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Review Article

Orthopedic sports injuries: advanced imaging modalities, return-to-play criteria, and injury prevention

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ABSTRACT

Orthopaedic sports injuries encompass a wide range of musculoskeletal conditions resulting from the physical demands of athletic activities. These injuries can vary from acute, such as sprains and fractures, to chronic overuse syndromes like tendinopathies. Prevalent due to the global enthusiasm for sports, they affect bones, muscles, tendons, ligaments, and joints. The etiology of these injuries is multifactorial, stemming from biomechanical stressors, training methods, genetics, and environmental conditions. Advanced imaging modalities like magnetic resonance imaging and Computed tomography have revolutionized the assessment and diagnosis of these injuries, aiding in treatment decisions and return-to-play criteria. Injury prevention is paramount and involves understanding intrinsic (athlete-related) and extrinsic (environmental) risk factors. Strategies include pre-participation screening, strength and conditioning programs, biomechanical analysis, neuromuscular training, proper equipment use, rule changes, education, and creating a safety-conscious culture. Effective prevention reduces the burden of these injuries. Treatment strategies range from conservative approaches to surgery, depending on the type and severity of the injury. Emerging trends in sports medicine, including biologic therapies and telemedicine, offer promising avenues for improved diagnosis and recovery. The holistic approach to orthopaedic sports injuries encompasses prevention, diagnosis, and treatment, ensuring athletes' well-being and longevity in their chosen sports.

Keywords: Sports medicine, Athletes, Radiology, Musculoskeletal injury, Orthopaedics

INTRODUCTION

In the realm of sports medicine, orthopaedic sports injuries represent a pervasive and multifaceted challenge. These injuries, which encompass a wide spectrum of musculoskeletal afflictions, result from the intense physical demands of athletic activities. Athletes, both amateur and professional, continually expose themselves to the risk of these injuries as they pursue excellence in their chosen sports. The repercussions of orthopaedic

sports injuries are far-reaching, impacting not only athletes' physical health but also their careers, quality of life, and overall well-being.[1] Orthopedic sports injuries encompass a diverse range of conditions, including acute injuries like sprains, strains, and fractures, as well as chronic overuse syndromes like tendinopathies and stress fractures.[2] These injuries can affect various components of the musculoskeletal system, such as bones, muscles, tendons, ligaments, and joints. Their presentation can vary from mild discomfort to severe pain and functional impairment.

The prevalence of orthopaedics sports injuries is noteworthy, given the global enthusiasm for sports and physical activity. Sports participation transcends age groups and encompasses a myriad of disciplines, from contact sports like football and rugby to non-contact activities like swimming and long-distance running. Consequently, the burden of orthopaedics sports injuries extends across diverse populations and contributes significantly to the overall landscape of musculoskeletal health. According to new investigations, each year in the United States, athletes incur 4 million sports-related injuries and need roughly 2.6 million ER visits, totalling nearly 2 billion USD in healthcare expenditures.[3-5] To date, only a few epidemiological studies are available about the prevalence of sports-related injuries in Saudi Arabia. One study based in Jeddah, Saudi Arabia, assessed the prevalence of sports injuries among basketball and soccer players in Jeddah and found that recreational practice (78.9%) alone constituted more sports injuries than professional and collegiate practice combined.[6] Further, the researchers found the most common mechanism of injury to be twisting (56%), and the most common type of injuries to be ligamentous injuries (26%). Another Madinah based study at King Fahd Hospital found football injuries (94%) to be the most common source of orthopaedics sports-related injuries and fractures (82%) to be the most prevalent injury type.[7] The aetiology of orthopaedic sports injuries is intricate, stemming from a complex interplay of factors.[8] These factors encompass biomechanical stressors, training methodologies, environmental conditions, genetic predispositions, and an athlete's age and conditioning.[9] Understanding the multifactorial nature of these injuries is imperative for devising effective strategies for prevention, diagnosis, and treatment. This comprehensive review embarks on an exploration of the expansive domain of orthopedic sports injuries.

METHODOLOGY

This study is based on a comprehensive literature search conducted on 12 November 2023, in the Medline and Cochrane databases, utilizing the medical topic headings (MeSH) and a combination of all available related terms, according to the database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed advanced imaging modalities, return-to-play criteria, and injury prevention about orthopaedic sports injuries. There were no restrictions on date, language, participant age, or type of publication.

DISCUSSION

Sports-related injuries encompass a wide spectrum of conditions, with their etiologys and pathophysiology varying depending on factors such as the type of sport, the athlete's age, and skill level. Traumatic injuries, often seen in contact sports, result from sudden, forceful impacts or movements, leading to fractures, dislocations, sprains, strains, and contusions.[10] These injuries involve tissue damage, inflammation, and pain. Overuse injuries, common in endurance sports, develop gradually due to repetitive stress, causing microtrauma to tissues and conditions like stress fractures, tendinitis, and shin splints.[11] Ligament injuries in sports involving quick direction changes often result from stretching or tearing of ligaments, causing joint instability.[12] Muscle injuries, prevalent in explosive sports, range from minor strains to severe tears, involving muscle fiber damage, inflammation, and scar tissue formation.[13] Concussions occur in contact sports, altering brain function due to acceleration or deceleration forces.[14] Cardiovascular issues may arise from the increased strain on the heart during intense exercise, while heat-related illnesses result from heat dissipation challenges during strenuous activities in hot environments.[15,16] Sports medicine professionals, including physicians, physiotherapists, and athletic trainers, play a vital role in managing these injuries and facilitating athletes' safe return to sports.

