Pain in elite athletes—neurophysiological, biomechanical and psychosocial considerations: a narrative review

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ABSTRACT

Pain is a common problem among elite athletes and is frequently associated with sport injury. Both injury and pain interfere with peak performance. Pain management should be based on the physiological, anatomical and psychosocial influences on the individual's pain and is not equivalent to injury management, which focuses on musculoskeletal recovery and return-to-play. This narrative review provides a foundation for understanding the differing causes and types of pain in elite athletes, thereby serving as a springboard for comprehensive pain management.

INTRODUCTION

Pain commonly accompanies sport injury,[1–3] which occurs frequently among elite athletes,[4–7] but pain can also occur independently of injury, or persist after an injury has healed.[8–11] Pain is defined as 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage'.[12] Pain is a personal experience influenced by a variety of factors, including neurophysiological, immunological, cognitive, affective and social/environmental influences.[13–18] The longer pain persists, the more opportunity there is for psychological, social and environmental or contextual factors to influence the pain and associated problems such as functional disability.[19]

In contrast to the vast literature on some pain problems, such as low back pain in primary care populations, there is a paucity of scientific information regarding management of pain associated with sport injuries. Similarly, although evidence-based and consensus-based guidelines exist for many pain problems,[20–22] guidelines are lacking for managing pain in athletes in general and elite athletes in particular. A rational approach to pain management in elite athletes involves identification of the cause(s) and type of pain and development of a treatment strategy that addresses the contributing factors across physiological, biomechanical and psychosocial domains. For optimal care, it is important to understand, to the extent possible, the aetiology of and influences on pain and to intervene using strategies with the optimal expected benefit and least expected harm. This narrative review underpins a broader consensus statement[23] by providing an overview of the neurophysiological, biomechanical and psychosocial contributors to pain in sport.

CONSIDERATIONS ABOUT PAIN

A fundamental shift in the understanding of pain in sport is warranted. Pain is not synonymous with sport injury, that is, injury may occur without pain, and pain may develop or persist independent of the status of injury recovery.[24 25] 'Abnormal' anatomical findings are commonly observed in imaging studies of asymptomatic individuals,[26–28] and patients commonly report pain in the absence of relevant imaging findings.[29] These loose associations between imaging findings and pain illustrate the complex aetiology of pain problems and the importance of identifying the type of pain prior to treatment planning.

PAIN MEDICINE AND SPORTS MEDICINE

Greater communication between experts in pain medicine and sports medicine has substantial potential to improve the understanding and management of pain in elite athletes. *Pain medicine* specialists use a broad-based and often multidisciplinary approach to manage pain.[30] *Sports medicine* is concerned with the treatment and prevention of illness and injury in athletes.[31] Sport clinicians help athletes to maximise function while minimising disability as a result of sports participation.[31] Although pain is common in sport, most pain medicine clinicians are not trained in sports medicine, and most sports medicine clinicians do not have specialty training in pain. This leads to a knowledge gap in managing pain in elite athletes and a cultural gap in understanding the unique aspects of pain in elite athletes.

TYPES OF PAIN

Nociceptive pain

Nociceptors are peripheral nerve terminals that can be activated by changes in the mechanical, thermal or chemical state of the tissues of the body; that is, they transduce and encode stimuli that are potentially dangerous—or noxious—for body tissue.[32] *Nociceptive pain* is pain generated by activation of nociceptors in peripheral tissues by an actually or potentially tissue damaging event[32] (see box 1 for pain definitions). *Nociception* refers to the neural processes of encoding and processing noxious stimuli.[32] Nociception can occur in the absence of pain, as evidenced by not feeling pain from an injury while competing, but then experiencing the pain once the competition has ended. Pain can occur without activation of nociceptors (eg, phantom limb pain). Nociceptive pain is associated with tissue damage or inflammation that activates nociceptors in peripheral tissues.[32] *Inflammatory*

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Box 1 Pain definitions

Nociceptive pain: pain generated by a noxious insult that activates nociceptors in peripheral tissues. Nociceptive pain is associated with tissue damage or inflammation that activates nociceptors in peripheral tissues. *Inflammatory pain* (pain associated with active inflammation) is a type of nociceptive pain.

