Proceedings of the 5th International Conference on Modern Medicine and Global Health
DOI: 10.54254/2753-8818/2027.38777

Biomechanical Injury Mechanisms and Preventive Measures of Ankle Injuries in Ball Games

Zijun Di

Department of Physical Education, Jinan, China
lwdzj04326@163.com

Abstract. Ankle joint injury is one of the most common lower limb injuries in ball sports, not only directly affecting the competitive performance of athletes, but also having a high recurrence rate and prone to developing into chronic strain, threatening the sports lifespan of athletes. This article takes football as a typical representative, combined with basketball, volleyball, badminton and other ball sports, and systematically reviews the main types of ankle joint injuries from a biomechanical perspective, explains three injury mechanisms: acute specific action abnormal load, chronic repetitive load accumulation and vicious cycle of mechanical imbalance after injury, and summarizes the corresponding prevention and rehabilitation intervention measures. The study found that although the high-incidence scenarios of ankle injuries in different ball sports vary, the core biomechanical mechanisms have commonalities. Targeted muscle strength training, proprioceptive training and functional rehabilitation are key to prevention. This research can provide a reference for the prevention of ankle joint injuries in different ball sports and provide a theoretical basis for optimizing training and rehabilitation plans.

Keywords: Ankle joint injury, ball games, preventive measure

1. Introduction

Among various competitive ball sports, the ankle joint is one of the most prone lower limb joints to injury. It serves as the connection point between the lower leg and the foot, and is responsible for bearing the body's weight and impact during running, jumping, changing direction, and pushing off. Take professional football as an example, severe ankle injuries typically cause athletes to miss games for about two months on average, and serious injuries such as ruptured Achilles tendons require a recovery period of up to six months [1]. What is even more notable is the high recurrence rate of ankle injuries: a systematic review shows that approximately 25% of patients with acute ankle sprains will eventually develop chronic ankle instability, and those with a history of sprains have a proportion of chronic instability nearly twice that of the general population, reaching 46% [2]. This often manifests as repeated pain, limited movement, and gradually leads to joint degeneration, forming a vicious cycle. Therefore, understanding the mechanism of ankle injuries, and taking effective preventive and rehabilitation measures, have always been the focus of attention in the field of sports medicine.

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2753-8818/2027.38777

It has been clearly established that the most common type of acute ankle injury is an external ligament sprain, which is commonly referred to as "turning the ankle". This usually occurs when the foot suddenly turns inward and the pulling force exceeds the limit of the ligament's capacity [3]. The injury scenarios in different sports vary greatly: in football, it often happens during sudden stops and changes of direction or during confrontations. The analysis and summary of injury videos in professional leagues have identified high-risk scenarios such as being tackled, jumping and landing, and sliding tackles [4]. In basketball, ankle injuries are related to the height of jumping and landing. When grabbing rebounds or landing after shooting, stepping on the foot or having an unstable center of gravity, severe sprains are easily caused [5]. In volleyball, the injury scenarios are more concentrated, with the vast majority occurring at the net area. Landing after blocking is the main reason for the injury [6]. In badminton, a sport that requires frequent stepping and changes of direction, the ankle joint of the supporting foot will repeatedly bear shear forces, and over time, cumulative injuries occur [7]. Regarding chronic injuries, "football ankle" refers to the gradual accumulation of wear and tear caused by repeated toe-offs and shooting, with the bones and soft tissues in the front of the ankle repeatedly colliding, resulting in degeneration, manifested as synovial hyperplasia and bone hyperplasia [8]. In terms of prevention and rehabilitation, existing studies have mentioned selecting appropriate shoes, improving the hardness of the playing surface, strengthening the strength of the muscles around the ankle, and training balance [9]. However, overall, many studies are focused on individual sports, and there are not many systematic analyses of acute injuries and chronic wear and tear in the same mechanical framework. Many preventive measures are also rather general and lack precise solutions tailored to specific movements in different sports.

Based on the shortcomings of the existing research, this article takes football as a typical representative and combines the characteristics of common ball sports such as basketball, volleyball, and badminton to systematically sort out the main types of ankle joint injuries in ball sports. From the three aspects of abnormal force during acute movements, accumulation of chronic wear and tear, and repeated aggravation after injury, the underlying biomechanical mechanisms are analyzed, and corresponding prevention and rehabilitation intervention measures are compiled. It is hoped that through this cross-sport analysis, the commonalities and differences in ankle injuries in ball sports can be presented more clearly, providing more comprehensive references for the prevention and control of injuries in different sports.

