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Management of Ankle Injuries and Chronic Ankle Instability in Football Players

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Abstract:
Ankle sprains are common injuries in football, with approximately 20% to 40% of patients progressing to chronic ankle instability (CAI), leading to recurrent sprains, residual pain, and functional limitations that affect athletic performance and daily activities. Existing treatments such as the RICE principle, physical therapy, and functional braces are effective but have limitations in long-term recovery, proprioceptive restoration, and stability maintenance, and their optimal timing and indications remain controversial. Emerging imaging technologies, such as dynamic ultrasound, MRI, and gait analysis, as well as novel therapeutic methods, including neuromuscular training, virtual reality–assisted rehabilitation, and wearable feedback systems, provide more accurate diagnosis and personalized rehabilitation programs, which may compensate for the shortcomings of traditional treatments. With the continuous progress of related technologies and the improvement of evidence-based rehabilitation strategies, the accuracy of clinical decision-making is expected to further improve, and patient rehabilitation outcomes are expected to improve. This review aims to evaluate the application effects of these new technologies in the management of CAI, analyze their clinical potential and current challenges, and propose directions and priorities for future research.

Keywords: Ankle sprain; chronic ankle instability; rehabilitation; neuromuscular training.

1. Introduction

Ankle sprains are highly prevalent in football and represent one of the most common acute injuries, ranking first among all lower-limb sports injuries. Clinically, acute ankle sprains are characterized by swelling, tenderness, and limited mobility [1]. These manifestations directly affect athletes' athletic performance and physical condition. Even after acute symptoms subside, some athletes continue to experience recurrent "giving way" during activity, often accompanied by persistent joint instability and discomfort. The pathogenesis of this condition is mainly lateral collateral ligament injury caused by

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rapid direction changes, unstable landing, or physical confrontation. In the long term, it can lead to ligament laxity, joint proprioceptive disorders, and impaired neuromuscular control, with some patients developing chronic ankle instability (CAI). This chronic pathological state increases the risk of recurrent sprains and early degenerative joint disease, seriously affecting athletic performance and career development.

At present, the treatment methods for ankle injuries are divided into two categories: traditional treatments and novel diagnostic and therapeutic methods. Traditional treatment methods are widely used but still face certain limitations and bottlenecks. Although conservative treatment is relatively widely applied, it has a high failure rate. It mainly helps patients with rehabilitation through functional braces, physical therapy, and progressive rehabilitation training. Its advantages are minimal trauma and the ability to return to sports early, but it has the problems of residual instability and high recurrence rate. Surgical treatment mainly includes ligament repair and reconstruction, which can better restore joint stability, but surgery may bring complications and the recovery period after surgery may be long [2]. Conservative treatment is more suitable for patients with first-time or mild-to-moderate injuries, while surgery is applicable to patients with recurrent injuries or those who fail conservative treatment.

With the advancement of science and technology, new diagnostic and therapeutic methods have emerged continuously. Modern diagnostic technologies include dynamic ultrasound, 3D MRI imaging, and gait kinematic analysis. These technologies can monitor ankle stability in real time, but their popularization is limited due to high costs. On the other hand, wearable sensors combined with inertial measurement units (IMU) and mechanical sensors can monitor load and joint kinematic changes during real competitions or training [3]. In terms of treatment methods, the application of biomaterials and tissue engineering has shown gradual progress. For instance, biodegradable polylactic acid ligament scaffolds have demonstrated ligament regeneration in animal experiments, while platelet-rich plasma (PRP) injection has been shown to promote a 30% increase in ligament healing speed. Stem cell therapy, though promising, still faces limitations such as insufficient long-term safety data in clinical applications [4]. This review aims to summarize the epidemiological characteristics, pathogenesis, and hazards of ankle injuries and chronic ankle instability in football players, evaluate the efficacy and limitations of existing treatment methods, focus on the application progress of novel diagnostic and rehabilitation methods, and provide evidence-based basis for formulating scientific prevention and treatment strategies.

