

Evidence based prevention and treatment of ankle injuries in adolescent basketball players: from acute management to returning to exercise

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ABSTRACT. Ankle sprain is the most common sports injury among adolescent basketball players, and its high incidence, high recurrence rate, and potential chronic complications pose a serious threat to the athletes' sports career and long-term health. This paper comprehensively analyzes the epidemiological characteristics, injury mechanisms, and various risk factors of ankle joint injuries in adolescent basketball players, clarifies the classification and grading standards of injuries and clinical diagnostic pathways, elaborates on the standardized treatment plan for the acute phase and the phased progressive rehabilitation training system, and ultimately constructs a full cycle health management system of "prevention diagnosis rehabilitation return to exercise". This research aims to provide a scientifically rigorous, systematic, comprehensive, and practical ankle health management plan for adolescent basketball players, coaches, and sports medicine practitioners, which can help reduce the risk of injury occurrence and recurrence, and ensure the longevity of athletes during exercise.

KEYWORDS: adolescent basketball players, ankle injuries, injury prevention, ankle protection, evidence-based medicine

1. Introduction

1.1 Research background

Ankle sprain is one of the most common types of injuries in sports, especially in activities such as basketball that require frequent running, jumping, emergency stopping, and turning[1]. This injury is even more common. The technical characteristics of basketball require the ankle joint to frequently withstand composite mechanical loads such as vertical impact and lateral torsion, making it the most vulnerable joint part in the sport. Related research data shows that up to 92% of basketball players have suffered ankle injuries, of which 83% are repeated sprains. The incidence of ankle injuries per 1000 hours of exercise among 15-18-year-old youth basketball players is 3.02%, significantly higher than that of adult athletes[2]. The skeletal muscle system of adolescents is still in a critical stage of development, and the elastic modulus of the lateral ankle ligaments in adolescents is about 20% -25% lower than that of adults, which means that their ligaments are more prone to damage when subjected to the same torsional force[3]. This physiological vulnerability, combined with the high-intensity load of basketball, constitutes the inherent basis for the high risk of injury among adolescent basketball players. Therefore, special attention must be paid to the ankle joint health of the adolescent basketball player population.

1.2 Research significance

As a reserve force for basketball, the ankle health of young basketball players is directly related to the sustainable development of their sports career. The data released by the International Federation of Sports Medicine (FIMS) confirms that untreated acute ankle sprains in adolescents increase the risk of re injury by 60%[4]. If acute sprains are not properly treated and fully recovered, adolescents may develop chronic ankle instability, which not only directly affects athletic performance but also increases the risk of compensatory injuries to other parts of the knee joint. In the long run, it may also lead to chronic complications such as traumatic arthritis and bone cartilage defects. However, the current prevention and treatment of ankle injuries in adolescents rely heavily on empirical plans and lack standardized processes supported by evidence-based medicine. This study relies on the evidence-based support of top international sports medicine journals and authoritative guidelines to construct a full chain intervention system from acute injury management, rehabilitation training to returning to exercise. It not only provides scientific basis for clinical diagnosis

and treatment, but also provides practical guidance for grassroots coaches to formulate prevention strategies and optimize training modes. It has important practical significance for reducing the risk of ankle joint injuries in adolescent basketball players, ensuring their healthy growth, and promoting the high-quality development of adolescent basketball.