Neuropathic pain: pain caused by a lesion—demonstrable by diagnostic investigations or by clear frank trauma—or disease (ie, a known disorder such as stroke or diabetes mellitus) of the somatosensory nervous system.

Nociplastic/algopathic/nocipathic pain: pain that arises from altered nociception despite no clear evidence of actual or threatened tissue damage causing the activation of peripheral nociceptors or evidence of disease or lesion of the somatosensory system causing the pain.

Pain of unknown origin: pain that cannot be classified as nociceptive, neuropathic or nociplastic/algopathic/nocipathic.

pain (pain associated with active inflammation) is a type of nociceptive pain.[32]

Nociceptors provide a thorough 'first detection' system within the tissues of the body. That nociceptive pain is clearly associated with tissue damage or inflammation does not mean that there is a linear correlation between nociceptor activation and pain. Although nociception is very influential in pain, pain is also modulated throughout the central nervous system[32] and is influenced by non-nociceptive aspects of the sensory input,[33] a wide range of potentially powerful contextual cues[34] and cognitive and affective factors (eg, attention, distraction and anxiety).[13] The sports clinician must remain cognizant that pain is not a sensory signal but a conscious event. Pain serves to protect body tissue and is necessarily open to modulation by any credible evidence (including biological and psychosocial) that tissue needs protecting.

Subacute (pain duration approximately 6–12 weeks) nociceptive pain in sport may be associated with a range of tissue-based issues. For example, there may be ongoing/repetitive tissue load beyond its capacity[35] such as lateral epicondylalgia, in which there may be an overuse pattern of repetitive strain in the extensor tendons of the elbow. This might result from an imbalance of cumulative repetitive forces placed on the tendons of the elbow joint potentially due to insufficient surrounding counterforces (commonly related to improper training, recovery or both), leading to tendon reactivity.[35] Even low-level inflammation (eg, linked to sleep deprivation, ongoing stress and load exceeding the tissue's capacity) can reduce the athlete's mechanical nociceptive threshold sufficiently to make normal mechanical demands of the sport painful. An ongoing cycle of inflammation–repair–remodelling–inflammation can feasibly alter mechanical properties of local tissues (including tendon and articular tissues) and thus introduce new local sources of nociceptive activation. In such cases, nociceptive contributions to pain will continue if the force imbalance and other contributing factors (eg, sleep and training load) are not properly addressed.

Neuropathic pain

Neuropathic pain is pain caused by a lesion—demonstrable by diagnostic investigations or by trauma—or disease (ie, a known disorder such as stroke or diabetes mellitus) of the somatosensory nervous system.[12 32 36] Neuropathic pain is a clinical description and not a diagnosis.[36] There does not exist a specific diagnostic tool for neuropathic pain; therefore, a grading system of definite, probable and possible neuropathic pain has been proposed,[37] with probable and definite requiring evidence from a neurological examination and confirmatory tests.

Nociceptive pain and neuropathic pain have different aetiologies. Nociceptive pain is necessarily associated with activation of nociceptors and therefore implies tissue-based issues. Neuropathic pain does not require activation of nociceptors. In elite athletes, neuropathic pain can occur following direct insult/trauma to the peripheral nerve, nerve roots or spinal cord.[38] Neuropathic pain is seen commonly in wheelchair athletes with a spinal cord lesion.[39 40] Neuropathic pain in elite athletes can also develop following surgery for a sport injury or from repetitive mechanical and inflammatory irritation of peripheral nerves in endurance sport athletes. It is important that treatment for neuropathic pain occur with the understanding that the primary contribution is a nervous system lesion rather than tissue injury.