The assessment, diagnosis, and management of sports-related injuries by these professionals have significantly improved owing to the advanced imaging modalities used today in the field of orthopaedic sports medicine. Among these modalities, magnetic resonance imaging (MRI) stands out for its non-invasive, high-resolution visualization of soft tissues, making it indispensable for evaluating ligaments, tendons, cartilage, and muscles.[17-19] MRI's multiplanar imaging capabilities and functional techniques, like diffusion-weighted imaging and magnetic resonance spectroscopy, provide in-depth insights into injury severity and recovery while avoiding ionizing radiation, which is particularly beneficial for repetitive imaging and pediatric athletes. However, the cost, contraindications, and time-consuming nature of MRI may pose limitations, especially in some healthcare settings.

Computed tomography (CT) imaging excels in visualizing bony structures, making it an essential tool for fractures, stress reactions, and complex joint injury assessment.[20] CT offers high-resolution bone imaging, rapid image acquisition, and multiplanar reconstruction capabilities, ensuring a comprehensive evaluation of bone-related injuries. Nevertheless, its ionizing radiation poses concerns, particularly for young athletes, and it offers

limited soft tissue visualization, rendering it less suitable for ligament and muscle evaluations.

Ultrasonography (US) provides real-time imaging of musculoskeletal structures, allowing dynamic assessment of joint and muscle function and guiding interventions.[21,22] Its portability, non-invasiveness, and cost-effectiveness enhance accessibility, but its operator-dependent nature, limited depth penetration, inability to visualize bone, and restricted field of view may hinder its utility in certain cases.

Nuclear medicine techniques, including bone scintigraphy and single photon emission computed tomography-computed tomography (SPECT-CT), are valuable for assessing bone metabolism and detecting stress fractures and other bone-related injuries at an early stage.[23] They offer the advantages of early detection and whole-body assessment, with SPECT-CT fusion providing precise localization of abnormalities.[24] However, these techniques involve radiation exposure and offer limited soft tissue detail, potentially requiring complementary imaging modalities.

Return-to-play (RTP) criteria in the context of orthopaedic sports injuries are a critical component of the comprehensive management of athletes. These criteria encompass a systematic and evidence-based approach to assessing an athlete's readiness to return to their respective sport following an injury. The primary goal of RTP criteria is to ensure the athlete's safe and successful return while minimizing the risk of re-injury. RTP decisions should be made collaboratively by a multidisciplinary team, including orthopaedic surgeons, sports medicine physicians, physical therapists, and athletic trainers, with a focus on individualized assessment and rehabilitation. The process of establishing RTP criteria begins with a thorough evaluation of the athlete's injury, including its type, severity, and location.[25] Imaging studies such as MRI and X-rays are often employed to provide insights into the extent of tissue damage and to guide treatment decisions. The timing of RTP decisions varies depending on the injury but typically follows a structured timeline that includes acute management, rehabilitation, and performance testing. Acute management involves an initial injury assessment and appropriate interventions. For instance, in the case of anterior cruciate ligament (ACL) tears, immediate management may involve reducing pain and swelling and bracing the injured knee.[26] Once the acute phase has been addressed, the focus shifts to rehabilitation, which is a cornerstone of the RTP process. Rehabilitation is a comprehensive and progressive program designed to restore the athlete's function, strength, and mobility.[27] It typically involves a combination of physical therapy, strength and conditioning exercises, and sport-specific drills. The rehabilitation process is highly individualized, taking into account the athlete's age, fitness level, and specific sports demands. The goal is not only to heal the injured area but also to address any underlying biomechanical issues and asymmetries that may have contributed to the injury.[28] Throughout the rehabilitation process, various clinical and functional assessments are conducted to monitor the athlete's progress. These assessments may include a range of motion tests, strength measurements, functional movement tests, and sport-specific performance testing.[29,30] The athlete's pain levels, psychological readiness, and confidence in their abilities are also essential factors to consider. One widely recognized model for RTP criteria is the "functional milestone" approach.[25] This approach involves a series of criteria or benchmarks that the athlete must meet before being cleared for full participation in their sport. For example, in the case of an ACL injury, these milestones may include achieving full knee range of motion, restoring strength and stability, demonstrating proper landing and cutting mechanics, and passing functional tests like the hop test and agility drills.[31] The athlete's ability to meet these criteria signifies their readiness to return safely to play. Psychological readiness is a crucial aspect of RTP criteria. Athletes often experience fear, anxiety, or lack of confidence after sustaining an injury. Addressing these psychological factors through counselling, mental conditioning, and gradual exposure to sport-specific activities is essential for a successful return.[32] It is important to note that the RTP process is not one-size-fits-all. Each athlete's journey is unique, and the criteria for returning to play should be adapted to their specific circumstances. Furthermore, the athlete should not be rushed through the process, as a premature return can lead to reinjury and long-term consequences. A patient-centred and multidisciplinary approach is essential to guide athletes through this challenging journey and ensure that they return to play with confidence and a reduced risk of reinjury.

