Piazza M, Galetta F, Morelli E. Low back pain in competitive rhythmic gymnasts. *J Sports Med Phys Fitness* 2004, 44:49-53.
- Cresswell A. Responses of intra-abdominal pressure and abdominal muscle activity during dynamic loading in man. *Eur J App Phys*. 1993;66:315-20.
- Crisco JJ, III, Panjabi MM. The intersegmental and multisegmental muscles of the lumbar spine. A biomechanical model comparing lateral stabilizing potential. *Spine*. 1991;16(7):793-9.
- Demoulin C, Distrée V, Tomasella M, Crielaard JM, Vanderthommen M. Lumbar functional instability: a critical appraisal of the literature. *Ann Readapt Med Phys* 2007, 50(8):677-84.
- Dimar JR 2nd, Glassman SD, Carreon LY. Juvenile degenerative disc disease: a report of 76 cases identified by magnetic resonance imaging. *Spine J* 2007, 7(3):332-7.
- Druss BG, Marcus SC, Olfson M, Pincus HA. The most expensive medical conditions in America. *Health Aff (Millwood)* 2002;21:105-11.
- Edgerton V, Wolf S, Levendowski D, Roy RR. Theoretical basis for patterning EMG amplitudes to assess muscle dysfunction. *Med Sci Sports Exerc*. 1996;28(6):744-751.
- Elliott B, Khangure M. Disk degeneration and fast bowling in cricket: an intervention study. *Med Sci Sports Exerc*. 2002;34(11):1714-8.
- Eriksson K, Nemeth G, Eriksson E. Low back pain in elite cross-country skiers. A retrospective epidemiological study. *Scand J Med Sci Sports* 1996, 6:31-5.
- Ford D, Bagnall KM, McFadden KD, Greenhill B, Raso J. Analysis of vertebral muscle obtained during surgery for correction of a lumbar disc disorder. *Acta Anat (Basel)*. 1983;116(2):152-7.
- Flynn T, Fritz J, Whitman J, Wainner R, Magel J, Rendeiro D, et al. A clinical prediction rule for classifying patients with low back pain who demonstrate short-term improvement with spinal manipulation. *Spine* 2002;27:2835-43.
- Fritz JM, Cleland JA, Childs JD. Subgrouping patients with low back pain: evolution of a classification approach to physical therapy. *J Orthop Sports Phys Ther* 2007;37:290-302.
- Fritz JM, Delitto A, Erhard RE. Comparison of classification- based physical therapy with therapy based on clinical practice guidelines for patients with acute low back pain: a randomized clinical trial. *Spine* 2003;28:1363-71.
- Fritz JM, George S. The use of a classification approach to identify subgroups of patients with acute low back pain. Interrater reliability and short-term treatment outcomes. *Spine* 2000;25:106-14.
- Fritz JM, Childs JD, Flynn TW. Pragmatic application of a clinical prediction rule in primary care to identify patients with low back pain with a good prognosis following a brief spinal manipulation intervention. *BMC Fam Pract* 2005;6:29.
- Gatchel RJ, Polatin PB, Mayer TG. The dominant role of psychosocial risk factors in the development of chronic low back pain disability. *Spine* 1995, 20:2702-9.
- Gatt CJ Jr, Boland AL. Rowing injuries. *Postgrad Adv Sports Med*. 1989;III:1-17.
- Gatt CJ Jr, Hosea TM, Palumbo RC, Zawadsky JP. Impact loading of the lumbar spine during football blocking. *Am J Sports Med*. 1997;25:317-21.