Athletes can present with both neuropathic and nociceptive pain problems. For example, a wheelchair athlete may have lower extremity neuropathic pain associated with spinal cord injury or localised neuropathic stump pain and may also have nociceptive pain related to tissue loading (eg, shoulder pain). In this case, both pain conditions should be addressed, and the treatment strategies may differ for each. The neuropathic pain arises from the original spinal cord injury and subsequent maladaptation of the somatosensory nervous system and requires a neuropathic-specific pain management strategy. The nociceptive pain may relate to the athlete being unable to properly activate the entire kinetic chain of forces from the feet to the torso to the shoulder, or from overuse related to wheelchair use, and may require short-term treatment to manage pain and longer term biomechanical and training adaptations.

Nociplastic/algopathic/nocipathic pain

Some patients have pain that does not appear to be associated with activation of nociceptors or damage or disease of the somatosensory nervous system.[36] A specific aetiology of the pain (eg, nerve or tissue injury) cannot be identified, but clinical and psychophysical findings such as hypersensitivity suggest altered nociceptive function.[36] Clinical examples include fibromyalgia, complex regional pain syndrome type 1, non-specific back pain and visceral pain disorders such as irritable bowel syndrome.[36] Some have referred to this type of pain as 'dysfunctional pain'[41]; however, this term is not helpful in suggesting possible mechanisms.

A third mechanistic descriptor (that will harmonise with the proposed ICD-11 diagnostic category 'primary pain')[42] was recently proposed for such chronic pain syndromes: *nociplastic/algopathic/nocipathic pain*.[36] This term is not a diagnosis and is not the same as central sensitisation, which is a neurophysiological construct referring to increased responsiveness of nociceptive neurons in the central nervous system to their normal or subthreshold afferent input.[32] However, central sensitisation may be the underlying mechanism of nociplastic/algopathic/nocipathic pain.[36] Nociplastic (change in function of nociceptive pathways), algopathic (pathological pain not generated by injury) and nocipathic (pathological state of nociception)

pain arises from altered nociception despite no clear evidence of actual or threatened tissue damage causing the activation of peripheral nociceptors or evidence of disease or lesion of the somatosensory nervous system causing the pain. Patients who have altered nociceptive function typically respond better to therapies that target central rather than peripheral pain mechanisms.[36] Nociplastic/algopathic/nocipathic pain is not the same as *pain of unknown origin*, in which pain cannot be classified as nociceptive, neuropathic or nociplastic/algopathic/nocipathic.[36] Athletes can present with one or any combination of these types of pain: nociceptive, neuropathic, nociplastic/algopathic/nocipathic and pain of unknown origin.

Thorough questioning and clinical assessment can shed light on the likely nociceptive, neuropathic and nociplastic/algopathic/nocipathic contributors to pain. Management will vary according to the type(s) of pain. Regardless of type of pain, when it persists long term and especially when it is moderate to severe, it is often accompanied by psychological distress (most commonly, depression, anxiety or both); sleep disturbance; poor physical conditioning; and physical, social and functional role limitations.[13 15] Thus, for individuals with moderate or severe chronic pain, multidisciplinary treatment is often indicated to improve pain, psychological distress and functioning.

PAIN MODULATION

Pain is modulated via multiple processes in the central and peripheral nervous systems. There is evidence that athletes have consistently higher pain tolerance as compared with normally active control subjects but less evidence for differences in pain threshold.[43] Pain tolerance is modulated by psychological factors such as confidence in ability to manage pain and willingness to participate in activities when pain is present. Attitudes of athletes towards pain have been shown to differ from those of non-athletes, and athletes may develop effective skills for coping with pain.[43] These skills may be helpful in managing minor discomfort during competition, but management of acute pain associated with injury may require different responses to allow injury healing to occur.

CONSIDERATIONS ABOUT THE ELITE ATHLETE IN PAIN

Table 1 provides aspects of a comprehensive assessment and interpretation of findings according to the likely types of pain. Clinicians who manage elite athletes are well-versed in performing a thorough sport history and musculoskeletal exam, but potentially important factors that might be overlooked are biomechanical and sensory assessment.

