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Rehabilitation Strategies for Adolescent Ankle Sprains: Evidence-Based and Integrated Approaches

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Abstract. Ankle sprain is one of the most common injuries among athletes, which can lead to chronic ankle instability (CAI). This article analyzes current rehabilitation strategies, including range of motion recovery, proprioceptive training, resistance based reinforcement, and functional exercise specific exercises. Innovative models such as blood flow restriction training, mobile based rehabilitation, and intelligent feedback systems were discussed together with supplementary traditional Chinese medicine methods. The results of this article indicate that multimodal rehabilitation is superior to isolated intervention, and specific stage plans can improve rehabilitation outcomes. Case based analysis emphasized the clinical benefits of joint strategies, while critical evaluation identified gaps such as small sample size, inconsistent protocols, and lack of framework for adolescents. The future direction emphasizes large-scale randomized trials, adolescent centered adaptation, and technology assisted personalized rehabilitation. This article proposes a structured and phased rehabilitation framework to reduce the risk of relapse in adolescent athletes and optimize their long-term functional recovery.

Keywords: Ankle sprain, adolescent rehabilitation, proprioceptive training, blood flow restriction, chronic ankle instability

1. Introduction

Ankle sprains represent one of the most common musculoskeletal injuries among adolescents, particularly those active in sports such as basketball, soccer, and track and field. These injuries are usually caused by excessive inversion combined with plantarflexion, leading to damage in the lateral ligament complex, with the anterior talofibular ligament (ATFL) being the most frequently affected structure [1]. Because adolescents are still undergoing musculoskeletal development and often engage in high-intensity sports, they face heightened vulnerability to both initial and recurrent ankle sprains [2]. Without systematic and well-structured rehabilitation, these injuries may progress to chronic ankle instability (CAI), resulting in long-term impairments in proprioception, joint stability, and functional mobility. In addition, CAI has been associated with lower quality of life, reduced physical activity, and an elevated risk of post-traumatic osteoarthritis [3]. For adolescent athletes, persistent instability not only affects sports performance but also interrupts school participation and can negatively influence psychological well-being due to prolonged recovery and fear of reinjury.

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Over the last decade, rehabilitation strategies for ankle sprains have shifted towards evidence-based, multifactorial protocols. Western studies have highlighted phased rehabilitation models, typically progressing through range of motion (ROM) restoration, neuromuscular control, strength enhancement, and sport-specific retraining [4]. More recent trials have explored advanced methods such as blood flow restriction (BFR) therapy, app-based rehabilitation systems, and intelligent feedback platforms that enable individualized recovery [5,6].

By contrast, Chinese rehabilitation practice frequently integrates traditional modalities—including herbal compress therapy and acupuncture—alongside conventional physiotherapy [7]. These treatments are aimed at alleviating pain, promoting circulation, and supporting soft tissue repair. Nevertheless, large-scale comparative evidence specifically focused on adolescents is limited, and few studies provide long-term follow-up or adolescent-centered frameworks.

Although a wide range of treatment approaches is available, there is still no consensus on the most effective rehabilitation pathway for adolescents. Many current protocols are adapted directly from adult populations, thereby neglecting developmental, physiological, and psychosocial differences in youth. This paper seeks to address this gap by synthesizing recent findings on adolescent ankle sprain rehabilitation and examining their effectiveness in clinical contexts. The analysis will emphasize proprioceptive training, balance and coordination enhancement, the application of intelligent rehabilitation systems, and the role of traditional Chinese medicine. A structured, phased framework is proposed, combining modern rehabilitation science with integrated nursing care, with the overarching aim of reducing recurrence and promoting full functional recovery in adolescent patients.

2. Rehabilitation mechanism and intervention strategies for adolescent ankle sprains

The high frequency of ankle sprains in adolescents is largely explained by their distinct anatomical and biomechanical features. The ankle joint, as a pivotal hinge-type synovial joint connecting the leg and foot, depends on the lateral ligament complex for stability between the tibia, fibula, and talus. The anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), and posterior talofibular ligament (PTFL) together provide the primary resistance to varus forces. In adolescents, incomplete bone ossification and the presence of growth plates reduce load-bearing strength, while ligamentous laxity is greater compared with adults [8]. This physiological profile—characterized as “weaker bones but more flexible ligaments”—lowers the injury threshold. In sports involving rapid directional changes, such as basketball or soccer, sudden plantarflexion combined with inversion often exceeds biomechanical tolerance, making the ATFL particularly vulnerable.

