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Mechanism and Prevention of Acute Knee Joint Injury During Exercise

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Abstract. Anatomically, the knee joint is the most complex joint in the human body. It consists of the medial and lateral condyles of the femur, the medial and lateral condyles of the tibia, and the patella. From the perspective of kinematics, the knee joint is one of the most critical joints to complete various actions in the human movement. Due to these two characteristics, it has also become a high incidence of sports injuries. Especially in sports activities, sports knee injury is extremely common, so it must be paid attention to, especially professional athletes, denying that it may affect the careers. This study mainly analyzes the common sports injuries of the knee joint and their mechanisms, and discusses the common sports injuries of the knee joint, as well as the mechanism of the knee joint injury and how to prevent the knee joint injury from three aspects, so as to prevent the small problems and help the development of sports.

Keywords: Knee joint; sports injurie; mechanism; prevention.

1. Introduction

As living standards rise, an increasing number of people start to take an interest in sports. No matter in sports competitions or mass sports, acute injury has always been a common problem, among which knee joint injury is one of the most common sports injuries. As human autonomy's largest and most intricate joint, the knee joint undertakes an important role in human movement. It contains multiple structures, and different structures all play different roles. An essential intra-articular ligament structure of the knee joint is the anterior cruciate ligament (ACL), which withstands loads from rotation and anterior tibial translation [1]. Additionally, the meniscus serves as a shock absorber, load bearer, load transmitter, joint lubricant, joint congruity, and joint stability. The risk of harm to meniscal pathology is enhanced by increased exposure to sports activity, even if the incidence of this condition is difficult to determine [2]. Knee injuries during sports not only affect exercisers' athletic performance, but can also greatly increase the risk of developing arthritis later in life.

In recent years, the number of people participating in sports in China has been increasing. An in-depth understanding of the mechanism of acute knee loss is of high practical significance for effectively protecting the health of the sports population and preventing sports injuries. The research in this field not only covers multiple dimensions and levels, but also has emerged many innovative views and conclusions. This paper will start with the four main parts of the knee joint to analyze the mechanism and prevention of acute knee joint injury during exercise.

2. Acute injury of meniscus in knee joint during exercise

Meniscus injuries are common in ball games and adversarial sports, and they account for a relatively high proportion of knee sports injuries. Studies showed that, out of all the internal injuries treated, medial meniscus lesion (MM) was the second most common injury, accounting for 24% of cases., as shown in Table 1 [1]. Meniscus injuries are usually caused by acute trauma or chronic strain, and in acute injuries, there are multiple pathogenic factors that may occur separately, which may occur alone or in other parts. While medial meniscal tears are more common in knees lacking an ACL, lateral meniscal tears frequently occur in conjunction with acute ACL ruptures [2]. Acute meniscus injury during exercise may be caused by excessive torsional stress and strong external compression.

Table 1: 2763 patients undergoing arthroscopy in relation to the total number of patients (3482) with internal knee trauma [1].

	(N)	(%)	(Rel. %)
No specification	13	0.47	41.93
LCL	43	1.55	48.86
MCL	358	12.96	58.49
ACL	1367	49.48	86.51
PCL	40	1.45	78.43
LM	241	8.72	84.85
MM	701	25.37	83.85
Total	2763	100	79.35

LCL: Lateral Collateral Ligament; MCL: Medial Collateral Ligament; ACL: Anterior Collateral Ligament

PCL: Posterior Collateral Ligament; LM: Lateral Collateral Ligament; MM: Medial Collateral Ligament

2.1. Mniscus injury caused by torsional external force

When the knee is in a twisted state, that is, when the knee is rotated and disguised in motion, such as the athlete's cutting shot in football, the emergency stop change direction in basketball, the bending knee in badminton, etc., the actions in these sports require the athlete to constantly and quickly change direction and stop urgently, so that the knee is in a twisted state, which in turn causes it to bear a large shear force. Analyzing one of the specific actions is meniscus injury occurs when the athlete's knee joint is in a semi-flexed state and the calf remains fixed, and the thigh rotates inward or outward, that is, the knee meniscus is subjected to strong torsion. The torsion that occurs in an instant can cause a tear in the lateral meniscus. In figure 1, Under ordinary loading circumstances, a large amount of shear stress is thought to be sustained by the meniscus. Its reaction to shear could play a role in the formation of both vertical and horizontal tears, especially in the two distinct planes parallel to the direction of their enormous fiber bundles [3]. According to the literature analysis. In most cases, football players are thought to get ACL and menisci injuries more frequently due to cutting, turning, and contact incidents [4].