2. The main types and mechanisms of ankle joint injuries in ball sports

2.1. Main types of injuries

In ankle injuries during ball sports, they can generally be classified into two major categories: acute injuries and chronic strain. Acute injuries are the most common, mostly caused by instantaneous external force or abnormal movement. The vast majority are lateral ankle sprains, where the ankle suddenly turns inward, straining the lateral ligament. In mild cases, the ligament stretches and swells; in severe cases, it may partially tear or even completely rupture [3]. Less frequently seen is the injury of the distal tibiofibular syndesmosis, which is a tear of the connection between the tibia and fibula above the ankle. This injury is more likely to occur when the foot is externally rotated combined with excessive dorsiflexion. The recovery time for this injury is slower than that of a common ankle sprain [10]. Severe acute injuries may also be accompanied by fractures and joint dislocations, but their occurrence rate is relatively low in ball sports. Chronic strain is more due to long-term accumulation and is also known as "overuse injury". The most typical one is the ankle

DOI: 10.54254/2753-8818/2027.38777

impingement syndrome, which is divided into anterior and posterior types. The anterior type is more common, where repeated flexion and extension, as well as pushing-off movements, cause repeated collisions between the tibia and talus, leading to inflammation of the synovium and bone hyperplasia over time. During movement, there will be a sensation of sticking or pain [8]. Domestic anatomical and biomechanical analysis and the investigation of injuries among female college football players also indicate that ankle sprains are one of the most common injury types in ball sports and should be given due attention for the prevention of ankle and knee joint injuries [11, 12].

2.2. The biomechanical mechanism of the ankle joint under normal conditions

The ankle joint is the main weight-bearing joint of the lower limb, composed of the tibia and fibula of the lower leg and the talus of the foot. It is fixed by ligaments, tendons and joint capsules and can perform actions such as eversion, inversion, flexion and extension, as well as small rotations. It is a key structure that transmits the force of the lower leg to the foot. During normal movement, the range of motion of the ankle joint has a threshold. For example, during running, the main movements are the alternating actions of bending and straightening the foot, and the range of inversion and eversion is very small, not exceeding the physiological limit. At the moment of foot impact, the joint will buffer the impact force through three layers: elastic stretching of ligaments, shock absorption of joint cartilage, and active contraction and force generation of surrounding muscles to alleviate the reactive force of the ground, so that no one point bears too much force. During low-speed running and light-intensity passing, the muscles and ligaments on the inner and outer sides of the foot will work together to maintain joint stability, and no abnormal pulling or compression will occur. Long-term trained athletes have stronger muscle strength around the ankle, more resilient ligaments, better perception of joint position (i. e., proprioception), and can withstand greater instantaneous loads. Generally, the ankle bears a weight of one to two times the body weight during exercise. Through subtle adjustments of the feet, the lateral shear force can be relieved. It is this stable mechanical balance that ensures athletes can complete various high-intensity movements. Once this balance is disrupted, whether it is a sudden external force or long-term movement deformation, abnormal stress will be generated, and if it persists for a long time or with great force, it will cause damage.

3. Abnormal mechanical load and acute injury mechanism of typical ball-related specific movements

The core reason for acute ankle injuries is that the instantaneous force exceeds the limit that the joint can withstand. Due to the different technical movements in various ball sports, the high-risk injury actions are also different, but essentially they are all combined stresses concentrating on the weak parts of the joint. In football, sudden direction changes during rapid movement is one of the most common actions that cause ankle sprains. When an athlete moves at high speed and suddenly changes direction, the body's center of gravity becomes unbalanced, but the foot does not adjust its posture in time, forcing the ankle to be in a state of flexion, external rotation, and external rotation. At this time, the inertia of the body and the reaction force of the ground combine and act on the lateral ligament of the ankle. If the speed is very fast, the tensile force exceeds the elastic limit of the ligament, causing a ligament tear. Systematic analysis of injury videos in professional leagues shows that sudden direction changes, being tackled, and jumping landing are the main injury scenarios for ankle sprains in football [4]; Video analysis of 345 cases of injury in professional men's football matches also presents a similar typical pattern of ankle injury [13]. Additionally, unstable center of

DOI: 10.54254/2753-8818/2027.38777

gravity during jumping to contest for the ball and being stepped on by the opponent during the contest can directly disrupt the stability of the joint and cause acute injury.