2. Conservative Treatment

Firstly, existing treatment methods are introduced, beginning with conservative approaches. The RICE principle, a mnemonic for Rest, Ice, Compression, and Elevation, is widely applied in the initial management of acute ankle sprains and can effectively alleviate local swelling and pain. Its main advantage lies in its simplicity and ease of implementation, making it particularly suitable for the on-site management of acute sports injuries during competitions. For example, when a football player sustains an ankle injury during a match, the RICE method can rapidly relieve symptoms. However, the RICE principle does not address long-term functional recovery or joint stability, and its effectiveness is limited in more severe internal ankle injuries, such as Achilles tendon rupture or fractures.

Physical therapy and rehabilitation training mainly include proprioceptive training, strength training, and neuromuscular control exercises. These interventions help restore joint function and reduce the risk of recurrent injury. For instance, the use of an incline board can improve calf flexibility, while tiptoe training can enhance muscle strength and endurance. Nevertheless, rehabilitation is often time-consuming and requires long-term adherence and close cooperation between patients and clinicians to achieve optimal recovery outcomes.

Adjunctive treatment with functional braces and sports supports is also important. Braces or ankle guards can provide additional stability to the injured ankle, which has poor stability during the recovery period, and braces can provide additional support. For example, rigid ankle braces and elastic bandage wrapping can offer external support to the joint. However, prolonged dependence on such devices may lead to reduced muscle strength and potentially hinder the restoration of normal motor function after rehabilitation [5].

3. Surgical Treatment

Surgical treatment has a significant effect on ankle injuries, especially in patients with chronic ankle instability. First, the modified Brostrom procedure, which mainly targets the lateral collateral ligament, can effectively restore ankle stability. The advantages of the surgery are minimal trauma and rapid recovery, and it is suitable for patients diagnosed with chronic lateral ankle instability who have failed conservative treatment for more than 6 months. However, patients with more severe chronic instability may not achieve significant improvement from this surgery and still need to cooperate with a long period of rehabilitation training. In terms of surgical reconstruction, autologous tendon transplantation and allogeneic tendon transplantation are commonly used techniques for reconstructing damaged ligaments and joints. These techniques aim to restore joint function and provide strong stability. However, these surgeries are relatively invasive, have a long recovery period, and may lead to complications such as donor site pain or rejection of the transplanted material. Ligament transplantation mainly uses gastrocnemius tendon tissue for transplantation, and bone tunnels are created to facilitate filling and reconstruction of damaged ligaments. The advantage of this method is that it can effectively restore ankle stability, and it is suitable for patients with long-term instability or severe injuries. The disadvantages are complex surgery, high technical requirements for doctors, long recovery period, and possible rejection of the transplanted material by the body.

4. Novel Imaging Diagnostic Technologies

The rapid development of imaging technology has brought significant advancements to the diagnosis and evaluation of ankle injuries. Dynamic ultrasound, as a non-invasive method capable of real-time visualization, can capture ligament elongation and joint stability changes during movement, providing immediate and accurate feedback. This approach is simple, non-invasive, and clinically valuable for rapidly assessing injury severity and functional recovery [7]. Nonetheless, its adoption is limited by the high cost of equipment and the substantial technical expertise required, posing challenges for implementation in resource-limited settings.

MRI and 3D imaging technologies further refine the diagnostic accuracy of ankle injuries by generating high-resolution images through strong magnetic fields and radiofrequency pulses. These methods enable detailed assessment of soft tissue injuries, ligament sprains, and cartilage damage. In particular, 3D MRI reconstructs two-dimensional images into three-dimensional structures, offering clearer visualization than conventional techniques [8]. However, these technologies remain costly and are unable to monitor ankle function during real-time dynamic movement, thereby constraining their widespread clinical use.