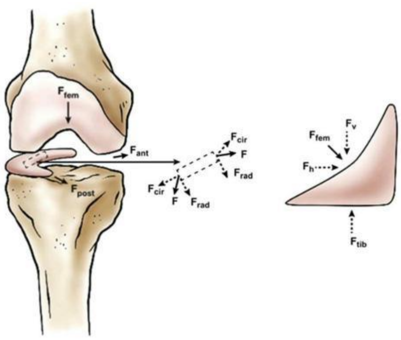

Figure 1: An illustration of the forces operating on the meniscus of the knee during loading [3].

2.2. Sueezing external force causes meniscus lesions(Non-contact injuries)

Due to the structural properties of the meniscus, which leads to its unique function in motion. The combination of low compressive stiffness and lo permeability suggests that the menisci, as structures, should function as highly efficient shock absorbers per unit mass. Since the combined mass of the menisci is much greater than that of the articular, cartilage bearing load across the tibiofemoral joint, it is likely that most of the shocks generated by knee joint loading are absorbed by the menisci [3]. Therefore, when the knee joint is compressed vertically, it is squeezed by gravity. The meniscus withstands the impact and absorb the pressure. In this case, the main possibility of injury is a change in the position of the meniscus joint, such as in volleyball, where the athlete performs a large number of repetitive vertical jumps, and if the landing position is not appropriate, the meniscus is compressed between the femoral condyle and the tibia, which can lead to injury.

A reasonable preventive suggestion would be to caution all female athletes involved in jumping sports who have recurvatum to pay close attention to their landing technique during training. It is important to emphasise landing with the knee flexed to those in whom this anatomical variationis identified. An ideal time to make this recommendation would be during the sports preparticipation exam by the physician [5].

3. acute injury of cruciate ligament in knee joint during exercise

Anterior cruciate ligament (ACL) tears are serious injuries that have terrible long-term consequences for the knee joint.

In China alone, 1.25 million people suffer anterior cruciate ligament (ACL) ruptures each year. These injuries often occur during sports and exercise. Although the estimated incidence of solitary cases is about 2–5% for ACL tears According to one study, up to 39% of trauma patients who report with acute knee injuries and hemarthrosis had structural damage to the ACL. As a result, more than 61% of ACL injuries are linked to other capsuloligamentous lesions; combined ACL and posterolateral corner (ALC) injuries are common, occurring in 17–43% of patients with ACL destruction

Noncontact wreckage constitutes approximately nearly all of the total number of ACL harming yourself. To maximize preventative efforts, it is essential to comprehend the process of harm. The above intercondylar notch's invasion is one of a hypothesis and together with risk elements that they were put out to describe how noncontact knee ligament damage happens [6].

3.1. Impingement

The impingement of the anterior cruciate ligament (ACL) upon the medial margin of the intercondylar notch has been postulated as a potential anatomic etiology [7]. However, non-contact factors really account for the majority of this harm. The research about constriction of the intercondylar area also an ACL injury prediction is contentious and constrained by the radiological methods employed to gauge the intercondylar notch's size. However, non-contact factors really account for the majority of this harm. The research interarticular space within the knee joint is notably constricted. an ACL injury prediction is contentious and constrained by the radiological methods employed to gauge the intercondylar notch's size. The fact which the prevalence of noncontact ACL injuries occurring predominantly at the femoral attachment site further debunks the notion that infringement is a causative factor in ACL injuries.

3.2. Biomechanical Factors

Studies suggest the anterior quadriceps vector is key in ACL injury causes, as it constitutes a primary source of anterior knee force during the phase of maximal or near-maximal knee extension [8,9]. Nonetheless, the orientation of the patellar tendon demonstrates a limited angle of inclination, ranging from 15°to 30°upon maximal extension, and the quadriceps muscle group predominantly elicits compressive forces on the tibiofemoral joint [10].

