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Main Causes and Preventive Measures of Anterior Cruciate Ligament Injury in Basketball

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Abstract. Anterior cruciate ligament (ACL) injuries have a high incidence in basketball and exert a profound impact on athletes' careers. This paper systematically sorts out the anatomical structure and physiological function of the ACL and analyzes the main causes of ACL injuries in basketball from two categories of injury mechanisms: non-contact and contact injuries. Non-contact injuries are dominant, which commonly occur during high-risk movements such as rapid change of direction, sudden stop and drive, and single-leg landing. Contact injuries are mostly induced by the loss of movement rhythm control caused by physical confrontation or indirect interference. Targeting these injury mechanisms, this paper puts forward prevention strategies with neuromuscular control training as the core, and also emphasizes standardizing landing and direction change techniques, strengthening the strength of lower limb and core muscle groups, rationally arranging training load and fatigue management, and establishing individualized intervention programs for high-risk groups. Studies have shown that multi-dimensional comprehensive interventions have higher feasibility and preventive value than single measures. This paper provides a theoretical basis and practical reference for the prevention and control of ACL injuries and training intervention for basketball athletes.

Keywords: Anterior cruciate ligament injury, Basketball, Main causes, Preventive Measure

1. Introduction

Basketball is a sport with intense confrontation, fast rhythm and extremely high physical requirements on the human body. Rapid turning, sudden stops, direction changes and other movements in the sport make athletes highly prone to knee injuries, among which anterior cruciate ligament injuries are particularly prevalent, accounting for as high as 64% of all knee injuries [1]. As the core stabilizing structure of the knee joint, the anterior cruciate ligament is a major cause of the decline in athletes' athletic ability and missed competitions. It may change the career trajectory of basketball athletes, often requires long-term rehabilitation, and the process of returning to the sport is full of challenges.

Foreign studies have revealed the mechanisms of ACL injuries from multiple perspectives including epidemiology, video analysis, biomechanics and neuromuscular control. It is generally believed that non-contact injuries account for a large proportion, and direction change and drive, sudden stop and deceleration, and single-leg landing are high-risk movements. A number of

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systematic reviews and randomized controlled trials have confirmed that neuromuscular training has a significant effect on reducing the risk of ACL injuries. Domestic research has received increasing attention in recent years, but most of it focuses on the summary of injury mechanisms, training intervention suggestions and functional assessment. There are still relative deficiencies in long-term follow-up of basketball-specific populations, position-stratified comparisons, and high-quality verification of intervention effects.

Therefore, this study aims to sort out the anatomical structure and physiological function of the anterior cruciate ligament, summarize the main causes and typical movement mechanisms of ACL injuries in basketball, systematically conclude the prevention strategies for ACL injuries in basketball, and put forward practical suggestions for high-risk groups. Through the systematic collation of mechanisms and prevention, this paper provides a theoretical basis and practical reference for injury prevention and control and training intervention for basketball athletes.

2. Anatomical structure and physiological function of the anterior cruciate ligament

The knee joint is one of the largest and most structurally complex synovial joints in the human body, mainly composed of the distal femur, the proximal tibia and the patella. Its periphery is surrounded by the joint capsule, forming a relatively closed joint cavity. To enhance stability, a number of important ligaments are distributed around the knee joint: the patellar ligament formed by the downward continuation of the quadriceps tendon is located anteriorly; the medial collateral ligament and lateral collateral ligament provide support on the medial and lateral sides respectively; the oblique popliteal ligament further strengthens the posterior aspect. In addition, the anterior cruciate ligament and posterior cruciate ligament exist in the joint cavity, which play a key role in limiting the abnormal anterior and posterior movement of the tibia.

Among these structures, the anterior cruciate ligament is particularly important for maintaining the stability of the knee joint, especially in controlling the anterior displacement of the tibia relative to the femur and rotational stability, which has an irreplaceable role. The articular cartilage inside the knee joint can also buffer impact, disperse load, and help maintain the overall stability of the joint. The anterior cruciate ligament is located in the knee joint and belongs to the intracapsular ligament, connecting the tibia and femur. It originates from the anteromedial area of the tibial intercondylar eminence, runs obliquely backward, upward and outward, and inserts into the posterior part of the medial surface of the lateral femoral condyle. Its main function is to prevent excessive anterior movement of the tibia, and it participates in maintaining the stability of the knee joint together with the surrounding muscles and other stable structures. However, due to its special anatomical position and biomechanical characteristics, the anterior cruciate ligament is relatively vulnerable to injury during sports [2,3].