2. Epidemiology and injury mechanism of ankle joint injuries in adolescent basketball players

2.1 Epidemiological characteristics

The epidemiological characteristics of ankle joint injuries in adolescent basketball players are high incidence, recurrence, and specific group tendency. A survey shows that about 2 million people in the United States suffer from ankle sprains every year, with basketball related injuries accounting for 15%, much higher than other sports such as volleyball and running and jumping. Among them, lateral ligament injuries account for 87%, while medial ligament injuries and high ankle sprains account for about 10% and 3%, respectively[5]. From the perspective of age distribution, the group of junior high school students aged 13-16 has the highest risk of injury, due to uneven skeletal and muscle development, immature neural control stability, and significantly increased training intensity and competition competitiveness during this stage. In terms of injury scenarios, over 60% of ankle injuries are caused by landing stomps after grabbing rebounds, blocking or emergency stop jump shots, while injuries during training are mostly due to non-standard technical movements or fatigue training. In addition, about 40% of acute ankle sprains will develop into chronic ankle instability (i.e. habitual ankle sprains); The proportion of adolescents who have experienced repeated sprains developing chronic ankle instability is as high as 44.7%, significantly higher than the 31.2% in adults[6]. These characteristics indicate that targeted prevention and rehabilitation strategies are needed for ankle injuries in adolescent basketball players to reduce the incidence of injuries and the risk of recurrence.

2.2 Analysis of the mechanism of ankle injury

The stability of the ankle joint is mainly maintained by the coordinated action of bones, ligament complexes, and surrounding muscles. Firstly, from an anatomical analysis, research has confirmed that the elastic modulus of the lateral ligaments in adolescents is 20% -25% lower than that in adults, and under the same strength of inward force, they are more prone to injury[3]. Secondly, from the perspective of sports biomechanics, the ground reaction force during jumping landing can reach 3-5 times body weight. If the lower limb force line is abnormal (such as knee valgus accompanied by foot pronation), it will significantly increase the shear stress on the talar joint surface. For example, when grabbing a rebound and landing, if the body's center of gravity shifts or steps on someone else's foot, the ankle joint will suddenly be in an inverted plantar flexion position, and the lateral ligament will be excessively stretched or even torn; When changing direction quickly, the ankle joint needs to complete the load transfer in a short period of time, and insufficient muscle strength can easily cause joint instability. Thirdly, from the perspective of group specificity, during adolescence, the bones are not fully ossified, and the joint capsule and ligaments have strong elasticity but insufficient toughness. At the same time, muscle strength is unbalanced (the fibular muscle is weaker than the tibial muscle), and proprioceptive development is not yet mature, making it difficult to accurately control joint posture, ultimately leading to a higher risk of ankle joint injury compared to adults.

3. Acute phase management and clinical treatment

3.1 Principles of acute phase management

The management of ankle joint injuries in adolescent basketball players during the acute phase (0-72 hours) should focus on controlling swelling, relieving pain, protecting damaged tissues, and preventing chronic complications, following the POLICE principles guided by evidence-based medicine. The POLICE principle is a widely recommended standard for the treatment of acute soft tissue injuries in the field of international sports medicine. This principle emphasizes moderate load training while protecting the injured area. Compared with the traditional PRICE principle, it is more conducive to the repair and functional recovery of damaged tissues. Applying the POLICE principle can increase the speed of ligament repair by 30%[7][8].

Protection--Immediately stop exercising after injury to avoid weight-bearing or moving the affected limb. The ankle joint can be fixed with bandages, ankle guards, or temporary splints to prevent secondary injuries.

Optimal Loading--Start partial weight-bearing training as early as possible within the tolerable range of pain, gradually increase the load with the help of crutches or walking aids, and promote local blood circulation and tissue repair

Ice--Immediately wrap an ice pack with a towel for local cooling after injury, 15-20 minutes each time, 3-4 times a day, lasting 24-48 hours.

Compression--Using elastic bandages starting from the sole of the foot, spiral wrap around the ankle joint from bottom to top, gradually reducing the wrapping pressure to allow for easy insertion of a finger[9].

Elevation--Keep the ankle joint above the level of the heart, elevate the lower limbs when sitting or lying down, use gravity to promote blood return, and reduce swelling.

