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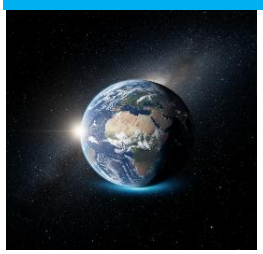

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Rehabilitation Strategies and Pain Management in Athletes with Musculoskeletal Injuries - a review

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Abstract

INTRODUCTION AND PURPOSE

Musculoskeletal injuries, including ligament ruptures, sprains, partial tears, muscle damage, and fractures, are among the most common injuries observed in athletes. Properly conducted rehabilitation is based on early and appropriate patient mobilization following trauma, aiming to restore mobility and strength of the affected musculoskeletal structures during convalescence. Effective management of post-traumatic pain remains a crucial

component of therapy, as pain reduction facilitates early mobilization and return to pre-injury functional status. The aim of this study was to review rehabilitation approaches used after various musculoskeletal injuries sustained during sports activity.

MATERIALS AND METHODS

Literature contained in PubMed and BioMed Central databases was searched using keywords such as rehabilitation, sport, musculoskeletal injuries, physical activity, pain management, exercise, therapy. Referenced sources in selected publications and thematic textbooks were also utilized.

CONCLUSIONS

Musculoskeletal injuries may result in significant functional limitations; however, their negative consequences can be effectively minimized through the timely initiation of structured rehabilitation. Exercises should be introduced gradually and adjusted to the injury stage to avoid excessive load on healing tissues. Adequate pain management is essential to support early mobilization and optimize recovery outcomes in athletes.

KEYWORDS

rehabilitation, sport, musculoskeletal injuries, physical activity, pain management, exercise, therapy

INTRODUCTION

Origin of Musculoskeletal Pain

Historically, musculoskeletal pain was managed primarily through conservative pharmacological approaches and limited physical interventions. Contemporary medicine offers a wide spectrum of therapeutic modalities, ranging from manual techniques such as massage to

advanced methods requiring specialized equipment, including electrotherapy, laser therapy, and structured rehabilitation exercise programs.

Pain therapy focuses on utilizing the reflex mechanisms of our organism and acts on sensory receptors - primarily at the site of pain origin. This approach is termed reflex therapy. To initiate appropriate treatment, one must understand the organism's response to nociceptive stimuli.

A specific painful stimulus activates a given spinal cord segment, resulting in various symptoms such as muscle spasms, cutaneous hypersensitivity, movement limitations, and dysfunction of internal organs. The organism responds not only to stimulation of specific spinal cord segments and their innervation areas but also activates the entire extremity. For example, lumbar spine pain restricts the mobility of all extensor muscle groups, not just the specific innervation segment of that muscle. Through this organismal response, maladaptive pain responses become established. In diagnosis, particular attention should be paid to autonomic and somatic reactions. Examples of somatic reactions include muscle weakness or increased muscle tension, while autonomic reactions include various cutaneous hypersensitivity features and responses of the respiratory, digestive, cardiovascular, and vasomotor systems. The patient's psychological state is not indifferent to pain, as it represents a significant stressor. The key to selecting appropriate therapy is knowledge of the type of musculoskeletal dysfunction. [2]

We have a wide range of therapeutic options available - from massage and stretching to acupuncture and radiotherapy. For example, for muscle contractures, post-isometric relaxation, heating, or anesthesia would be appropriate solutions. Periosteal pain can be addressed using deep massage, while joint stiffness can be treated with various manipulations. Corrective exercises can remedy movement pattern disorders. In diagnosis, it is important to determine whether the disorders are primary or secondary. Secondary manifestations may include systemic symptoms such as cardiovascular, respiratory, digestive, or nervous system disorders, while primary manifestations include joint blockages.