3. Main causes of ACL injuries in basketball

Basketball has the characteristics of high intensity, fast rhythm and multi-directional conversion. Athletes frequently perform sudden stops, take-offs, landings, accelerations, decelerations and direction changes during competitions, which puts the knee joint in a state of high load stress for a long time. As an important structure to maintain the anterior and rotational stability of the knee joint, the anterior cruciate ligament is vulnerable to abnormal tension and torsional load during the above movements, resulting in injury. According to whether there is a contact factor of direct external action on the knee joint when the injury occurs, it can be divided into two categories: contact injury and non-contact injury.

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Existing studies have shown that in the on-court position distribution of ACL injuries in basketball players, point guards and shooting guards are the high-incidence positions, accounting for about 54% to 74%, forwards account for 16% to 27%, while centers only account for 3% [4]. It can be seen that guard players undertake more tasks of ball handling, breakthrough and direction change, sudden stop shooting and rapid offensive and defensive conversion in the game, and their knee joints are more likely to bear large shear force and rotational load during high-speed movement and direction change, so the risk of ACL injury is relatively higher.

3.1. Non-contact injuries

Non-contact injury refers to the anterior cruciate ligament injury of athletes caused only by improper control of their own movements, abnormal joint alignment or excessive local load, without direct action from other people or foreign objects. A large number of studies have shown that non-contact injury is one of the main types of anterior cruciate ligament injuries in basketball, especially more common among female athletes.

3.1.1. External movement characteristics

Rapid change of direction and sudden stop drive are the most main inducing movements. Movements such as breakthrough and drive in basketball games, dribble direction change, sudden stop and start, and defensive lateral movement all require athletes to quickly complete direction change and speed adjustment under high-speed movement. In this process, the lower limbs not only need to bear a large ground reaction force but also cope with significant shear force and rotational load.

Studies have shown that the most common injury action of anterior cruciate ligament rupture in professional basketball players is direction change drive during offense, especially in the process of two-step sudden stop, dribble breakthrough and the first step acceleration under the basket. Among them, the first step breakthrough to the basket after catching the ball is considered to be a relatively common injury scenario, accounting for about 34% [5]. This action requires athletes to complete catching the ball, center of gravity transfer, rapid start and direction adjustment in a short time, which has extremely high requirements on the stability of the lower limbs and neuromuscular control ability. If accompanied by body deviation, insufficient support or abnormal alignment of the lower limbs at this time, the anterior cruciate ligament may bear overload stress in an instant and be injured.

Single-leg landing after jumping is also an important inducement of non-contact injury of the anterior cruciate ligament. After shooting, blocking, competing for rebounds and breaking through the layup in basketball, athletes often land in a state of body imbalance or center of gravity deviation, especially when the unilateral lower limb bears the main buffering task, the compression, shear and rotational stress on the knee joint increases significantly. If the knee joint flexion is insufficient, the hip-knee-ankle synergistic buffering ability is poor, or the knee joint has obvious valgus when landing, the tension of the anterior cruciate ligament increases rapidly, and it is very easy to tear.

3.1.2. Intrinsic factors

In addition to external movement characteristics, insufficient neuromuscular control ability is also an important cause of non-contact injuries. If basketball athletes have insufficient core stability,

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weak gluteal muscle strength, imbalance between quadriceps and hamstring strength, poor landing buffering ability or decreased proprioception, it is difficult for them to effectively control the lower limb arrangement and knee joint movement trajectory in high-speed movements, and thus more prone to knee valgus, tibial anterior movement and rotational imbalance. In addition, fatigue will further weaken the dynamic stability of muscles, reduce the accuracy of movement control, and thus increase the incidence of anterior cruciate ligament injuries.

3.2. Contact injuries

Contact injury refers to the anterior cruciate ligament injury caused by direct or indirect external force on the knee joint when athletes have physical contact with opponents, teammates or the external environment during the game or training. According to different stress modes, contact injuries can be divided into direct contact injuries and indirect contact injuries.

3.2.1. Direct contact injuries

Direct contact injury mainly refers to the external force directly acting on the knee joint itself. For example, the lateral side of the athlete's knee joint is impacted during confrontation, resulting in knee valgus, tibial rotation or anterior movement, so that the anterior cruciate ligament bears a load exceeding its physiological limit and tears. In basketball games, such injuries are mostly seen in scenarios such as scrambling under the basket, landing after grabbing rebounds, collision during supplementary defense, or falling to the ground due to body imbalance. Although the proportion of typical direct contact anterior cruciate ligament injuries in basketball is relatively lower than that in high confrontation sports such as football and rugby, it is still a non-negligible injury factor under high-intensity physical confrontation.