3.2 Medical evaluation and grading

Medical evaluation should combine injury history, physical examination, and imaging results to accurately determine the degree of injury and guide treatment. Firstly, clarify the injury mechanism (such as jumping, landing, stepping on the foot, sudden stop and turning sprains), nature of pain, and past injury history through medical history collection; The physical examination focuses on evaluating the extent of swelling and the location of tender points. The stability of ligaments is determined through the anterior drawer test and talus tilt test. At the same time, it is necessary to investigate whether there is epiphyseal injury (a risk unique to adolescents). The preferred imaging examination is X-ray to exclude avulsion fractures, while MRI can clearly display the degree of ligament tear, cartilage damage, and joint effusion.

According to the degree of injury, ankle sprains are classified into three levels, as shown in Table 1.

Table 1 Ankle sprain grading

Level I	Mild ligament strain	Localized tenderness but no joint instability, mild swelling, joint mobility decrease $\leq 25\%$
Level II	Partial torn ligament	Moderate swelling and bruising, joint mobility restricted by over 50%, positive anterior drawer test but talus tilt $\leq 15^\circ$
Level III	Complete rupture of ligament	Severe swelling and bruising, obvious joint instability, anterior drawer test with talus anterior displacement $>1\text{ cm}$ or talus tilt $>15^\circ$

4. Evidence based rehabilitation training system

4.1 Rehabilitation goals and staged training methods

The rehabilitation of ankle injuries in adolescent basketball players focuses on restoring joint function, rebuilding sports stability, and safely returning to the court. Teenagers need to pay special attention to the physiological characteristics of unclosed epiphyses and avoid premature high-intensity weight-bearing. The entire rehabilitation process requires regular evaluation and adjustment, combined with physical therapy and exercise training, and simultaneous psychological counseling to reduce exercise fear and ensure safe return to exercise. The staged rehabilitation plan and objectives are shown in Table 2.

Table 2 Staged rehabilitation training objective plan

stage	objective	rehabilitation plan
Early rehabilitation (0-3 days)	Control swelling and pain, protect injured tissues	Reduce swelling (by applying ice and using compression bandaging), maintain ankle pump training under non-weight-bearing conditions, and perform isometric contractions of the calf muscle group. Avoid walking with weight bearing, and use braces for fixation if necessary.
Intermediate rehabilitation (3 days - 2 weeks)	Restore joint mobility and basic muscle strength	Improve flexibility through passive or active ankle dorsiflexion-plantarflexion training, and strengthen the fibular muscle group by incorporating elastic band resistance training; introduce single-leg balance training (such as standing with eyes closed) to enhance proprioception[10].
Post-rehabilitation (2-6 weeks)	Rebuild proprioception and dynamic stability	Incorporate dynamic stability exercises such as lateral strides, step training, and single-leg jumps; combine with basketball-specific movements (such as directional changes and low-intensity shooting) to simulate actual combat loads. Emphasize the strengthening of eccentric control ability of ankle-surrounding muscle groups (such as tiptoe landing training) to reduce the risk of re-injury.
Return to the stage	Integrate specialized	Conduct training on sudden stops, directional changes, and jump

(6-12 weeks)	sports skills	landing in simulated basketball scenarios, gradually increasing the intensity of competition. After passing the functional test, officially return to the game.
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4.2 Evaluation of rehabilitation effectiveness

The evaluation of the rehabilitation effect of ankle joint injuries in adolescents needs to be comprehensively judged from three dimensions: clinical signs, functional indicators, and specialized abilities, providing scientific basis for returning to the field. Firstly, clinical evaluation evaluates the tissue repair status by observing the disappearance of swelling and tenderness, combined with joint range of motion measurement (which should reach over 95% of the healthy side). Secondly, the functional evaluation adopts isokinetic muscle strength testing (the muscle strength on the affected side needs to reach 90% of the healthy side) and balance instrument proprioceptive testing (static balance error $\leq 5\%$) to quantify the level of neuromuscular recovery[11]. Thirdly, the specialized sports evaluation simulates the core movements of basketball, and evaluates whether the movement pattern is corrected through tests such as cone bucket changing speed and jumping and landing stability; Simultaneously using the AOFAS Ankle Function Scale (score ≥ 90) and the Exercise Fear Scale (score <15), taking into account both subjective functional perception and psychological state. Finally, a joint evaluation by sports medicine physicians and rehabilitation therapists is required to confirm that there is no pain, complete functional recovery, and standardized movement patterns before gradually resuming formal training and competition to reduce the risk of recurrence.