The patient's psychological state also affects musculoskeletal function. Depression, chronic stress, and anxiety can lead to changes in muscle tension patterns and movement patterns; therefore, psychological support is an important element in treating pain syndromes. [1,2]

Contemporary Approach to Rehabilitation

Modern rehabilitation is based on three fundamental pillars: reduction of functional limitations through therapeutic interventions such as exercise therapy and pharmacological support; adaptation of the patient to temporary or permanent functional restrictions, for example through the use of assistive devices; and modification of the environment to meet the individual's needs. Rehabilitation goals should be long-term and implemented in a stepwise manner, leading to progressive improvement in functional independence. The effectiveness of rehabilitation is enhanced when therapeutic objectives are formulated according to the SMART principle, meaning they are Specific, Measurable, Achievable, Relevant, and Time-limited. Evaluation of rehabilitation outcomes should consider functional improvement, prevention of complications, coordination of therapeutic interventions, and the patient's ability to return to physical activity. Continuous development and innovation in rehabilitation strategies remain essential to optimize outcomes in athletic populations.[2,3]

DISCUSSION

Knee Joint Injuries

Analysis of selected articles examining the frequency and characteristics of injuries in athletes reveals patients with tendinopathy primarily of the patella and cruciate ligaments. Research has demonstrated the positive impact of specific exercises on improving function in these patients. [2,4,5,6,7,8]

Patellar tendinopathy represents one of the most frequent overuse injuries of the knee. Although the adult patellar tendon demonstrates considerable resistance to rupture, several predisposing factors may increase injury risk, including inflammatory rheumatic diseases, chronic renal failure, systemic connective tissue disorders, prolonged corticosteroid therapy, and previous extensive knee surgery, such as arthroplasty or anterior cruciate ligament reconstruction using a patellar tendon graft. [2]

Management of complete patellar tendon rupture is primarily surgical and should be performed as early as possible. Postoperatively, temporary immobilization using an orthosis or plaster cast is typically maintained for approximately six weeks to ensure tendon healing under minimal tension. Rehabilitation is initiated immediately and includes isometric exercises for

the quadriceps and posterior thigh muscles beginning on the first postoperative day. Subsequent phases involve active knee flexion combined with passive extension, while active knee extension is usually introduced after 3–4 weeks. Partial weight-bearing is generally permitted early after surgery, with progression to full weight-bearing after six weeks. [4,5,6,7,8]

Research has established the patellar loading index, which considers parameters such as peak load, loading impulse, and total patellar load, helping to select appropriate exercise types and loading. The exercise considered the gold standard is the single-leg squat on an inclined surface; however, it is too demanding during the initial rehabilitation phase. The "Spanish squat," which involves isolated and controlled quadriceps loading with minimal hip involvement, can effectively strengthen the knee extension mechanism. This exercise is beneficial in earlier injury phases as it limits patellar tendon overload through better-controlled movement. Another approach involves squats, which should initially be performed bilaterally, then gradually deepened and progressed to unilateral execution. At the intermediate level, plyometric exercises (e.g., forward jumps, single-leg jumps) may be introduced, but should be implemented cautiously due to considerable reinjury risk. For jumping exercises, body position should be considered, where greater trunk inclination reduces knee joint loading. In the aforementioned exercises, determining execution frequency, progression tempo, and total rehabilitation cycle duration is crucial. The average process is considered to last approximately 8-24 weeks; however, extension to 32 weeks would not be erroneous. [6,7] In specific clinical circumstances, patients may manifest phobic behaviors regarding rehabilitation participation. Notably, individuals presenting with high levels of kinesiophobia or pain catastrophizing tend to demonstrate diminished precision and reduced intensity during exercise execution.[13]

Rupture of the cruciate ligaments, particularly the anterior cruciate ligament (ACL), constitutes another common knee injury in athletes. Complete ligament rupture usually necessitates surgical reconstruction, whereas partial tears may be managed conservatively depending on patient age, activity level, and functional demands. In young and physically active individuals, surgical reconstruction is generally recommended to restore knee stability and facilitate return to sport, while conservative treatment is more frequently applied in older or less active patients.

Return to sports activity following ACL reconstruction is typically permitted no earlier than 4–6 months postoperatively and is based on functional assessment. Satisfactory recovery is defined as restoration of at least 85% of strength and functional capacity compared with the contralateral limb. Rehabilitation programs emphasize eccentric strengthening exercises, in which muscles generate force while lengthening under load, as these exercises promote tendon and ligament adaptation. [3,4]

Isometric exercises may be safely introduced as early as two weeks after surgery, as they do not compromise joint stability and facilitate early range-of-motion recovery. Additionally, low-load resistance exercises combined with blood flow restriction using thigh compression bands have been shown to reduce early muscle atrophy while alleviating pain and edema. In later rehabilitation phases, plyometric training and agility drills are incorporated to restore dynamic knee stability and sport-specific movement patterns. Balance and proprioceptive training also play a crucial role by enhancing neuromuscular control and reducing reinjury risk. [4,5,9]