3.2.2. Indirect contact injuries

Indirect contact injury is a more common mechanism in basketball. Its characteristic is that the external force does not directly act on the knee joint, but the contact interference breaks the athlete's original movement rhythm, body center of gravity or landing control ability, and finally leads to anterior cruciate ligament injury.

Existing studies have shown that most of the anterior cruciate ligament injuries of professional male basketball players occur in offensive rounds and are often accompanied by indirect contact in non-knee parts before or at the time of injury, such as interference from defensive players on the upper limbs, trunk or pelvic area. Although this contact does not directly hit the knee, it will lead to trunk deviation, gait disorder and abnormal lower limb force line of athletes during high-speed breakthrough, ball-holding direction change, two-step sudden stop or take-off and landing, so that the knee joint bears multi-plane composite load in a short time, and significantly increases the risk of anterior cruciate ligament tear.

From the perspective of game scenarios, contact injuries are particularly prone to occur in high confrontation scenarios such as breakthrough under the basket, ball-holding drive, sudden stop layup and close defensive interference. At this time, athletes often need to complete rapid acceleration, deceleration and direction change in a limited space. Once accompanied by defensive pressure or physical contact, it is easy to cause movement compensation, leading to increased knee valgus, anterior tibial translation and rotational load, thus inducing anterior cruciate ligament injury.

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4. Preventive measures for ACL injuries in basketball

4.1. Strengthening neuromuscular control training is the core measure to prevent ACL injury

A large number of studies have shown that neuromuscular training is one of the most effective means to reduce the risk of ACL injury. Basketball-specific studies have shown that multi-component neuromuscular warm-up can significantly reduce the incidence of lower limb injuries and can reduce the risk of ankle sprains and knee injuries [6]. The cluster randomized controlled trial by Stojanović et al. confirmed that the multi-component neuromuscular warm-up program for basketball players can significantly reduce the incidence of non-contact lower limb injuries by 74%, among which the risk of ankle sprains is significantly reduced by 74%, and the risk of knee injuries shows a clear downward trend.

Most non-contact ACL injuries in basketball occur during sudden stops, direction changes and single-leg landings, which are essentially closely related to insufficient dynamic stability of the lower limbs, poor control of knee valgus and reduced trunk control ability. Therefore, systematic neuromuscular training should be used to improve athletes' posture control ability in high-speed sports, focusing on improving the coordinated stability of hip, knee and ankle, as well as the joint alignment during landing and turning. The training content can include balance training, proprioception training, single-leg stability training, agility training and reaction training, so as to enhance athletes' control over the center of gravity, support surface and movement trajectory in complex confrontation environments, thereby reducing the stress load of ACL in high-risk positions.

The preventive value of the above training has been supported by empirical evidence. The research data shows that compared with the control group with conventional warm-up, the intervention group with neuromuscular warm-up has an incidence rate ratio (IRR) of total knee injuries of only 0.32, and the number of non-contact ACL injuries in the intervention group is only 1/3 of that in the control group, which further confirms that neuromuscular control training is the core means of ACL injury prevention for basketball players [5].

4.2. Standardizing landing and direction change technology is an important way to reduce injuries caused by high-risk actions

Since ACL injuries in basketball mostly occur in the actions such as the first step breakthrough, sudden stop drive and single-leg landing, it is of great significance to strengthen the standardized training of special technical actions. Prevention training should focus on correcting bad action patterns such as excessive knee valgus, insufficient flexion, trunk lateral tilt and center of gravity deviation when landing, and guide athletes to form an effective buffer strategy of "hip flexion - knee flexion - ankle flexion" to improve the absorption capacity of lower limbs to impact load.

In direction change and deceleration training, emphasis should be placed on lowering the center of gravity, shortening the braking time, optimizing the landing point of the supporting foot and controlling the trunk posture, so as to reduce the abnormal load of the knee joint in the coronal and axial planes. For players in high-risk positions such as guards, special technical intervention should also be carried out for typical scenarios such as the first step breakthrough after catching the ball, jump shot after sudden stop and dribble direction change, so as to improve the stability and safety of actions.