Acute ankle injuries in basketball are highly related to the jumping action. In basketball games, rebounding, shooting, and driving through the basket all require frequent jumping, and if the landing causes stepping on the foot of the defending player or the center of gravity is off-balance, the ankle will suddenly turn inward and cause a sudden large pulling stress. Systematic reviews and meta-analyses show that the incidence of ankle sprains in basketball games is approximately 2.51 times per 1,000 athlete exposures, which is 2.8 times that of the training period [5]. This is because after the first injury, the ligaments become lax, and the joint stability decreases. When encountering the same scenario again, ankle injuries are more likely to occur.

The injury scenarios in volleyball are more concentrated, and the vast majority occur at the net position. During the block, when the athlete jumps and then drops down, it is easy to step on the foot of the opponent who has crossed the center line, causing a sudden inward twist and sprain of the ankle. Recent epidemiological reviews show that ankle injuries account for approximately 25.9% of all injuries in professional elite volleyball players, and nearly half (47.4%) are caused by physical contact between players [6]. Due to this characteristic, volleyball projects have relatively obvious effects in reducing the incidence of ankle injuries through rules to limit crossing the center line and wearing protective gear.

For ball games like badminton, which involve net confrontation, although there is no direct physical confrontation, the ankle joint of the supporting foot also bears a large shear force due to frequent lunge steps and left-right changes. Especially during the large stride when receiving a kill shot, the center of gravity of the front foot tilts forward, and the ankle not only bears vertical load but also external torsion force. The latest biomechanical research shows that in fatigue state, when badminton players strike the ball and land, the plantar flexion angle and inversion angle of the ankle significantly increase, the peak value of inversion moment rises, and the risk of lateral ligament sprain increases [7].

In summary, regardless of which ball sport it is, the essence of acute ankle injuries is the same: the movement exceeds the normal range of the joint, and the instantaneous stress exceeds the limit of the ligaments and soft tissues. The difference lies in that in competitive sports, it is more due to external force and competition, while in net ball games, it is more due to footwork and center of gravity control.

4. The biomechanical mechanism of chronic ankle injuries in ball sports under long-term repetitive loading

Unlike acute injuries, chronic injuries accumulate gradually. By repeatedly performing the same action for a long time, the joint is repeatedly subjected to minor impacts, and over time, small micro-injuries accumulate. Eventually, inflammation, hyperplasia and other problems occur, which is what we commonly refer to as "overuse injury". The most typical example is "football ankle", also known as anterior ankle impact syndrome. Football players often perform shooting and pushing-off movements, and their ankles remain in a stretched and exerting force state for a long time. The talus neck and the anterior edge of the tibia repeatedly collide. Each impact may be very slight and will not cause acute injuries, but with dozens or hundreds of training sessions per day over a long period of time, it will stimulate inflammation and congestion in the synovium of the joint, and small bony growths will form on the bones, which is also known as bone spurs. Gradually, the space for joint movement becomes smaller, and when bending the foot or pushing off, pain occurs, and the range of motion decreases [8].

DOI: 10.54254/2753-8818/2027.38777

A case series of elite football players shows that posterior ankle impact is significantly concentrated among players who frequently shoot and exert force with their feet [14]. In fact, not only football, but also tennis, badminton, and other sports that require frequent pushing-off and stretching of the feet also present similar chronic anterior ankle impacts, although the incidence is not as high as in football.

In addition to repeated impacts, long-term unbalanced loading can also lead to chronic injuries. Many athletes have a preferred foot, using one side for shooting and pushing-off. Over time, the forces on the two ankles are different, and the muscles and ligaments on the preferred side are constantly subjected to a greater load, resulting in compensatory tension on one side. The imbalance of force on both sides causes the trajectory of joint movement to shift, and even normal training movements can generate abnormal shear forces, gradually exacerbating the accumulation of micro-injuries.

Environmental factors can also amplify the risk of chronic injuries. For example, artificial turf is harder than natural turf and has a poor buffering effect. Each time an athlete pushes off or lands, the ground's reactive force acts more directly on the ankle. Long-term training on hard surfaces accelerates the wear of joint cartilage and the elasticity of ligaments, increasing the probability of chronic injuries [9]. If the hardness of indoor basketball and volleyball synthetic courts is too high, the same problem will occur.

5. The mechanical imbalance vicious cycle mechanism of ankle joint injury

Ankle joint injury has a prominent feature, which is a high recurrence rate. Many athletes will frequently sprain their ankles after suffering one injury. This actually represents a "injury - imbalance - re-injury" vicious cycle, and it is the core reason why many acute injuries develop into chronic ones.