Lower Leg, Ankle, and Foot Injuries

Approximately 25% of all sports injuries involve the ankle and foot, with 45% being ankle sprains. Most ankle injuries occur in individuals participating in basketball and figure skating. In foot injuries, disciplines such as hiking and high-speed motorsports dominate. The aforementioned injuries are typically not mild, as approximately 40% of simple ankle sprains contribute to permanent disability and career termination in athletes. Ankle instability is among the most common lower extremity injuries in sports, with recurrence rates reaching 70%. [9,10] A systematic review indicates that chronic ankle instability develops in 25% of patients following lateral ankle sprain.[15] Comprehensive patient assessment after ankle sprain necessitates the implementation of appropriate outcome measures that quantify strength, range of motion, proprioception, and neuromuscular control.[16]

Initial treatment importantly involves cold compresses, compression bandaging, and elevation of the injured limb (the RICE method: R-rest, I-ice, C-compression, E-elevation). Electrical stimulation and iontophoresis may play important roles in alleviating pain and edema.

If the injury does not involve syndesmosis and no fracture is present, ankle rehabilitation should begin immediately after pain resolution to restore strength, range of motion, and proprioception. When the athlete stops experiencing pain during movement, they may progress to more advanced sports activities such as turns, jumps, and running. Return to sport is possible after completing the third rehabilitation phase, typically lasting 3-6 weeks. [9,12] Evidence suggests that kinesiotaping may exert beneficial effects on individuals with chronic ankle instability through enhancement of postural stability and joint kinematics. The therapeutic mechanism of kinesiotaping encompasses the provision of mechanical support and sensory stimulation to the ankle joint.[17]

Rehabilitation utilizes exercises such as static balance training, where the patient stands on one leg with eyes closed. This helps develop proprioception and body position control. Dynamic balance training is also employed, which determines the patient's ability to maintain balance while reaching for objects. [11,12] Functional exercises involve lateral jumps and direction changes. Training these skills improves reaction time, landing, and limb push-off strength. Resistance band exercises enable ankle strengthening in all movement directions (plantar flexion, dorsiflexion, eversion, inversion), with resistance levels increased as rehabilitation progresses. [11] BAPS platform training is also utilized. This is a pendulum platform containing openings for weights that change difficulty level and movement direction.[14] It is superior to classic BOSU balls or sensorimotor cushions as it allows controlled movements performed in multiple planes. [9,11]

Shoulder Injuries

Shoulder injuries rank third in frequency among athlete injuries, following knee and ankle injuries. This type is divided into direct injuries or repetitive overuse. Most commonly, injury is caused by overhead arm movement and consequent overloading of soft tissues around the joint. Dislocation can be relatively easily induced due to its structure - a large humeral head and shallow glenoid fossa. [10,20] The most common injury is subacromial impingement syndrome. It is caused by prolonged and repeatedly performed overhead movements. This can cause narrowing of the space between the humeral head and the coracoacromial arch, which includes the acromion, coracoacromial ligament, and coracoid process. This narrowing causes inflammation, edema, rotator cuff laxity, pain, and functional impairment through rotator cuff

damage. Poor vascularization in this area hinders regeneration. Treatment involves nonsteroidal anti-inflammatory drugs and physiotherapy. [10,18]

Cryotherapy, iontophoresis or phonophoresis, and nerve stimulation may prove helpful. If the aforementioned methods fail, corticosteroid injection into the subacromial space would be a good solution. The foundation of shoulder joint rehabilitation is restoration of range of motion in the patient, which may be initially difficult due to accompanying pain. In this case, cryotherapy, ultrasound, galvanic stimulation, and analgesics are effective pain management approaches. [10,20]