Gait analysis and biomechanical monitoring provide a biomechanical perspective for the pathological mechanism research and clinical diagnosis of CAI. By evaluating mechanical loading patterns and joint behavior throughout the gait cycle, these techniques reveal characteristic abnormalities in CAI patients and provide objective data to guide personalized rehabilitation strategies [9]. For example, evidence indicates that when the heel strike inversion angle exceeds 8°, it is necessary to strengthen the long and short fibular muscles through resistance training with elastic bands, aiming to reduce the inversion angle to within 5°. Despite its diagnostic value, gait analysis faces limitations including high equipment costs, reliance on advanced 3D motion-capture systems, and the requirement for specialized expertise in biomechanical data interpretation.

Novel diagnostic and therapeutic methods for ankle injuries mainly involve advanced imaging approaches and emerging rehabilitation techniques. Dynamic ultrasound offers real-time visualization of ligament movement and joint instability, enhancing functional assessment but facing constraints related to equipment and operator requirements. MRI and 3D imaging provide high-resolution evaluation of soft tissue pathology yet lack the ability to capture dynamic joint behavior. Gait analysis, while essential for identifying biomechanical deficits and informing individualized rehabilitation, remains restricted by its technological and interpretative demands.

5. Novel Rehabilitation and Therapeutic Methods

Rehabilitation for ankle injuries has evolved beyond traditional methods, with proprioceptive and neuromuscular control training recognized as essential for restoring joint stability and motor function. Exercises such as balance-pad training and visual-interference tasks enhance proprioceptive input and neuromuscular coordination, thereby improving balance, strength, and pain in CAI, though long training cycles and high compliance requirements may limit early effectiveness [10]. Virtual reality (VR)-assisted rehabilitation provides an immersive and interactive environment that strengthens patient engagement and adherence by simulating realistic movement scenarios, yet widespread adoption is restricted by the high cost of VR equipment. Biological treatments such as PRP injections further expand therapeutic options by promoting ligament and soft-tissue repair through concentrated growth factors, potentially shortening recovery time by 30%–50%, although outcomes vary considerably with age and injury severity, and large-scale clinical evidence remains limited [11].

With growing demand for individualized rehabilitation, AI-assisted analysis, wearable devices, and remote monitoring systems offer new avenues for precision management. These technologies can continuously track ankle biomechanics, identify abnormal movement patterns, and provide timely feedback for adjusting rehabilitation protocols. In parallel, advances in minimally invasive surgery, robot-assisted techniques, and biomaterials, including PRP

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and bioengineered cartilage, enhance the precision and effectiveness of structural repair. Despite these promising innovations, further multicenter and long-term clinical studies are needed to validate their efficacy and support broader clinical implementation.

6. Conclusion

This study summarizes the application of emerging imaging technologies and treatment modalities in ankle injuries and chronic ankle instability, while examining the limitations of traditional approaches. Although methods such as the RICE principle, physical therapy, and functional braces provide short-term relief during the acute phase, they are insufficient for achieving long-term functional recovery and maintaining joint stability. Emerging imaging technologies, including dynamic ultrasound, MRI, 3D imaging, and gait analysis, offer more precise visualization of soft-tissue injury, joint stability, and biomechanical deficits, thus supporting more accurate diagnosis and personalized rehabilitation planning. Meanwhile, novel therapeutic strategies such as proprioceptive and neuromuscular training, virtual reality–assisted rehabilitation, and platelet-rich plasma (PRP) therapy show promising benefits in enhancing neuromuscular control and promoting tissue repair, though their clinical application remains constrained by high equipment costs, operator dependence, and variability in treatment outcomes.

Despite these advancements, several limitations persist, including insufficient large-scale evidence, the lack of standardized rehabilitation protocols, and restricted accessibility in resource-limited settings. Future research should strengthen the integration of multimodal diagnostic information and establish evidence-based, individualized rehabilitation frameworks. Technologies such as AI-assisted analysis, wearable sensors, and remote monitoring are expected to further enhance precision rehabilitation and early intervention, while innovations in minimally invasive surgery and biomaterials may contribute to improved structural repair and long-term recovery. Continued efforts to bridge the gap between technological innovation and practical clinical application will be essential for optimizing ankle injury management.

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