- Gibbs NJ, Cross TM, Cameron M, Houang MT. The accuracy of MRI in predicting recovery and recurrence of acute grade one hamstring muscle strains within the same season in Australian Rules football players. *J Sci Med Sport*. 2004;7(2):248-58.
- Greene HS, Cholewicki J, Galloway MT, Nguyen CV, Radebold A. A history of low back injury is a risk factor for recurrent back injuries in varsity athletes. *Am J Sports Med* 2001, 29:795-800.
- Gregoire L, Veeger HE, Huijing PA, van Ingen Schenau GJ. Role of mono- and biarticular muscles in explosive movements. *Int J Sports Med*. 1984;5(6):301-5.
- Gundry CR, Fritts HM. MR imaging of the spine in sports injuries. *Magn Reson Imaging Clin N Am*. 1999; 7:85-103.
- Hanrahan S, Van Lunen BL, Tamburello M, Walker ML. The short-term effects of joint mobilizations on acute mechanical low back dysfunction in collegiate athletes. *J Athl Train* 2005, 40:88-93.
- Harreby M, Kjer J, Hesselsøe G, Neergaard K. Epidemiological aspects and risk factors for low back pain in 38-year-old men and women: a 25-year prospective cohort-study of 640 Danish school children. *Eur Spine J* 1996, 5(5):312-8.
- Hestbaek L, Leboeuf-Yde C, Engberg M, Lauritzen T, Bruun NH, Manniche C. The course of low back pain in a general population. Results from a 5-year prospective study. *J Manipulative Physiol Ther* 2003, 26:213-9.
- Hestbaek L, Leboeuf-Yde C, Kyvik KO, Manniche C. The course of low back pain from adolescence to adulthood: eight-year follow-up of 9600 twins. *Spine* 2006, 31(4):468-72.
- Hicks GE, Fritz JM, Delitto A, McGill SM. Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a stabilization exercise program. *Arch Phys Med Rehabil* 2005;86:1753-62.
- Hides JA, Richardson CA, Jull GA. Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine*. 1996;21(23):2763-9.
- Hill JJ, Keating JL. Risk factors for the first episode of low back pain in children are infrequently validated across samples and conditions: a systematic review. *J Physiother*. 2010;56(4):237-44.
- Hodges P, Richardson C. Inefficient muscular stabilization of the lumbar spine associated with low back pain: a motor control evaluation of transversus abdominus. *Spine*. 1996;21(22):2640-50.
- Hodges PW, Richardson CA. Delayed postural contraction of transversus abdominis in low back pain associated with movement of the lower limb. *J Spinal Disord*. 1998;11(1):46-56.
- Hodges PW, Moseley GL, Gabrielsson AH, Gandevia SCI. Acute experimental pain changes postural recruitment of the trunk muscles in pain free humans. *Exp Brain Res*. 2003;151(2):262-271.
- Hollenberg GM, Beitia AO, Tan RK, Weinberg EP, Adams MJ. Imaging of the spine in sports medicine. *Curr Sports Med Rep*. 2003;2(1):33-40.
- Hosea TM, Gatt CJ, McCarthy KE, Langrana NA, Zawadsky JP. Analytical computation of rapid dynamic loading of the lumbar spine. *Trans Orthop Res Soc*. 1989; 14:358.

- Hungerford B, Gilleard W, Hodges P. Evidence of altered lumbo-pelvic muscle recruitment in the presence of sacroiliac joint pain. *Spine*. 2003; 28(14): 1593-600.
- Hutchinson MR. Low back pain in elite rhythmic gymnasts. *Med Sci Sports Exerc* 1999, 31:1686-8.
- Iwai K, Nakazato K, Irie K, Fujimoto H, Nakajima H. Trunk muscle strength and disability level of low back pain in collegiate wrestlers. *Med Sci Sports Exerc* 2004, 36:1296-300.
- Iwamoto J, Abe H, Tsukimura Y, Wakano K. Relationship between radiographic abnormalities of lumbar spine and incidence of low back pain in high school and college football players: a prospective study. *Am J Sports Med* 2004, 32:781-6.
- Iwamoto J, Abe H, Tsukimura Y, Wakano K. Relationship between radiographic abnormalities of lumbar spine and incidence of low back pain in high school rugby players: a prospective study. *Scand J Med Sci Sports* 2005, 15:163-8.
- Jacob T, Baras M, Zeev A, Epstein L. Physical activities and low back pain: a community-based study. *Med Sci Sports Exerc* 2004, 36:9-15.
- Jacobs R, Bobbert MF, van Ingen Schenau GJ. Mechanical output from individual muscles during explosive leg extensions: the role of biarticular muscles. *J Biomech*. 1996;29(4):513-23.
- Jackson DW, Wiltse LL, Cirincoine RJ. Spndylolysis in the female gymnast. *Clin Orthop*. 1976;117:68-73.
- Janda V. Evaluation of muscular imbalance. In: Liebensohn C. *Rehabilitation of the spine*. Baltimore: Lippincott Williams & Wilkins, 1996; ch 6, pp 97-112.
- Johnson AW, Weiss CB Jr, Stento K, Wheeler DL. Stress fractures of the sacrum: an atypical cause of low back pain in the female athlete. *Am J Sports Med*. 2001; 29:498-508
- Jones DM, Tearse DS, el-Khoury GY, Kathol MH, Brandser EA. Radiographic abnormalities of the lumbar spine in college football players. A comparative analysis. *Am J Sports Med* 1999, 27(3):335-8.
- Jorgensen K, Nicholaisen T, Kato M. Muscle fiber distribution, capillary density, and enzymatic activities in the lumbar paravertebral muscles of young men. Significance for isometric endurance. *Spine*. 1993;18(11):1439-50.
- Kaigle A, Holm S, Hansson T. Experimental instability in the lumbar spine. *Spine*. 1995;20(4):421-430.
- Kankaanpää M, Taimela S, Laaksonen D, Hänninen O, Airaksinen O. Back and hip extensor fatigability in chronic low back pain patients and controls. *Arch Phys Med Rehabil*. 1998;79(4):412-7.
- Kavic N, Grenier S, McGill SM. Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine* 2004, 29:2319-29.
- Keyserling WM. Workplace risk factors and occupational musculoskeletal disorders, Part 1: A review of biomechanical and psychophysical research on risk factors associated with low-back pain. *AIHAJ*. 2000;61(1):39-50.
- Koes BW, van Tulder MW, Ostelo R, Kim Burton A, Waddell G. Clinical guidelines for the management of low back pain in primary care: an international comparison. *Spine* 2001, 26:2504-13.