Initially, shoulder movements should remain within ranges that do not cause pain below 90 degrees of abduction and 90 degrees of forward flexion. In most cases, the early exercise goal is to achieve 90 degrees of limb elevation and 45 degrees of external rotation with the arm comfortably positioned. Regarding surgical procedures, the surgeon must ensure at least 90 degrees of stable elevation in the operated limb during surgery. Range of motion exercises should begin with the patient supine, placing the arm at the side with a pillow or other object under the bent elbow. This positioning shortens the lever arm for the upper extremity, thus reducing gravitational force acting on the glenohumeral joint. An important element is strengthening the shoulder girdle muscles. Initially, closed kinetic chain exercises are a safe solution. In these exercises, both agonistic and antagonistic muscle groups contract. These exercises enable precise imitation of proper motor patterns and act as shoulder stabilizers. They involve stabilizing the distal segment on an immobile object, which for the shoulder may be a flat surface such as a wall or door frame. The goal is to generate resistance for shoulder and scapular movements. An example is the "clock exercise," where the hand is stabilized on a wall or table, depending on the allowable degree of abduction, and performs rotation to different positions, like clock face positions. This movement is very effective in stimulating rotator cuff activity. Initially, this maneuver can be performed with shoulder abduction or flexion less than 90 degrees. In early shoulder rehabilitation phases, strengthening scapular stabilizers is also essential. This begins with closed-chain exercises and then progresses to open-chain exercises. Proprioceptive neuromuscular facilitation (PNF) exercises are helpful for return to form. [18-22]

Elbow Injuries

Among the most common elbow injuries are overuse injuries, including tennis elbow, golfer's elbow, and cubital tunnel syndrome. Tennis elbow is lateral epicondylitis of the humerus. It is characterized by pain in the lateral epicondyle region radiating to the forearm. Tenderness is also noticeable in the extensor carpi radialis brevis muscle attachment area. Elbow mobility is preserved. Treatment is primarily conservative, avoiding overloading of the painful limb, and an upper extremity orthosis may be applied. [10]

One rehabilitation method involves stretching exercises for the extensor carpi radialis brevis. This requires slowly and controllably increasing wrist flexion in the ulnar direction until tension is felt in the elbow region. Optimally, this exercise can be performed in three daily sets of 4 stretches. This improves muscle and connective tissue length and prepares the hand for further exercise phases. Eccentric wrist extensor exercises also yield good results. These occur when the patient is seated with the elbow and wrist maximally extended and the forearm pronated. The exercise involves slowly lowering the wrist to flexion, which should take about 30 seconds. The hand then drops down, and the movement ends in the flexed position with the hand dropping down. Return to the starting position of the injured hand is performed by the healthy hand. This exercise is responsible for stimulating damaged tendon remodeling, reducing pain, and increasing wrist extensor endurance and elasticity. [10,23]

In certain situations, surgical treatment appears appropriate. It is used when the patient's pain does not resolve for over a year. One recommended method is excision of the damaged and scarred proximal ECRB attachment, removal of granulation tissue, and drilling of the cortical layer to the subchondral bone to stimulate new vessel formation. [9]

Golfer's elbow is characterized by medial epicondylitis of the humerus. It is a less common cause of elbow pain than tennis elbow. The initial symptom is worsening pain in the medial elbow region that does not reduce mobility, strength, or sensation. The greatest tenderness is felt distally and laterally from the medial epicondyle where two muscles originating from the epicondylar ridge begin (pronator teres and flexor carpi ulnaris). Treatment of golfer's elbow initially involves conservative management including rest, compresses, NSAIDs, and temporary orthosis. If this does not help, steroids are used. [10]

The rehabilitation plan is usually similar to lateral epicondylitis. For severe symptoms, ultrasound, isometric strengthening, and HVGS (High Voltage Galvanic Stimulation) therapy involving high-voltage galvanic stimulation are worthwhile. HVGS uses pulsed unidirectional current with high voltage and very short pulse duration. It enables edema treatment, blood and lymph circulation improvement, pain reduction, and soft tissue regeneration. [9]

For moderate pain symptoms, transverse friction massage (called Cyriax massage) is beneficial, involving intensive massage and rubbing of soft tissues across the course of muscle fibers, tendons, and ligaments. This massage yields good results in chronic tendinitis and in scars and adhesions in soft tissues. [9,24]

UCL anterior bundle insufficiency or laxity typically leads to ulnar nerve compression, which may result in cubital tunnel syndrome. This nerve damage most commonly occurs due to repeated tensioning episodes combined with ulnar collateral ligament laxity, resulting from recurrent subluxation or external displacement of the nerve from the cubital groove, nerve entrapment, or direct trauma. [9]