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4.3. Improving the strength level of lower limb and core muscle groups is the basis for maintaining the dynamic stability of the knee joint

The occurrence of ACL injury is not only related to the external movement pattern, but also closely related to the athlete's own muscle strength level and muscle group coordination ability. Studies suggest that insufficient function of hip circumference muscle groups, quadriceps femoris, hamstring muscle and core muscle groups will weaken the dynamic protective effect of lower limbs on the knee joint, and increase the risk of tibial anterior movement, knee valgus and rotational imbalance. Basketball-specific empirical studies have further confirmed that the decline of muscle strength of trunk, hip and knee will directly aggravate the knee valgus amplitude and stress moment in landing and single-leg support actions and significantly improve the probability of non-contact ACL injury.

Therefore, in prevention training, attention should be paid to lower limb strength and core stability training, especially to strengthen the functional development of gluteus medius, gluteus maximus, hamstring muscle and deep core muscle groups, so as to improve the hip and knee control ability and lower limb force line stability [7]. At the same time, attention should also be paid to the strength balance between quadriceps femoris and hamstring muscle, so as to avoid increasing the ACL tensile load due to the imbalance of anterior and posterior muscle groups. The combination of strength training and stability training can effectively improve the injury resistance of knee joint in high-speed starting, braking and landing.

The preventive value of the above training program has been verified by randomized controlled trials. A study on female college basketball players showed that adding 8 weeks of targeted core and hamstring training (including plank, side plank, Nordic hamstring exercise) at least 4 times a week on the basis of conventional training can significantly enhance the muscle strength of hip flexors, hip abductors, knee flexors and trunk flexors and extensors of athletes. At the same time, it can significantly reduce the knee valgus moment in high-risk actions, optimize the trunk posture control ability, correct the biomechanical pattern that is easy to cause ACL injury, and provide effective protection for non-contact ACL injury [8].

4.4. Reasonable arrangement of training load and fatigue management is an important guarantee to reduce the risk of injury

Fatigue will significantly reduce the athlete's movement control ability and neuromuscular reaction speed, lead to the decline of landing buffer ability and the weakening of knee joint stability, thus increasing the risk of ACL injury. Basketball games have a fast pace and frequent offensive and defensive conversion. If the training and game load is not arranged reasonably, athletes are more prone to technical action deformation and posture control imbalance under high fatigue state.

Therefore, in the prevention of ACL injury, attention should be paid to training load monitoring and fatigue management, reasonably control the training intensity, training volume and recovery cycle, and avoid functional decline under continuous high load stimulation [9]. At the same time, restorative training, sleep management and post-injury functional assessment should be arranged in combination with the season cycle to ensure that athletes complete high-risk actions in a good physical state.

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4.5. Establishing individualized prevention programs for high-risk groups

Basketball athletes of different genders, different on-court positions and different functional levels have different risks of ACL injury. Existing studies have shown that guard players are high-risk groups of ACL injury because they undertake more tasks of ball handling, sudden stop and direction change and rapid breakthrough; female athletes are more prone to non-contact ACL injury [10].

Therefore, in prevention practice, individualized intervention programs should be formulated according to the athletes' gender characteristics, position tasks, previous injury history and functional screening results. For high-risk groups, focus should be laid on the monitoring and training of landing stability, direction change deceleration ability, hip and knee control, and movement quality under fatigue, so as to improve the pertinence and effectiveness of preventive measures.

5. Conclusion

Based on the perspective of anatomical structure and sports biomechanics, this study sorts out the main mechanisms of ACL injury in basketball, emphasizes that non-contact injury is dominant, and points out that rapid direction change, sudden stop drive and single-leg landing are high-risk actions. The prevention strategy should take neuromuscular control training as the core, supplemented by the standardization of action technology, the strengthening of lower limb and core strength, load and fatigue management, and individualized intervention for high-risk groups. On the whole, multi-dimensional comprehensive intervention has more practical feasibility and preventive value than single measures.

However, some of the current conclusions rely on the induction of existing studies, which may be affected by sample groups, project differences and research methods. Stratified verification for different genders, positions and competitive levels has not been carried out, and the extrapolation is still limited. In the future, it is necessary to further carry out prospective cohort studies and intervention experiments for basketball-specific populations to verify the actual effect of the prevention program. People should strengthen the combination of quantitative assessment of action quality and training load monitoring to improve the accuracy of early warning and intervention. Stratified prevention models should be established for different genders, positions and levels to form more targeted practical guidelines.

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