Current research has indicated that the lower extremity's sagittal biomechanics is the most important factor that causes anterior cruciate ligament stress. Reducing the knee bending Angle, An increase in the quadriceps muscle's tension and an elevation in the leg's ground reaction force will amplify the valgus torque acting on the knee joint, subsequently leading to an enhanced load on the ACL. Although it has been found that there is a correlation between knee valgus torque and ACL injury, the existing studies do not support the idea that knee valgus and rotation torque can cause ACL injury when the knee is not stressed on the sagittal plane. A large number of literatures indicate that non-contact ACL injury is likely to be caused by biomechanical factors within and outside the sagittal plane of lower limb, or by biomechanical factors within the sagittal plane of lower limb alone [11].

4. Acute injury of cartilage in knee joint during exercise

Knee cartilage injury is a common orthopedic disease that causes pain. Articular cartilage is transparent connective tissue, attached to the surface of the bone junction. The role of articular cartilage is to withstand load and absorb shock during movement. A functioning articular cartilage undergoes a load environment that includes compression, shear, friction, and tension. Research that explores the properties of articular cartilage from a sport medical perspective provides healthcare practitioners with more effective pathologic analyses. Its damage is mainly caused by the shear force of joint movement and wear and degradation and mechanical damage caused by excessive use and has a slow recovery. The studies show that all sports injuries to articular cartilage are caused by excessive mechanical stress.

Shear stress is two forces, parallel to each other but in opposite directions, that cause one part of an object to move or displace with respect to another. In knee the studies have shown that when the joint is in the active state of motion, especially high intensity exercise, synovial fluid will produce high intensity fluid shear force leading to chondrocyte degeneration, causing pain [12].The clip injury occurs in knee also due to the stress of the improper use of the patellofemoral joint and the femoral tibial joint, the articular cartilage gradually changes from friction to wear under the action of shear force and spinning force.

Moreover, overuse also causes cartilage damage through the resulting mechanical stress. Sustained or sudden mechanical stress causes microdamage within the cartilage structure, creating cracks, fissures, and localized stress concentration areas. This microdamage is a tipping point that triggers a complex series of biochemical reactions within the cartilage. In response to microdamage, chondrocytes activate a complex network of signaling pathways. This includes the release of inflammatory mediators, strom-degrading enzymes and pro-inflammatory cytokines. The inflammatory environment lays the foundation for the enhancement of the catabolic state in cartilage and promotes the degradation of matrix components such as collagen and proteoglycan [13].

5. Acute injury of patella in knee joint during exercise

The patella, the largest sesamoid bone in the human body, plays a paramount role in the focusing of the extensor apparatus, the augmentation of the lever arm, the relaying of the quadriceps muscle forces and the distributing of the forces on the trochlea [14]. About a quarter of knee pain is caused by patellar lesions. The most popular groups are athletes, people who walk incorrectly, women who often wear high heels, and middle-aged and elderly people. There are four main types of patellar injury: patellar fracture, patellar dislocation, and contusion of patella, patellar malacia. This chapter deals with acute patellar injury and its treatment, so patellar malacia as a result of long-term wear is not included in the discussion.

5.1. Patella fracture

The injuries of patella fractures, which are most prevalent among the people aged 20 to 50, are serious and account for about 1% of all skeletal injuries, with a wide range of subtypes [15]. There are two specific causes of fracture: direct violence and indirect violence. Direct violence refers to the external force directly hit on the patella (like an egg hitting a rock), such as bumping, kicking injury (which will cause pulverized fractures), indirect violence is mostly because of the quadriceps muscle contraction caused by the pull injury, such as suddenly fall quadriceps muscle tension is too large, pull the patella upward, but the patellar strap fixed the lower section of the patella, can cause patellar fracture (mostly transverse fracture).

As a kind of fracture, patellar crack fracture is also a common phenomenon.When the patella is subjected to direct violence, such as falling and kneeling, the patella directly hits the ground, resulting in patellar crack fracture. In other cases, the quadriceps muscle violently contracts and pulls the patella to maintain body stability or cumulative strain can also cause patellar crack fracture.