Treatment of this condition may involve conservative or surgical management. In the initial conservative treatment phase, NSAIDs, night splints, physiotherapy, and corticosteroid injections are used. In case of failure, surgical treatment is employed using techniques such as simple decompression, decompression with anterior transposition (submuscular, intramuscular, or subcutaneous), and medial epicondylectomy. Simple decompression involves removing all structures compressing the nerve in its course through the elbow joint while maintaining its natural location - behind the medial epicondyle. Subcutaneous transposition involves creating a new subcutaneous nerve pathway, moving it anterior to the medial epicondyle and above the muscle belly. This procedure may be performed with or without a fascio-fat flap. [25]

In the first week of postoperative exercises, placing the limb in a splint with 90-degree elbow flexion while leaving wrist movement freedom is recommended, enabling initiation of grip exercises and wrist ROM. Isometric shoulder exercises and compression bandaging are also recommended during this time. In the second postoperative week, initiating isometric elbow and wrist exercises and expanding elbow ROM exercises in the 15-120 degree range is beneficial. In subsequent weeks, flexibility exercises such as wrist extension and flexion; forearm supination and pronation; and elbow extension and flexion should be introduced. In

the advanced strengthening phase, weeks 8-11 of rehabilitation, an eccentric exercise program and plyometric exercises are introduced. [9] Considering other therapies, therapeutic ultrasound (US) and low-level laser therapy (LLLT) have been proven to show beneficial effects in treating ulnar nerve entrapment syndrome (UNE), improving clinical outcomes, grip strength, and reducing pain. [26]

Pain in Athletes - Selected Issues

Myofascial Pain

Myofascial pain represents one of the most common etiologies of pain in athletes. It is characterized by stabbing, burning sensations ranging from moderate to severe intensity. The pain manifests either as episodic attacks or continuous discomfort and may present with multifocal distribution. Patients typically present with localized or referred pain, restricted range of motion, weakness, tenderness, muscle tension, autonomic dysfunction, and local contractile responses in the affected muscle. Physical examination reveals trigger points, which are hyperirritability foci within skeletal muscles and ligaments. Active trigger points can be distinguished, demonstrating spontaneous tenderness, impaired muscle relaxation capacity, and serving as foci of pain radiation. Conversely, passive trigger points exhibit pressure-induced tenderness that limits muscle relaxation ability. Given the difficulty in determining pain etiology, treatment focuses on symptom reduction through nonsteroidal anti-inflammatory drugs (NSAIDs), local injections, physiotherapy, and acupuncture. [27,28]

Kinesiotaping may prove beneficial when combined with conventional therapeutic modalities such as massage, strength training, acupuncture, and electrical therapy, particularly in patients with chronic nonspecific low back pain. [29]

Literature also reports efficacy of cupping therapy. Improvement in soft tissue condition within the upper back region was observed in a cohort of baseball players with myofascial pain syndrome following 4 weeks of cupping treatment. [30]

Acupuncture combined with cervical muscle stretching has also demonstrated efficacy. Following such therapy, patients showed significant improvement in range of motion and

reduction in pressure-induced pain. Furthermore, the combination of acupuncture with stretching proved significantly more effective than stretching alone in long-term myofascial pain reduction. [31]

In the contracted state, myofascial trigger points (MTPs) receive insufficient oxygen and nutrients, leading to prolonged contraction and pathological tissue changes. These alterations promote the release of substances that stimulate nerve endings, triggering pain and autonomic responses. Clinical techniques can deactivate trigger points, while appropriate exercises support therapy by improving muscle perfusion and metabolism. Aerobic exercise increases blood flow, reduces inflammatory marker levels, and promotes analgesic substance production. However, training must be moderate and well-planned, as premature activity may exacerbate muscle tension. [32]

Back Pain and Lumbar Region Pain

Back pain and lumbar region pain caused by various etiologies represent significant clinical problems. The transversus abdominis (TrA), internal oblique (IO), multifidus muscle, diaphragm, and pelvic floor muscles are classified as deep trunk muscles. They play crucial roles in spinal stabilization and motor control. Spinal stability is essential for proper movement execution in both the trunk and extremities, which is particularly significant in athletes. Athletes with low back pain (LBP) demonstrate reduced spinal stabilization, segmental lumbar instability, and impaired deep trunk muscle activation. [33]