Recurrent sprains may establish a vicious cycle: damaged proprioceptive receptors reduce neuromuscular precision, muscle imbalances weaken stability, and the risk of reinjury increases, eventually leading to chronic ankle instability [9]. This progressive decline is especially concerning in adolescents, as their neuromuscular systems are still maturing and compensatory capacity remains underdeveloped. Once this cycle begins, long-term instability is more likely.

Understanding the grading and epidemiological profile of ankle sprains is essential for formulating targeted interventions. Clinically, sprains are categorized into three grades depending on ligament damage. Grade I injuries involve mild stretching, yet if poorly managed, residual inflammation or incomplete muscle recovery may cause hidden problems. Grade II injuries (partial tears) and grade III injuries (complete ruptures) directly undermine anatomical stability, significantly increasing the likelihood of chronic instability if rehabilitation is insufficient. Epidemiological studies reveal that 30%–40% of adolescent athletes sustain at least one severe sprain before adulthood—considerably higher than in adults [8]. For example, Huang et al. reported that 62% of

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adolescents with grade II or III sprains developed signs of chronic instability within six months [8]. These findings stress that adolescent ankle sprain rehabilitation should extend beyond symptom control, ensuring both structural repair and functional restoration, thereby preventing the injury–instability–reinjury loop.

Management should address both the acute phase and long-term recovery. The RICE method remains a cornerstone in the initial 48–72 hours post-injury, mitigating bleeding, swelling, and inflammation through rest, icing, compression, and elevation [4]. Yet, excessive emphasis on rest may induce stiffness, muscle atrophy, and delayed recovery, so a timely shift toward active rehabilitation is crucial. Early gentle ROM exercises prevent adhesions, but over-enthusiastic adolescents may overload healing ligaments. Thus, progressive plans are needed: passive movements, followed by active mobility, and later resistance-based activities.

Proprioceptive and balance training directly address the underlying deficits of chronic instability. Balance boards and pads stimulate joint receptors, reinforcing neuromuscular feedback [5]. To maintain adolescent compliance, gamification elements may be added [1]. Long-term consistency is vital to consolidate gains and prevent regression. Balance and posture training, combining static and dynamic drills such as single-leg stance or star-excursion tasks, enhances ankle stability while also activating core muscles, given their neural interplay. Sport-specific adaptations—cutting maneuvers for soccer or jumping drills for basketball—ensure that improved balance translates to real play [2].

Strengthening of peroneal and tibialis anterior muscles forms the “hardware” for resisting inversion. Blood flow restriction (BFR) training, by applying controlled compression, enables adolescents to achieve hypertrophy and metabolic adaptation at lower loads, an advantage for their still-developing musculoskeletal systems [1,6,7]. However, parameters must be carefully regulated to avoid compromising growth. Functional drills—such as side-hops, sprint-stops, and cutting maneuvers—reconstruct motor memory and prepare for sport re-entry. Critically, clearance should be based on objective functional assessments rather than subjective readiness, ensuring safe return-to-play and reducing reinjury risk [8].

Modern innovations are reshaping adolescent rehabilitation. Mobile applications can deliver interactive tasks with real-time feedback, transforming tedious routines into engaging “missions” while enabling remote monitoring by clinicians and parents [1,2]. Intelligent motion analysis detects biomechanical errors, such as abnormal inversion, and corrects them immediately, reducing compensatory injuries [5]. Meanwhile, complementary therapies from Traditional Chinese Medicine (TCM), including acupuncture and herbal compresses, have demonstrated benefits in pain relief and circulation improvement [7]. When combined with Western rehabilitation, this dual approach often accelerates pain resolution and function restoration, fostering greater adherence among adolescents reluctant to endure long-term discomfort [2]. Care, however, must be taken to avoid inappropriate herbal use during adolescent growth stages.

