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To the investigation of the tension of the inter-cracked ligaments knee joint

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Annotation

This article presents the results of a study of the tension of the inter-cracked ligaments of the human knee joint. A dynamic model of the knee tension tension with torque moments involved in torsion on the supporting leg is compiled. It has been established that by optimizing the parameters of the tread pattern of the sole of the shoe, the materials of the contact surface can significantly reduce the likelihood of damage to the anterior cruciate ligament, by reducing the amount of friction torque due to the geometric slip of the sole of the shoe.

Keywords: tension, inter-cracked ligaments, knee joint, dynamic model, torque, force, torsion, supporting leg, body, hip, shin, foot, optimization, protector, sole, shoes, contact, probability, cruciate ligament, friction torque, geometric slip.

It is known that injuries in sports, according to various sources, account for 2-5% of the total injuries (domestic, street, industrial, etc.) [1]. Some disagreements in numbers are related to the fact that sports injuries depend on both the trauma of the danger of sports and the degree of employment of people being surveyed in sports.

According to statistics [1], more than 50% of all injuries were on the lower limbs. Ankle sprains were the most common trauma of popular sports and accounted for 15% of all injuries. Indicators of bruises and damage to the anterior cruciate ligament increased significantly compared with previous years (annual average growth rate of 7% [1].

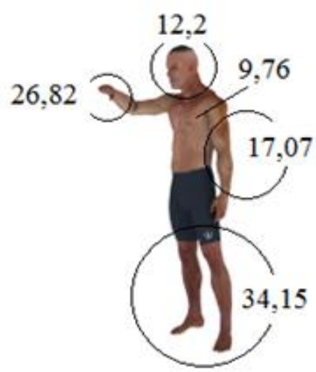

Figure 1. Topography of injuries of limbs in basketball (according to the authors)

Sprains and injuries of the anterior cruciate ligament are a very common trauma. For example, in the United States about 200,000 anterior cruciate ligament fractures are diagnosed each year, of which an operation of the anterior cruciate ligament is performed in 100,000 cases. Among all other ligaments of the knee, the anterior cruciate is injured more often, for example, anterior cruciate ligament ruptures occur 15-30 times more often than the posterior cruciate ligament ruptures. In sports, anterior cruciate ligament rupture in women occurs 4-10 times more often than men [2].

Based on the function performed by the anterior cruciate ligament (keeping the tibia from moving forward and towards the inside), the mechanism of injury, in which the anterior cruciate ligament is stretched or ruptured, becomes clear. As a rule, the torsion is on the supporting leg, when the body with the hip rotates outward, and the tibia and the foot remain in place.

However, in reality, the mechanism and causes of anterior cruciate ligament rupture are more complicated. Fundamentally, the causes of rupture of the anterior cruciate ligament include direct injury (contact mechanism: impact on the lower leg, hip) and indirect injury (non-contact mechanism: torsion on the foot during sudden braking, landing after a jump, etc.) (see table) [2].

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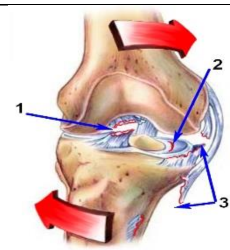
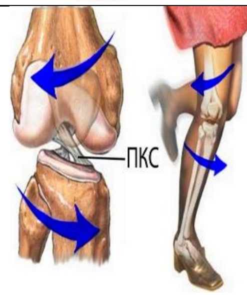
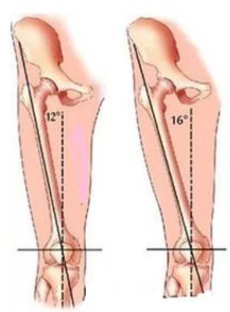
Table

Causes of anterior cruciate ligament rupture [2]

Main reasons	Ligament rupture mechanism	Factors and ligament rupture process
Deviation of the tibia to the outside and torsion of the thigh to intra-ligament ligament		This mechanism of anterior cruciate ligament rupture is the most common: handball, basketball, football, volleyball.
Deviation of the lower leg to the inside and twisting of the thigh to the outside.		This mechanism of rupture of the anterior cruciate ligament of the knee joint is opposite to the previous one: handball, basketball, football, volleyball
The width of the inter-muscle cut (Notch-cut).		The anterior cruciate ligament is located in the knee joint in the inter-muscled tenderloin. In women, it is narrower than in men. When the tibia is rotated with a flattening in the knee, a narrow inter-musculate tenderloin can clamp the anterior cruciate ligament and break it.
The angle between the thigh and shin.		The thigh connects to the lower leg at an angle, which is called the quadriceps angle or the Q-angle. The size of the angle Q is determined by the width of the pelvis. In women, the pelvis is wider than in men, therefore, in women, the Q-angle is larger than in men. A large angle Q leads to the fact that when the lower leg is tilted outwards, the load on the anterior cruciate ligament is greater.