Pain assessment of the elite athlete in pain

For all patients who present with pain, including elite athletes, assessment should include usual and variable pain intensity; usual and variable location; the impact of pain on performance, mood and physical and social function; duration of pain; nature of any triggering event; and aggravating and alleviating factors. Well-localised pain is commonly associated with a well-localised injury; dermatomal pain or nerve root pain, that is, pain that follows a well-described peripheral nerve pathway, is commonly associated with peripheral nerve or nerve root injury.[38] If spreading pain is due to spreading injury, it will follow known anatomical and biomechanical patterns. Pain that spreads over time in patterns that do not follow these pathways and in patterns where pain occurs in different parts of the body on different days, or is widespread, is typically nociplastic/algopathic/nocipathic pain.[36] Thorough and precise questioning regarding the location of pain is critical for understanding the likely contribution of nociceptive, neuropathic and nociplastic/algopathic/nocipathic components. Athletes commonly point to a singular event as the cause of pain, but careful questioning and examination may reveal a range of possible contributing mechanisms. For example, a single overhead serve may precipitate shoulder pain in a tennis player, but biomechanical, contextual and psychological factors may all be relevant.[44 45]

Asking patients to rate the extent to which pain interferes with activities (eg, "In the past week, how much has pain interfered with your daily activities, rated on a 0–10 scale where 0 is 'no interference' and 10 is 'unable to carry on any activities?' ") is important for understanding how much pain impacts the patient's ability to participate in customary activities.[46] This is particularly important when pain persists beyond the acute time period. It can serve as a springboard for discussion about how the patient's activities have changed because of pain and can guide treatment aimed at restoring normal function. The general rule relating to duration of pain is that the longer pain persists, the less likely it is to reflect tissue damage and the more benefit there is likely to be in taking a multidisciplinary approach to the problem.

The importance of nociceptive, neuropathic and nociplastic/algopathic/nocipathic contributors can be clarified by careful assessment of history and aggravating and alleviating factors. In acute and subacute nociceptive pain after a clear inciting event, the primary aggravating and alleviating factors usually involve mechanical loads or thermal stimuli, and clinical interpretation considers tissue damage and healing and the presence or not of active inflammation. As pain persists, the potential influence of factors within the wider biological domain (fatigue state, menstrual cycle, training load and nutrition); the psychological domain (stress, mood, pain-related appraisals and expectations); and the social/environmental domain (eg, responses from coach and parents, team dynamics and structure and economic implications) needs to be assessed and considered in planning treatment (figure 1). The informed sports clinician will consider the possibility of psychosocial factors modulating pain and behavioural responses and become skilful in working with the athlete to identify and manage such factors.

Physical examination of the elite athlete in pain

Taking a full-body approach to biomechanical assessment requires an understanding of the *kinetic chain*, which refers to the sequence of events that must occur for forces to be transmitted from one body part to another through the ground via the legs, and then successively through the trunk and upper body in order to generate speed and power, leading to mechanical efficiency (eg, forces transmitted from the legs, and then successively through the trunk and to the upper body in a tennis serve).[47 48] A breakdown in the kinetic chain can lead to excessive application of compensatory forces in an attempt to maintain a certain level of performance.[47] The sports clinician also needs to consider patterns of *training load*[49–53] and periodisation[49 51 54–56] as part of the biomechanical assessment. A breakdown in training regimen with poor *periodisation* renders the athlete vulnerable to injury and poor recovery.

Careful sensory examination will allow the clinician to identify neuropathic and nociplastic/algopathic/nocipathic contributions to pain. Although full sensory examination may warrant referral to a specialist in neurological care, a basic sensory exam can help identify neuropathic pain because of sensory loss and associated hyperalgesia that correlates with a known lesion or disease of

Table 1 Linking history and physical examination findings to the likely contributing pain types