After an acute sprain occurs, the ligaments will be stretched and their elasticity will decrease. The soft tissues in the joint will become edematous, and the proprioception of the joint will also deteriorate - that is, the ankle's ability to sense its own position will decline. At this time, if training is resumed before full recovery, the athlete's ability to control the ankle posture will weaken, and their running and turning movements will become distorted. They will unconsciously compensate with other parts. As a result, the force distribution trajectory of the joint becomes incorrect, and the originally evenly distributed force will concentrate on a few points, making it more likely to experience pulling or impact again.

Repeated abnormal force application will continuously stimulate the already damaged soft tissues, causing more and more minor injuries, and bone spurs will grow larger. The joint space will become narrower. This leads to more restricted joint movement and abnormal force distribution, forming a closed loop. Over time, a minor acute sprain will develop into chronic joint instability, causing repeated pain, frequent ankle sprains, and in severe cases, it will affect the athlete's strength and movement quality, and even shorten their sports career [2].

This vicious cycle also explains why rehabilitation cannot only aim to eliminate pain; it must wait until muscle strength and proprioception are restored, and the mechanical balance of the joint is re-established, so as to truly reduce the risk of recurrence.

6. Prevention and rehabilitation intervention measures for ankle joint injuries

Regarding the injury mechanism mentioned above, the intervention can be divided into two levels: prevention and rehabilitation. The core is to restore or maintain the mechanical balance of the ankle

DOI: 10.54254/2753-8818/2027.38777

joint.

At the prevention level, the first step is targeted strength and function training. Strengthening the strength of the muscles around the ankle, especially the lateral muscles, can better stabilize the joint and counteract abnormal shear forces. Additionally, balance training and proprioceptive training are also important, such as single-leg standing and balance pad training, which can enhance the ankle's ability to perceive position and make adjustments more quickly when the center of gravity is unstable. The latest systematic review and meta-analysis included 14 randomized controlled trials involving 2,182 patients with acute ankle sprains. The results showed that a rehabilitation program centered on single-leg balance, proprioceptive training, and progressive strength training significantly reduced the risk of re-injury within 12 months (OR = 0.60, 95% CI 0.36 - 0.99) [15]. The second step is to do a good job in warm-up and specific preparatory activities. Before competitions or training, fully mobilize the ankle and activate the muscles to reduce the risk of muscle strain during exercise. Also, the choice of equipment and the venue is important. For example, choosing shoes with appropriate spikes based on the venue and wearing ankle braces can reduce the impact of ground reaction forces.

At the rehabilitation level, in the early stage of acute injury, it is necessary to reduce swelling and relieve pain, but it is not recommended to completely rest. The current concept leans more towards functional rehabilitation, that is, within the range of pain tolerance, moving the joint as early as possible, and gradually restoring strength and range of motion. Systematic reviews show that compared with conventional care, exercise-based rehabilitation training reduces the risk of re-injury 7-12 months after acute ankle sprain by approximately 47% (OR = 0.53, 95% CI 0.30 - 0.94), and this study indicates that acute ankle sprain should be started with activity and functional training as early as possible within the pain tolerance range, rather than long-term immobilization [15]. For patients with chronic impact syndrome, mild cases can be relieved by adjusting training movements, strengthening strength, and physical therapy; if the condition is more severe, with large bone spurs and obvious compression, surgery may be necessary.

In both prevention and rehabilitation, it is necessary to combine the characteristics of the project. For example, football players should focus on ankle control during changes of direction, volleyball players should strengthen landing buffer training, and badminton players should emphasize the stability of the bow step support. This is more targeted and will have better effects.

7. Conclusion

This article takes football as a typical example and combines basketball, volleyball, badminton and other sports to systematically analyze the main types and biomechanical mechanisms of ankle joint injuries in ball sports. The research shows that the essence of acute injuries is that instantaneous combined stress exceeds the joint's tolerance limit, while chronic injuries result from the accumulation of micro-injuries under long-term repetitive loads. The vicious cycle of mechanical imbalance after injury is the core reason for recurrent and persistent injuries; the injury scenarios caused by different sports vary, but the mechanical logic is similar, and prevention experiences can be mutually learned. The limitations of this study lie in that the evidence relied on mostly comes from observational epidemiology and biomechanical experiments, and direct cross-project comparative studies are still rare. Specialized biomechanical data for prevention measures are still insufficient. Future research should further combine the technical characteristics of each sport to conduct cross-project comparative studies and intervention trials, and provide more powerful evidence for the precise prevention of ankle injuries.