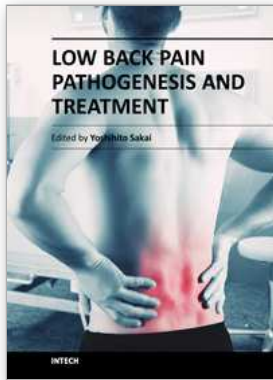
- Kornberg C, Lew P. The effect of stretching neural structures on grade one hamstring injuries. *Journal Orthop Sports Phys Ther.* 1989;10:481-487.
- Kujala UM, Salminen JJ, Taimela S, Oksanen A, Jaakkola L. Subject characteristics and low back pain in young athletes and nonathletes. *Med Sci Sports Exerc.* 1992, 24(6):627-32.
- Kujala UM, Sarna S, Kaprio J, Koskenvuo M. Hospital care in later life among former world-class Finnish athletes. *JAMA* 1996, 276:216-20.
- Kujala UM, Taimela S, Erkontalo M, Salminen KK, Kaprio J J. Low-back pain in adolescent athletes. *Med Sci Sports Exerc* 1996, 28(2):165-70.
- Kujala UM, Taimela S, Oksanen A, Salminen JJ. Lumbar mobility and low back pain during adolescence. A longitudinal three-year follow-up study in athletes and controls. *Am J Sports Med* 1997, 25(3):363-8.
- Lamoth CJ, Meijer OG, Daffertshofer A, Wuisman PI, Beek PJ. Effects of chronic low back pain on trunk coordination and back muscle activity during walking: changes in motor control. *Eur Spine J* 2005, 15:23-40.
- Leboeuf-Yde C, Lauritsen JM. The prevalence of low back pain in the literature. A structured review of 26 Nordic studies from 1954 to 1993. *Spine* 1995, 20:2112-8.
- Leinonen V, Kankaanpää M, Airaksinen O, Hänninen O. Back and hip extensor activities during trunk flexion/extension: effects of low back pain and rehabilitation. *Arch Phys Med Rehabil.* 2000;81(1):32-7.
- Lennard TA, Crabtree M. *Spine in Sports.* Mosby, 2005.
- LeResche L, Mancl LA, Drangsholt MT, Saunders K, Korff MV. Relationship of pain and symptoms to pubertal development in adolescents. *Pain* 2005, 118(1-2):201-9.
- Lundin O, Hellstrom M, Nilsson I, Sward L. Back pain and radiological changes in the thoraco-lumbar spin of athletes. A long term follow up. *Scand J Med Sci Sports* 2001, 11:103-9.
- Lusins JO, Elting JJ, Cicoria AD, Goldsmith SJ. SPECT evaluation of lumbar spndylolysis and spondylolisthesis. *Spine.* 1994; 5:608-612.
- Macintosh JE, Valencia F, Bogduk N. The morphology of the human lumbar multifidus. *Clin Biomech.* 1986;1:196-204.
- Mahlamaki S, Soimakallio S, Michelsson JE. Radiological findings in the lumbar spine of 39 young cross-country skiers with low back pain. *Int J Sports Med* 1988, 9:196-7.
- Major NM, Helms CA. Sacral stress fractures in long distance runners. *Am J Roentgenol.* 2000; 174:727-729.
- Manek NJ, MacGregor AJ. Epidemiology of back disorders: prevalence, risk factors, and prognosis. *Curr Opin Rheumatol.* 2005;17(2):134-40.
- McGill S. *Low back disorders: Evidence based prevention and rehabilitation.* Human Kinetics. United States of America. 2002.
- McKenzie R, May S. *The Lumbar spine: mechanical diagnosis and therapy.* 2nd ed. Waikanae: Spinal Publication Ltd; 2003. 6 Delitto A, Erhard RE, Bowling RW. A treatment-based classification approach to low back syndrome: identifying and staging patients for conservative treatment. *Phys Ther* 1995;75:470-85; invited commentary 485-8.