	Assessment	Nociceptive	Inflammatory	Neuropathic	Nociplastic/algopathic/nocipathic
Onset	**History/physical exam**				
Trauma		●	●	○	
Insidious		○	●	●*	○
Associated with swelling		●	○		
Associated with autonomic disturbance			○	●	●
Associated with spike in load		●			
Associated with psychosocial stress			○		●
Location	**History/physical exam**				
Confined to anatomical structure		●	○		
Spread along anatomical lines		●	○		
Spread along biomechanical movement		●			
Spread along dermatome			●	●	
Spread within limb/immediate area				○	●
Spread to whole limb/extended area				○	●
Spread to hemibody					●
Spread to full body					●
Aggravators	**History**				
Mechanical load		●			
Inactivity			●		○
Heat			●		
Cold				○	
Biomechanical assessment	**Physical exam**				
Inefficient load transfer		●	○		
Sensory exam	**History/physical exam**				
Numbness		○		●	
Local mechanical sensitivity		●	○		
Local heat sensitivity			●		
Widespread mechanical sensitivity					●
Local cold sensitivity				●	
Demonstrable sensory/motor loss	Neurological exam			●	○
Psychological factors	**Interview and questionnaires**				
Depression and/or anxiety					●
Catastrophising					●
Fear-avoidance (fear of pain and avoidance of activity due to excessive fear of pain and/or inaccurate beliefs that activity will cause physical harm)					●
Lifestyle factors					
Poor sleep volume or quality					
Poor nutrition			○		●
Poor sense of well-being			●		○

Filled circles indicates most likely, shaded circles less likely and no circles least likely.
*Denotes possibility of disease process and should be considered in light of general medical screening for red flags.

the somatosensory nervous system. When no known lesion or disease is identified, regional, generalised or widespread sensitivity to pain may reflect nociplastic/algopathic/nocipathic contributions to pain.

Assessment of the elite athlete with subacute or chronic pain

When pain persists beyond expected time for tissue healing, assessment and management need to broaden.

Assessment of psychosocial factors

Psychological factors can play important roles in pain and the athlete's responses to pain and injury. Psychological assessment is warranted when there are signs of psychosocial problems or when pain persists beyond expected injury healing time. Such assessment includes inquiry into the athlete's understanding of his/her pain, appraisals of the pain and its implications, cognitive and behavioural responses to pain and levels of