In the domain of orthopaedic sports injuries, injury prevention emerges as a paramount concern. Its fundamental goal is to curtail both the frequency and severity of such injuries in athletes. These injuries encompass a spectrum of musculoskeletal, ligament, tendon, and bone-related issues, all of which cast significant impacts on an athlete's career trajectory and long-term well-being.[33] Effective injury prevention adopts an evidence-based approach, necessitating a deep understanding of risk factors, the application of preventive measures, and the fostering of a safety-centric ethos within the sports community.

The foundation of sound injury prevention lies in a comprehensive grasp of the risk factors associated with orthopaedic sports injuries. These risk factors can be categorized into two main types: intrinsic and extrinsic.[34] Intrinsic factors revolve around an athlete's characteristics, including age, gender, genetic predisposition, injury history, and biomechanical traits.[35] For instance, female athletes may exhibit a higher susceptibility to ACL injuries due to anatomical and hormonal factors.[36] On the other hand, extrinsic factors pertain to external conditions such as environmental factors, playing surfaces, equipment quality, and coaching techniques.[37] To effectively prevent

injuries, strategies should be deeply rooted in evidence and customized to the specific sport and athlete demographic. Instead of following a rigid set of numbered steps, a holistic approach involving several key elements is used. Efforts commence with thorough pre-participation screening, where athletes undergo comprehensive physical evaluations before engaging in sports activities.[38] This screening process can uncover pre-existing conditions or risk factors requiring intervention. Strength and conditioning programs are crucial in enhancing an athlete's muscular strength, flexibility, and endurance.[39] Proper conditioning equips athletes to withstand the physical rigors of their sport and mitigates injury risks. Biomechanical analysis plays a pivotal role in scrutinizing athletes' movement patterns and techniques to identify flawed practices that might contribute to injuries.[40] Corrective exercises and coaching adjustments are then incorporated as needed. Neuromuscular training programs are designed to improve an athlete's proprioception, balance, and coordination.[41] These programs have proven effective in reducing injury risks, especially in sports with high ACL injury rates. The appropriate use of protective equipment, including helmets, pads, braces, and footwear, serves as an important aspect of injury prevention, especially in contact sports.[42] Sporting organizations often introduce rule changes aimed at lowering injury risks. For instance, rule alterations in American football have sought to minimize head and neck injuries.[43] Education and awareness initiatives are crucial for athletes, coaches, and parents. These programs impart knowledge about injury risks and prevention strategies, encouraging safer practices and early injury recognition.[33] In addition to these strategies, cultivating a safety-conscious culture within the sports community is pivotal for injury prevention. This involves creating an environment where athletes feel comfortable reporting injuries, seeking medical assistance, and adhering to rehabilitation protocols.[44] Coaches and sports organizations play a central role in nurturing this culture by emphasizing athlete well-being over a relentless pursuit of victory. Furthermore, the ongoing research and evaluation of injury prevention strategies are essential for refining and enhancing their efficacy. Epidemiological studies, clinical trials, and biomechanical investigations all contribute to the development of evidence-based prevention measures. Additionally, injury surveillance systems play a vital role in monitoring injury trends and assessing the impact of prevention programs.[45]

Treatment strategies for orthopaedic sports injuries span a continuum, from non-invasive and conservative approaches to surgical interventions. The choice of treatment modality is influenced by several factors, including the nature and severity of the injury, the athlete's goals, and the specific demands of their sport.[46] Emerging trends in sports medicine hold promise for further enhancing the management of orthopaedic sports injuries. Biologic therapies, regenerative medicine, and telemedicine are areas of active exploration, offering novel avenues for diagnosis, treatment, and recovery.[47]

CONCLUSION

Advanced imaging techniques have transformed orthopaedic sports medicine, aiding in injury assessment and management. MRI offers detailed soft tissue visualization without radiation, while CT excels in bone injury evaluation but raises radiation concerns. Ultrasonography provides real-time imaging but has limitations. Nuclear medicine aids early bone injury detection but involves radiation exposure. Return-to-play criteria are crucial for athletes, requiring evidence-based assessments and personalized rehabilitation. Injury prevention involves a multifaceted approach, addressing risk factors, customized strategies, and fostering a safety-centric culture. Treatment options range from conservative to surgical approaches, with emerging trends like biological therapies and telemedicine showing promise for the future of sports medicine.

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