5.2. Patellar dislocation

When the patella disconnects the femoral trochlear groove, patellar dislocation occurs, whose leading mechanism is non-contact knee sprain in flexion and valgus, accounting for up to 93% of all cases. Two-thirds of acute patellar dislocations arise in young active patients (less than 20 years old). In the severe displacement of the patella, the medial stabilizing structures are torn, and especially the medial patellofemoral ligament, which is likely to get injured in acute patellar dislocation, most oftentimes at its femoral attachment, as seen in Figure 2 [16]. Acute patellar dislocation often leads to other structural injuries of the knee joint. Inaugural traumatic patellar dislocation is most often due to trauma sustained during physical or sports activity. Most patients suffer chondral damage and MPFL tears following after a first-time patellar dislocation [17].

Figure 2 Anatomic diagram showing MPFL position. From Maitrise orthopédique No.186-2009 [16]

5.3. Contusion of patella

Patellar contusion refers to the cortical bone of the patella is not damaged, but the cancellous bone of the patella is damaged, and the corresponding symptoms appear.

The main cause of patellar contusion is the violent impact of foreign objects on the patella. Usually in life falls or sports in the process of a very serious collision, easy to damage the patellar tissue resulting in patellar contusion phenomenon. After the patient has a patellar contusion, it will stimulate the pain receptors in the patellar area, which will cause painful symptoms, but also lead to an increase in local exudation, causing the problem of patellar swelling. If the degree of contusion is more serious, it is easier to directly affect the patient's range of motion, resulting in motor dysfunction.

6. Preventive suggestions for knee joint injuries

First of all, people should do exercise in moderation. Warming up before exercise can help the muscles relax and activate the elasticity and extension of the joints, this reduces the risk of acute knee injuries during exercise.In a study on warming up before exercise can reduce the risk of injury.They discovered that the intervention group maintained a much lower rate of 0.5 injuries per 1000 players/h in comparison to the control group, which had 0.9 injuries per 1000 players/h. An organized warmup, according to the authors, decreased the incidence of ankle and knee injuries by at least 50% [18]. People should also avoid prolonged exercises that put pressure on knees, such as lifting weights, climbing mountains, and squats.

Secondly, Strengthens neuromuscular and proprioceptive training. First, use strategies like core stability and balance training. These programs can help people maintain their balance over their weight-bearing knee, which lowers knee stresses in the frontal and transverse planes [18]. At the same time can build strength in quadriceps. If the thigh muscles are not strong enough, the joint will lose support and stability, making the joint more vulnerable to shocks and external pressures, increasing the risk of damage to the articular cartilage. Eleven female high school volleyball players participated in a rigorous 6 weeks of jump training that enhanced their vertical jump and diminished landing impact and increased strength and balance of muscles, these may have prevented knee injury [19]. It is important to note that the specific training method should be selected and developed according to the individual's physical condition, sports goals and professional guidance. Before starting any new training program, it is best to consult the advice of a professional coach or doctor.

Thirdly, control the weight in a healthy range. Because the weight load is mainly on the knee cartilage. For every kilogram of body weight, the pressure on the articular cartilage increases by three kilograms when walking and ten kilograms when running. Prolonged excessive stress on the knee can lead to osteoarthritis and serious cartilage damage.

Fourth, eat more calcium tablets or other calcium-containing foods. This can effectively prevent the development of osteoporosis and reduce the risk of fracture.

Lastly, put on safety gear. Wearing a brace or using muscle bonding before exercise can help to stabilize the knee joint, facilitate knee movement, and guard against damage.

7. Conclusion

Knee joint injuries are prevalent in sports-related activities. There are many types and the degree of injury is more serious. The severity and location of knee joint injury vary in different sports events. This paper mainly studies the common injury types of knee joint, the injury conditions of different items and its generation mechanism. At the same time, the mechanical mechanism of knee joint injury might be the starting point for the introduction of the biomechanical model in order to identify the process of injury formation. The integration of the finite element model with the muscle dynamic model is the path of development for the biomechanical model. Introducing this hybrid model into the field of sports injury can effectively find out the location of injury and is also one of the future development directions. In addition, this paper does not deeply analyze the intervention and recovery aspects of injury. Therefore, based on the existing research, the rehabilitation and treatment of knee joint sports injury should be further explored, and corresponding intervention strategies should be proposed in order to form a more complete system in the future.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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