- McGill SM. Kinetic potential of the lumbar trunk musculature about three orthogonal orthopaedic axes in extreme postures. *Spine*. 1991;16(7):809-15.
- McHardy A, Pollard H. Low back pain in golfers: a review. *J Chiropr Med* 2005, 4:135-43.
- McManus A, Stevenson M, Finch CF, Elliot B, Hamer P, Lower A, Bulsara M. Incidence and risk factors for injury in non-elite Australian Football. *J Sci Med Sport* 2004, 7:384-91.
- Meir RA, McDonald KN, Russell R. Injury consequences from participation in professional rugby league: a preliminary investigation. *Br J Sports Med* 1997, 31:132-4.
- Micheli LJ, Wood R. Back pain in young athletes. Significant differences from adults in causes and patterns. *Arch Pediatr Adolesc Med* 1995, 149(1):15-8.
- Mundt DJ, Kelsey JL, Golden AL, Panjabi MM, Pastides H, Berg AT, Sklar J, Hosea T. An epidemiologic study of sports and weight lifting as possible risk factors for herniated lumbar and cervical discs. The Northeast Collaborative Group on Low Back Pain. *Am J Sports Med*. 1993;21(6):854-60.
- Nadler SF, Malanga GA, Feinberg JH, Prybicien M, Stitik TP, DePrince M. Relationship between hip muscle imbalance and occurrence of low back pain in collegiate athletes: a prospective study. *Am J Phys Med Rehabil*. 2001;80(8):572-7.
- Nadler SF, Malanga GA, Bartoli LA, Feinberg JH, Prybicien M, DePrince M. Hip muscle imbalance and low back pain in athletes: influence of core strengthening. *Med Sci Sports Exerc* 2002, 34:9-16.
- Nadler SF, Moley P, Malanga GA, Rubbani M, Prybicien M, Feinberg JH. Functional deficits in athletes with a history of low back pain: a pilot study. *Arch Phys Med Rehabil* 2002, 83:1753-8.
- New Zealand Low back Pain Guide. Accident Rehabilitation and Compensation Insurance Corporation of New Zealand and the National Health Committee. Wellington 1997.
- Ong A, Anderson J, Roche J. A pilot study of the prevalence of lumbar disc degeneration in elite athletes with lower back pain at the Sydney 2000 Olympic Games. *Br J Sports Med*. 2003;37(3):263-6.
- Ogon M, Riedl-Huter C, Sterzinger W, Krismer M, Spratt KF, Wimmer C. Radiologic abnormalities and low back pain in elite skiers. *Clin Orthop Relat Res* 2001, 390:151-62.
- O'Kane JW, Teitz CC, Lind BK. Effect of preexisting back pain on the incidence and severity of back pain in intercollegiate rowers. *Am J Sports Med* 2003, 31:80-2.
- Orchard J. The use of local anaesthetic injections in professional football. *Br J Sports Med* 2001, 35:212-3.
- Orchard JW. Intrinsic and extrinsic risk factors for muscle strains in Australian football. *Am J Sports Med*. 2001;29(3):300-303.
- Orchard J. Missed time through injury and injury management at an NRL club. *Sport Health* 2004, 22:11-9.
- Orchard JW. Is it safe to use local anaesthetic painkilling injections in professional football? *Sports Med* 2004, 34:209-19.
- Orchard JW, Farhart P, Leopold C. Lumbar spine region pathology and hamstring and calf injuries in athletes: is there a connection? *Br J Sports Med*. 2004;38(4):502-4.