These are predominantly non-radicular pain syndromes. They are characterized as dull, deep-seated pain of moderate to severe intensity. The pain localizes unilaterally or bilaterally in the paravertebral region, sometimes radiating laterally or distally. These pains are often difficult to localize due to the absence of corresponding dermatomes in the affected area. Pain intensifies during prolonged maintenance of static positions and decreases with movement. [27]

Regarding applicable exercises, these should focus on activation and control of deep trunk muscles, particularly abdominal and paraspinal muscles. An example is the "dead bug" exercise, which involves simultaneous, alternating lowering of the extended arm and contralateral leg in supine position while maintaining abdominal muscle tension and pressing

the lumbar spine against the floor. Other effective exercises include side plank, "cat-cow" stretch, shoulder bridge, plank, and lumbar extension stretches. It is advisable to apply kinesiotaping in a V-shaped pattern to the lumbosacral region before each stabilization exercise. This enables better reduction of low back pain as measured by the Visual Analog Scale (VAS) and enhances the effects of stabilization exercises. [34]

Example Exercise Protocol for Back Pain and Lumbar Region Pain Therapy

type of exercise	**number of repetitions**
Dead bug – 10 repetitions of each leg	3 sets, 30 sec rest
Lateral plank – 30 sec. Isometric – 1 repetitions of each side	3 sets, 30 sec rest (modification with supported knees)
Cat camel – flexion and extension 10 repetitions	3 sets, 30 sec rest
Shoulder bridge – 10 repetitions	3 sets, 30 sec rest
Pointer - 10 repetitions of each leg	3 sets, 30 sec rest
Plank – 30 sec isometric, 1 repetition	3 sets, 30 sec rest
Lumbar flexion – flexion and extension – 10 repetitions	3 sets, 30 sec rest

Table 1. Lumbo-pelvic core stability training [34]

Bone Overuse Injuries

Bone overuse injuries represent another compelling pain-related topic. One of the most common causes of lower extremity overuse pain is medial tibial stress syndrome (MTSS), with a prevalence ranging from 4% to 35% among athletes and military personnel. The etiology of this condition remains incompletely understood, with various potential mechanisms described in the literature, including increased intracompartmental pressure and periosteal inflammation induced by tractional forces. MTSS management often involves progressive running

(depending on patient fitness level) and exercises that strengthen and stretch the calf muscles. The isolated effect of stretching has not been definitively established in research; however, physiological loading has been shown to promote tibial bone remodeling, contributing to pain reduction. Weakness of muscles responsible for tibial stabilization may increase the risk of microtrauma. [35]

Typical stress fractures present with localized pain of insidious onset, which initially appears only at the end of running sessions. In more advanced stages, pain occurs with greater intensity and manifests during activities of daily living (e.g., walking), independent of running activity. [36] Focal bone tenderness represents one of the physical examination findings. Other potential symptoms include edema, erythema, or limb warmth. [37]

The management of stress fractures requires not only protection and rest but also identification of predisposing factors. For instance, when low bone density is detected, appropriate treatment must be implemented, while biomechanical abnormalities or inappropriate footwear and training require targeted rehabilitation. Methods aimed at accelerating healing may also be employed. Research has demonstrated that therapeutic ultrasound can reduce healing time for acute tibial shaft fractures, distal radius fractures, and navicular stress injuries. Electrical stimulation shows some efficacy in treating delayed union and nonunion, although this evidence derives primarily from uncontrolled studies of stress fractures. [38]

Conclusions

Rehabilitation constitutes an essential component enabling athletes to restore function following injuries and reduces the consequences of trauma. Among the most common athletic injuries are musculoskeletal system damage, including ligament ruptures, muscle injuries, joint damage, and tendon injuries. The rehabilitation plan should be individualized according to patient needs, depending on injury type and treatment phase progression. Early controlled mobilization, implementation of various exercises adapted to the injury type (including isometric and eccentric exercises), and appropriate pain management are crucial. Examples include knee or shoulder injury treatment, which requires progressive loading and proprioception restoration. Conversely, ankle sprains should be rehabilitated as early as possible following pain resolution. Contemporary rehabilitation also considers aspects such as

psychological patient support, manual therapy, electrotherapy, and other modern techniques. Well-planned and comprehensive rehabilitation enables athletes to successfully return to physical activity while reducing the risk of injury recurrence.

Disclosure

Author's contribution:

All authors contributed to the article.

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