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Based on the function performed by the anterior cruciate ligament (keeping the tibia from moving forward and towards the inside), the mechanism of injury, in which the anterior cruciate ligament is stretched or ruptured, becomes clear. As a rule, the torsion is on the supporting leg, when the body with the hip rotates outward, and the tibia and the foot remain in place.

However, in reality, the mechanism and causes of anterior cruciate ligament rupture are more complicated. Basically, as a cause of anterior cruciate ligament rupture, direct injury (contact mechanism: impact on the lower leg, hip) and indirect injury (non-contact mechanism: torsion on the foot during sudden braking, landing after a jump, etc.) can be identified.

In most cases, anterior cruciate ligament rupture is the result of a sports injury. The usual mechanism of injury is twisting the supporting leg at the knee joint. Based on this, for a detailed analysis of dynamic values that contribute to the twisting of the supporting leg in the knee joint, a dynamic model of the knee joint is compiled when the lower leg is tilted towards the inside and the torsion of the hip is towards the outside (see Figure 2)

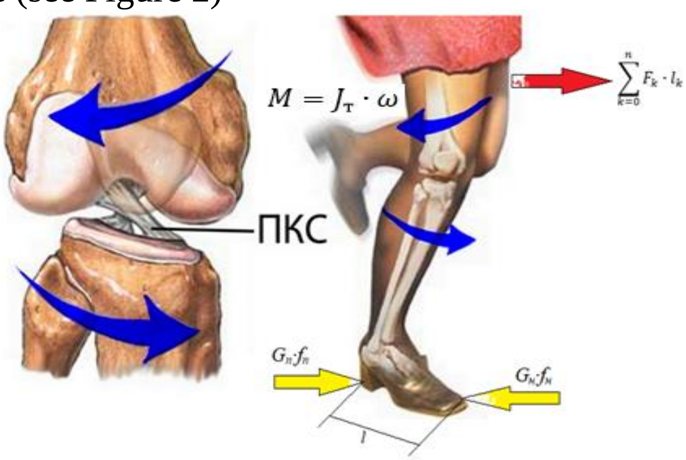

Fig.2. Model of the knee joint [2] (revised)

Figure 2 shows that during torsion, the athlete's body is on the supporting leg, when the body with the hip rotates out, and the shin and foot remain in place on the body with the following torques:

1. $M_t = J_t \cdot \omega$ (1)

2. $M_{sum} = \sum_k^n F_k \cdot l_k$ (2)

3. $M_{тр} = (G_п \cdot f_п + G_н \cdot f_н) \cdot l$ (3)

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Analysis of formulas (1), (2) and (3) of the twisting M_t ,M_{sum} , M_{tp}, that the torsion on the supporting leg, when the body with the thigh rotates out, and the shin and foot remain in place. To a large extent depends on the moment of inertia Jt, the angular velocity ω body, on the total moment of force F_k of the muscles involved in maintaining the balance of the body, on gravity the body G_n falling on the soles of the shoe, Gn respectively on the toe of the shoe, on the friction coefficients fп between the sole of the shoe and the contact surface and fn between the toe of the shoe and the contact surface.

Under the condition when $M_t \leq M_{sum}$ there is no probability of damage to the anterior cruciate ligament, the fulfillment of this condition is largely determined by the technique and fitness of the athlete. High sports equipment and muscle development are the main factors ensuring this condition.

Under the condition of M_t - M_{sum} > 0 and M_t - M_{sum} << M_{tp} the athlete's body begins to twist the knee joint around the lower leg because, at the same time, the sole of the shoe firmly fixes the foot. The moment of friction of the sole is formed as a result of geometric friction, and its magnitude is determined by the length of the contact, that is, the athlete at the moment of twisting if he rose to the toe of the shoe, the magnitude of the moment is significantly reduced as this reduces the length l of the sole. The magnitude of the friction torque M_{tp} is completely determined by the materials of the contact surface and the sole of the shoe, the quality of the sole of the shoe, the evenness of the contact area. The forces $G_n \cdot f_n$ and $G_н \cdot f_н$ and the shoulder of these forces also depend on the elastic-viscosity characteristics and the tread patterns of the sole of the shoe.

The analysis carried out using the dynamic model made it possible to establish that by optimizing the parameters of the tread pattern of the sole of the shoe, the materials of the contact surface can significantly reduce the likelihood of damage to the anterior cruciate ligament by reducing the amount of friction moment during the geometric slip of the sole of the shoe. Strengthening the knee joint by applying personal protective equipment that directly increases the strength of the anterior cruciate ligament by stretching also reduces the likelihood of injury to the knee joint associated with the rupture of its ligament.

Bibliography

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