- Orchard J, Seward H. Epidemiology of injuries in the Australian Football League, seasons 1997-2000. *Br J Sports Med* 2002, 36:39-44.
- Orchard J, Wood T, Seward H, Broad A. Comparison of injuries in elite senior and junior Australian football. *J Sci Med Sport* 1998, 1(2):83-8.
- Panjabi MM. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *J Spinal Disord.* 1992a;5(4):383-9.
- Panjabi MM. The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. *J Spinal Disord.* 1992b;5(4):390-6.
- Panjabi MM. Clinical spinal instability and low back pain. *J Electromyogr Kinesiol.* 2003;13(4):371-9.
- Renkawitz T, Boluki D, Grifka J. The association of low back pain, neuromuscular imbalance, and trunk extension strength in athletes. *Spine J.* 2006;6(6):673-83.
- O'Sullivan P, Twomey L, Allison G. Dysfunction of the neuro-muscular system in the presence of low back pain - implications for physical therapy management. *J Man Manip Ther.* 1997a;5(1):20-26.
- O'Sullivan P, Twomey L, Allison G, Sinclair J, Miller K. Altered patterns of abdominal muscle activation in patients with chronic back pain. *Aust J Physiother.* 1997b;43(2):91-98.
- Ramond A, Bouton C, Richard I, Roquelaure Y, Baufreton C, Legrand E, Huez JF. Psychosocial risk factors for chronic low back pain in primary care--a systematic review. *Fam Pract.* 2011;28(1):12-21.
- Ranson CA, Burnett AF, Kerslake RW. Injuries to the lower back in elite fast bowlers: acute stress changes on MRI predict stress fracture. *J Bone Joint Surg Br.* 2010;92(12):1664-8.
- Rossi P, Dragoni S. The prevalence of spondylolysis and spondylolisthesis in symptomatic elite athletes: radiographic findings. *Radiography.* 2001; 7:37-42.
- Roy SH, De Luca CJ, Snyder-Mackler L, Emley MS, Crenshaw RL, Lyons JP. Fatigue, recovery, and low back pain in varsity rowers. *Med Sci Sports Exerc.* 1990;22(4):463-9.
- Salminen JJ, Erkintalo M, Laine M, Pentti J. Low back pain in the young. A prospective three-year follow-up study of subjects with and without low back pain. *Spine* 1995, 20(19):2101-7.
- Salminen JJ, Erkintalo MO, Pentti J, Oksanen A, Kormano MJ. Recurrent low back pain and early disc degeneration in the young. *Spine* 1999, 24(13):1316-21.
- Simonsen EB, Thomsen L, Klausen K. Activity of mono- and biarticular leg muscles during sprint running. *Eur J Appl Physiol Occ Physiol.* 1985;54(5):524-32. *d Rehabil Clin N Am.* 2000;11:785-803.
- Standaert CJ, Herring SA, Halpern B, King O. Spondylolysis. *Phys M, Sward L, Hellstrom M, Jacobsson B, Peterson L.* Back pain and radiologic changes in the thoracolumbar spine of athletes. *Spine* 1990, 15:124-9.
- Teplick JG, Laffey PA, Berman A, Haskin ME. Diagnosis and evaluation of spondylolisthesis and/or spondylolysis on axial CT. *Am J Neuroradiol.* 1986; 7:479-491.
- Teitz CC, O'Kane JW, Lind BK. Back pain in former intercollegiate rowers. A long-term follow-up study. *Am J Sports Med* 2003, 31:590-5.