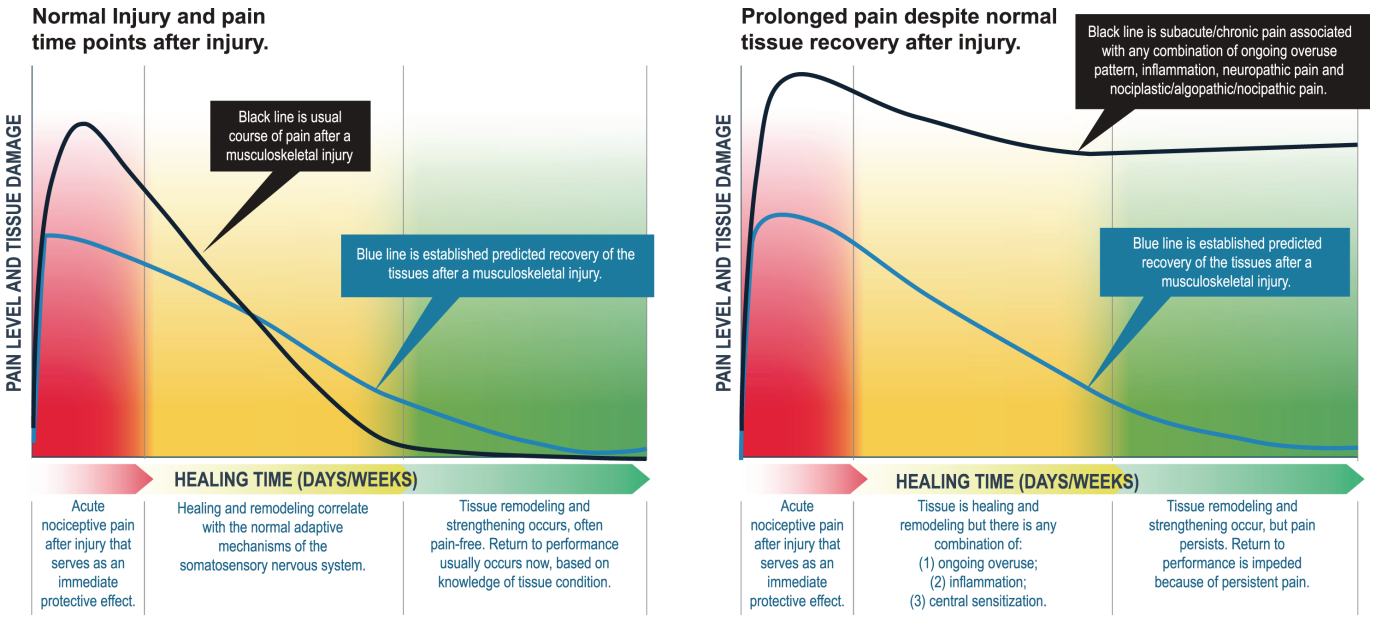

Figure 1 Schematic diagram demonstrating pain levels over time influenced by differing contributors to pain.

psychosocial stress and psychological distress (eg, anxiety and depression). Fear of pain and inaccurate beliefs that certain movements or activities will cause physical harm can lead to activity avoidance, physical deconditioning and disability.[57] Bidirectional relationships exist between pain and anxiety, depression, stress and anger. The psychological assessment includes evaluation of these relationships and assessment of psychological disorders (eg, mood, anxiety and eating disorders) that may warrant treatment.

Assessment of social and environmental factors relevant to the pain problem is also a core component of psychosocial factors.

Lifestyle

Sleep is critical for physical, mental and emotional recovery.[58] Sleep deprivation interrupts physical recovery and impairs growth hormone release and may predispose to depression and anxiety,[59] which can worsen pain and impede performance.[60] Pain can disrupt sleep, and sleep problems can worsen pain. A sleep-deprived athlete is not in an optimal state of recovery, and sleep deprivation can alter tissue sensitivity[61] and load capacity, thereby increasing risk of injury and pain. In fact, athletes who sleep less than 8 hours per night increase their risk of injury by almost twofold.[62]

Nutrition

Nutrition provides the energy requirements of athletes who train and compete.[63] Disordered eating means that the caloric requirement is insufficient to match the caloric needs, and this can lead to osteopaenia and performance diminution, both of which predispose to changes in tissue loading capacity and injury.[64 65] If disordered eating is not addressed, long-term management will not be successful. Overall, low levels of perceived wellness, poor sleep and an unhealthy diet can make the athlete susceptible to illness and injury.[66 67]

Social

The elite athlete may present with considerable personal and family conflicts regarding sport participation.[67 68] Family or other members of the athlete's sphere of influence may be living vicariously through the athlete's success and may directly or indirectly pressure the athlete to not report pain, to ignore pain or treat pain with short-term therapies that may result in long-term negative health consequences in order to continue to play.[68] While keeping their focus on performance (sometimes at all cost), athletes may also pressure clinicians to treat pain symptoms so as to allow 'immediate' return-to-play.[69]

Finally, there may be dynamics within the wider sports management team, from coaches to management and ultimately to fans, that can influence the athlete's responses to pain. In some cases, removal from the sporting or competitive environment due to pain may serve an important function for athletes who do not want to play or compete but have felt pressured to do so. In such cases, pain behaviours may be 'reinforced' by removal from stressful/aversive/undesired situations. These are complex issues and at times will require guidance from clinicians with high-level psychology expertise. However, sports clinicians need to consider this complexity and manage patients from a patient-centric biopsychosocial conceptual framework. Critically, this approach must be endorsed by the entire clinical team and, ideally, the wider team including teammates, coaches and management.

SUMMARY

The biological processes that underpin pain are complex. The sports clinician needs a broad appreciation of modern pain biology to optimally manage elite athletes in pain. Contextualising pain experience to the athlete's individual situation is paramount for targeted and optimal management and requires consideration of relevant factors that modulate pain experience including biological, psychological, social and sport-specific and training-specific domains. A contemporary understanding of pain as a protective mechanism modulated

by the individual's context and perspective of evidence of danger and safety may guide clinicians to a multidimensional approach of pain management in elite athletes.

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