DOI: 10.54254/2753-8818/2027.38777

References

[1] Oztekin, H. H., Boya, H., Ozcan, O., Zeren, B., & Pinar, P. (2009). Foot and ankle injuries and time lost from play in professional soccer players. *The Foot, 19*(1), 22–28. https://doi.org/10.1016/j.foot.2008.07.003

[2] Hong, C. C., Tan, K. J., & Calder, J. (2023). Chronic lateral ankle ligament instability: Current evidence and recent management advances. *Journal of Clinical Orthopaedics and Trauma, 48*, Article 102328. https://doi.org/10.1016/j.jcot.2023.102328

[3] Hertel, J. (2002). Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *Journal of Athletic Training, 37*(4), 364–375.

[4] Buckthorpe, M., Verhagen, E., D'Hooghe, P., Osti, L., Di Paolo, S., & Della Villa, F. (2025). Systematic video analysis of ankle sprain injuries in elite male football (soccer): Injury mechanisms, situational patterns, biomechanics and neurocognitive errors study: A study on 140 consecutive players. *Knee Surgery, Sports Traumatology, Arthroscopy, 33*(11), 4035–4049. https://doi.org/10.1002/ksa.70049

[5] Stojanović, E., Faude, O., Nikić, M., Scanlan, A. T., Radovanović, D., & Jakovljević, V. (2023). The incidence rate of ACL injuries and ankle sprains in basketball players: A systematic review and meta-analysis. *Scandinavian Journal of Medicine & Science in Sports, 33*(6), 790–813. https://doi.org/10.1111/sms.14328

[6] Young, W. K., Briner, W., & Dines, D. (2023). Epidemiology of common injuries in the volleyball athlete. *Current Reviews in Musculoskeletal Medicine, 16*(6), 229–234. https://doi.org/10.1007/s12178-023-09826-2

[7] He, Z., Liu, G., Zhang, B., Ye, B., & Zhu, H. (2024). Impact of specialized fatigue and backhand smash on the ankle biomechanics of female badminton players. *Scientific Reports, 14*(1), Article 10282. https://doi.org/10.1038/s41598-024-61141-z

[8] Liu, L. P., Liao, X., Zhang, J. X., et al. (2011). Research progress on the pathogenesis of football ankle injuries. *Chinese Journal of Traditional Medical Traumatology & Orthopedics, 19*(10), 75–77. (In Chinese)

[9] O'Connor, A. M., & James, I. T. (2013). Association of lower limb injury with boot cleat design and playing surface in elite soccer. *Foot and Ankle Clinics, 18*(2), 369–380. https://doi.org/10.1016/j.fcl.2013.02.012

[10] Lin, C. F., Gross, M. L., & Weinhold, P. (2006). Ankle syndesmosis injuries: Anatomy, biomechanics, mechanism of injury, and clinical guidelines for diagnosis and intervention. *Journal of Orthopaedic & Sports Physical Therapy, 36*(6), 372–384. https://doi.org/10.2519/jospt.2006.2195

[11] Zheng, N. (2022). Analysis of ankle injuries and preventive measures in soccer based on anatomy and biomechanics. *Bulletin of Sport Science & Technology, 30*(12), 252–255, 265. (In Chinese)

[12] Wang, W. (2023). Common joint injuries and prevention among female college soccer players. *Journal of Science of Teachers' College and University, 43*(10), 79–81. (In Chinese)

[13] Klein, C., Luig, P., Henke, T., Bloch, H., & Platen, P. (2020). Nine typical injury patterns in German professional male football (soccer): A systematic visual video analysis of 345 match injuries. *British Journal of Sports Medicine*. https://doi.org/10.1136/bjsports-2019-101344

[14] Kudaş, S., Dönmez, G., Işık, Ç., Çelebi, M., Çay, N., & Bozkurt, M. (2016). Posterior ankle impingement syndrome in football players: Case series of 26 elite athletes. *Acta Orthopaedica et Traumatologica Turcica, 50*(6), 649–654. https://doi.org/10.1016/j.aott.2016.03.008

[15] Wagemans, J., Bleakley, C., Taeymans, J., Schurz, A. P., Kuppens, K., Baur, H., & Vissers, D. (2022). Exercise-based rehabilitation reduces reinjury following acute lateral ankle sprain: A systematic review update with meta-analysis. *PLOS ONE, 17*(2), Article e0262023. https://doi.org/10.1371/journal.pone.0262023