Case studies highlight the effectiveness of comprehensive programs. For instance, a 15-year-old basketball player undergoing six weeks of combined ROM, proprioceptive, and functional training showed ankle function scores rising from 58 to 91 [3]. This outcome reflected the synergy of restoring mobility, rebuilding neuromuscular control, and integrating these into sport-specific movements. Comparative evidence suggests that single-method rehabilitation leaves deficits: isolated strength training may neglect flexibility, while balance-only approaches may ignore endurance. Comprehensive protocols, tailored by sport demands—for example, emphasizing rotation for dancers or impact absorption for runners—yield superior outcomes [4,8].

Nonetheless, current literature presents limitations. Small sample sizes, inconsistent protocols, and short follow-up durations restrict generalizability [8]. Gender differences remain underexplored

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despite evidence that female adolescents, with greater ligamentous laxity, may require longer proprioceptive training [3]. Future directions lie in AI-driven platforms that auto-generate personalized programs considering age, injury grade, and sport type, adapting dynamically as recovery progresses [4,5]. Wearable sensors can provide real-time biomechanical feedback during daily activity, enhancing awareness of gait or posture [1]. Ultimately, large randomized trials are needed to establish stronger evidence bases and optimize strategies for adolescent rehabilitation.

3. Conclusion

This paper consolidates emerging evidence on adolescent ankle sprain rehabilitation, emphasizing phased, multifaceted and evidence-based approaches. Proprioceptive and balance training, combined with resistance work and sport-specific drills, consistently improve outcomes when embedded in comprehensive frameworks. Novel technologies—such as mobile platforms and intelligent feedback tools—boost engagement and customization, while TCM modalities may serve as valuable adjuncts.

The integration of these diverse approaches supports not only short-term recovery but also long-term protection against chronic instability. Crucially, adolescent-specific protocols are required, as adult-derived models may fail to account for developmental and psychosocial distinctions. Future research should prioritize large-scale trials, longer follow-up, and the integration of AI- and sensor-based platforms to advance individualized care. In summary, this paper contributes to the field of adolescent musculoskeletal rehabilitation by outlining a holistic, evidence-informed framework to minimize recurrence and enable safe return to sport.

References

[1] Liu, S., Tang, J., Hu, G., Xiong, Y., Ji, W., & Xu, D. (2023). Blood flow restriction training improves the efficacy of routine intervention in patients with chronic ankle instability. Sports Medicine and Health Science, 6(2), 159–166.
[2] Qu, X., Li, K., & Nam, S. (2022). Effects of mobile-based rehabilitation in adolescent football players with recurrent lateral ankle sprains during the COVID-19 pandemic. Healthcare (Basel), 10(3), 412.
[3] Wen, Z. (2023). Effect of low-load blood flow restriction (LL-BFR) training on ankle muscle strength, thickness, and balance in functional ankle instability (FAI). Journal of Sport Rehabilitation, 32(8), 863–870.
[4] Correia, F. D., Paterson, J. T., Issa, A., MacLellan, M. J., & Corriveau, H. (2021). Fully remote digital rehabilitation for acute ankle sprains: A prospective cohort study. JMIR Rehabilitation and Assistive Technologies, 8(3), e31247.
[5] Galli, J., Baranyi, R., Hoelbling, D., Pinter, K., Aigner, C., Hörner, W., & Grechenig, T. (2023). Prevention and rehabilitation gaming support for ankle injuries using a MetaMotion IMU sensor. Applied Sciences, 13(16), 9193.
[6] Burkhardt, M., Burkholder, E., & Goetschius, J. (2021). Effects of blood flow restriction on muscle activation during dynamic balance exercises in individuals with chronic ankle instability. Journal of Sport Rehabilitation, 30(6), 870–875.
[7] Zhou, L., Tan, Y., Gan, J., Li, C., Bao, D., & Zhou, J. (2024). Complex training with blood flow restriction increases power output and bar velocity during half-squat jumps: A pilot randomized controlled study. Frontiers in Physiology, 15, 1368917.
[8] Thompson, C., Schabrun, S., Romero, R., Bialocerkowski, A., van Dieen, J., & Marshall, P. (2018). Factors contributing to chronic ankle instability: A systematic review and meta-analysis of systematic reviews. Sports Medicine, 48(1), 189–205.
[9] Killinger, B., Lauver, J. D., Donovan, L., & Goetschius, J. (2020). The effects of blood flow restriction on muscle activation and hypoxia in individuals with chronic ankle instability. Journal of Sport Rehabilitation, 29, 633–639.