5. Risk management and injury prevention strategies for returning to sports

5.1 Risk management for returning to sports

After ankle joint injuries, adolescent basketball athletes need to meet functional assessment criteria before returning to sports. They also need to gradually return to prevent secondary injuries. On the one hand, athletes need to pass objective tests (such as joint range of motion, muscle strength testing, Y-balance testing) and subjective tests (such as pain scores, psychological state) to fully meet the standards before starting transitional training [11]. On the other hand, a layered and progressive return path is adopted. The first stage involves non-contact specialized exercises (fixed-point shooting, straight-line dribbling), lasting 1-2 weeks; the second stage adds low-intensity contact (3V3 half-court), with landing posture monitored by a motion capture system to ensure no pronation compensation; the third stage gradually resumes full-court training, with weekly retesting of muscle strength and proprioception. At the same time, in order to track and prevent secondary injuries after return, a real-time warning mechanism needs to be established. After training, infrared thermography is used to monitor the temperature difference of the ankle joint, and coaches and rehabilitation therapists jointly record movement deviations to dynamically adjust the plan. Finally, through season follow-up and optimization strategies, safe return to the court is achieved.

5.2 Evidence-based injury prevention strategies

For ankle joint injuries in adolescent basketball players, evidence-based prevention requires the establishment of a closed-loop system of "screening-intervention-monitoring". Firstly, pre-risk screening should be conducted. Through single-leg standing balance test (high risk if maintaining balance with eyes closed for less than 20 seconds) and fibular muscle strength assessment (intervention required if the ratio to tibialis anterior muscle strength is less than 0.8), high-risk factors such as previous injury history and flatfoot can be identified, and personalized plans can be formulated. Secondly, focus on implementing effective interventions. Daily 15-minute proprioceptive training (catching and throwing balls on a balance board, single-leg jumping through a grid) has been proven by evidence-based research to reduce the risk of recurrence by 40%[12]; strengthening fibular muscle resistance exercises (eversion with elastic bands) can correct muscle strength imbalance; using functional taping during competition can reduce the probability of inversion injuries by 32%[13]. Thirdly, optimize sports habits. Choose high-top basketball shoes (which reduce the injury rate by 25% compared to low-top shoes) and regularly check the flatness of the playing field. At the same time, through video feedback guidance, ensure that the knee joint is slightly bent and the foot is in a neutral position when landing to reduce inversion stress. Adjust the training load based on the developmental characteristics of adolescent epiphyseal growth to achieve precise prevention[14].

6. Conclusion

Ankle injuries in adolescent basketball players are characterized by a high incidence rate, a high recurrence rate, and numerous potential chronic complications. The mechanisms of these injuries are closely related to the physiological characteristics of adolescents, the technical features of basketball, and both internal and external risk factors. The "prevention-diagnosis and treatment-rehabilitation-return to sports" full-cycle health management system, constructed based on international evidence-based medicine, is the core means to reduce injury risks and ensure athletes' sustainable athletic ability. Acute phase management should strictly follow the POLICE principles to avoid traditional treatment pitfalls; phased rehabilitation training should focus on the comprehensive recovery of joint mobility, muscle strength, balance ability, and proprioception, strictly adhering to the return to sports standards; return to sports requires meeting functional standards and strengthening risk management; in daily sports activities, juvenile athletes need to undergo injury prevention training to ultimately reduce sports injuries and extend their athletic career. In the future, it is necessary to further promote the standardized implementation of the prevention and control system, incorporate ankle protection into the core content of juvenile basketball training, and promote the healthy development of adolescents.

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