- Tewes DP, Fischer DA, Quick DC, Zamberletti F, Powell J. Lumbar transverse process fractures in professional football players. *Am J Sports Med.* 1995;23(4):507-9.
- Toueg CW, Mac-Thiong JM, Grimard G, Parent S, Poitras B, Labelle H. Prevalence of spondylolisthesis in a population of gymnasts. *Stud Health Technol Inform.* 2010;158:132-7.
- Turl SE, George KP. Adverse neural tension: a factor in repetitive hamstring strain?. *J Orthop Sports Phys Ther.* 1998;27(1):16-21.
- van Tulder M, Koes B, Bombardier C. Low back pain. *Best Pract Res Clin Rheumatol* 2002, 16:761-75.
- Verrall GM, Slavotinek JP, Barnes PG, Fon GT, Spriggins AJ. Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging. *Br J Sports Med.* 2001;35(6):435-439.
- Verrall GM, Slavotinek JP, Barnes PG, Fon GT. Diagnostic and prognostic value of clinical findings in 83 athletes with posterior thigh injury: comparison of clinical findings with magnetic resonance imaging documentation of hamstring muscle strain. *Am J Sports Med.* 2003;31(6):969-73.
- Videman T, Sarna S, Battie MC, Koskinen S, Gill K, Paananen H, Gibbons L. The long-term effects of physical loading and exercise lifestyles on back-related symptoms, disability and spinal pathology among men. *Spine* 1995, 20:699-709.
- Videman T, Saarela J, Kaprio J, Näkki A, Levälahti E, Gill K, Peltonen L, Battie MC. Associations of 25 structural, degradative, and inflammatory candidate genes with lumbar disc desiccation, bulging, and height narrowing. *Arthritis Rheum.* 2009;60(2):470-81.
- Vogt L, Pfeifer K, Banzer W. Neuromuscular control of walking with chronic low-back pain. *Man Ther.* 2003;8(1):21-28.
- Waicus KM, Smith BW. Back injuries in the pediatric athlete. *Curr Sports Med Rep.* 2002, 1(1):52-8.
- Walden M, Hagglund M, Ekstrand J. UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. *Br J Sports Med* 2005, 39:542-6.
- Walker BF. The prevalence of low back pain: a systematic review of the literature from 1966 to 1998. *J Spinal Disord* 2000, 13:205-17.
- Walker BF, Muller R, Grant WD. Low back pain in Australian adults: prevalence and associated disability. *J Manipulative Physiol Ther* 2004, 27:238-44.
- Watson KD, Papageorgiou AC, Jones GT, Taylor S, Symmons DP, Silman AJ, Macfarlane GJ. Low back pain in schoolchildren: occurrence and characteristics. *Pain* 2002, 97:87-92.
- Werneke M, Hart D, Oliver D, McGill T, Grigsby D, Ward J, Weinberg J, Oswald W, Cutrone G. Prevalence of classification methods for patients with lumbar impairments using the McKenzie syndromes, pain pattern, manipulation, and stabilization clinical prediction rules. *J Man Manip Ther.* 2010; 18(4):187-204.
- Wilke H, Wolfe S, Claes L, Arand M, Wiesend A. Stability increase of the lumbar spine with different muscle groups. *Spine.* 1995;20(2):192-98.

- Wojtys EM, Ashton-Miller JA, Huston LJ, Moga PJ. The association between athletic training time and the sagittal curvature of the immature spine. *Am J Sports Med* 2000, 28(4):490-8.
- Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A. The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries. *Br J Sports Med*. 2004;38:36-41.



Low Back Pain Pathogenesis and Treatment

Edited by Dr. Yoshihito Sakai

ISBN 978-953-51-0338-7

Hard cover, 244 pages

Publisher InTech

Published online 14, March, 2012

Published in print edition March, 2012

Low back pain is a common disorder which affects the lumbar spine, and is associated with substantial morbidity for about 80% of the general population at some stages during their lives. Although low back pain usually is a self-limiting disorder that improves spontaneously over time, the etiology of low back pain is generally unknown and the diagnostic label, "non-specific low back pain", is frequently given. This book contains reviews and original articles with emphasis on pathogenesis and treatment of low back pain except for the rehabilitative aspect. Consisting of three sections, the first section of the book has a focus on pathogenesis of low back pain, while the second and third sections are on the treatment including conservative and surgical procedure, respectively.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Wayne Hoskins (2012). Low Back Pain and Injury in Athletes, Low Back Pain Pathogenesis and Treatment, Dr. Yoshihito Sakai (Ed.), ISBN: 978-953-51-0338-7, InTech, Available from:

<http://www.intechopen.com/books/low-back-pain-pathogenesis-and-treatment/low-back-pain-and-injury-in-athletes>

INTECH
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.