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Scientific Protection and Training Strategies for Badminton Players after Anterior Cruciate Ligament Surgery Recovery

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Abstract: This study examines on badminton players following anterior cruciate ligament (ACL) surgery. It analyses the risk factors in badminton that may cause re-injury to the knee joint, such as sports postures and exercise intensity. Scientific and reasonable sports protection measures and training plans are formulated, including correcting sports postures and reasonably controlling exercise intensity and frequency. Rehabilitation training is carried out in stages, and the training intensity and frequency are gradually adjusted according to the recovery situation. Through scientific protection and training, the risk of re-injury to athletes can be reduced, and they can be helped to restore their best sports conditions. At the same time, future research directions are prospected, covering personalized rehabilitation programs, application of new technologies, and research on psychological factors.

Keywords: ACL surgery; Badminton players; Sports protection; Training plan

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1. Introduction

Badminton is a sport characterized by high intensity and competitiveness, demanding a high level of physical fitness and technical proficiency from athletes. The anterior cruciate ligament (ACL) is a crucial stabilizing structure of the knee joint. Once damaged, it can severely affect an athlete's athletic ability. With the development of surgical techniques, anterior cruciate ligament reconstruction surgery has become quite mature [1]. However, postoperative rehabilitation training is relatively weak, which is also a significant factor affecting the postoperative functional recovery of athletes. Therefore, it is of vital importance to formulate scientific and reasonable sports protection measures and training plans for badminton players recovered from ACL surgery. The training intensity, frequency, and content should be gradually adjusted according to the athlete's recovery. In the initial postoperative stage, the focus should be on restoring joint mobility and muscle strength, and some low-intensity rehabilitation training, such as ankle pump exercises, straight leg raises, and side leg raises, can be carried out. As recovery progresses, the training intensity can be gradually increased, and training exercises such as wall squats and step exercises can be introduced. During the training process, close attention should be

paid to the athlete's physical reactions. If any discomfort occurs, the training plan should be adjusted promptly.

In conclusion, by formulating scientific and reasonable sports protection measures and training plans, badminton players recovered from ACL surgery can safely return to the court and continue to pursue their athletic dreams.

2. Knee joint rehabilitation principles

After ACL surgery, the rehabilitation of the knee joint is a complex process involving multiple physiological changes. Understanding the physiological changes and key rehabilitation points of the knee joint during the recovery process is of utmost importance [2].

2.1. Ligament repair mechanism

The natural repair process from ACL surgery is relatively slow. In the initial stage of the surgery, the body initiates an inflammatory response to remove damaged tissues and begins to form blood clots. Over time, fibroblasts gradually invade the blood clots, synthesize collagen, and form preliminary scar tissue. However, this process is susceptible to various factors, such as blood supply and local inflammatory response, and usually takes several weeks or even months.

Postoperative rehabilitation training also plays a crucial role in ligament repair. Appropriate rehabilitation training can promote blood circulation, increase the nutrient supply to the ligaments, and accelerate the repair process.

2.2. The role of muscle recovery

Muscle strength training is of vital importance for the stability of the knee joint [3]. Strong leg muscles can effectively reduce the pressure on the knee joint and maintain joint stability. Research shows that enhancing leg muscle strength can reduce the pressure on the knee joint by approximately 30%. Around the knee joint, muscle groups such as the quadriceps femoris and hamstrings play a key role in knee joint stability. The quadriceps femoris can extend the knee joint and prevent excessive knee flexion. The hamstrings can flex the knee joint and work in coordination with the quadriceps femoris to maintain knee joint stability. Through targeted muscle strength training, such as straight leg raises, squats, and leg curls, the strength of these muscle groups can be effectively enhanced, and the stability of the knee joint can be improved.

3. Risk factor analysis

3.1. Sports postures

Badminton is a sport that requires a high level of technique. Correct hitting postures and footwork are crucial for reducing knee joint injuries [4]. However, incorrect hitting postures and footwork can pose potential hazards to the knee joint.

3.1.1. Excessive knee flexion

In badminton, excessive knee flexion can lead to many adverse consequences. Firstly, excessive flexion may increase the pressure on the knee joint by 30% to 50%. Secondly, excessive knee flexion affects muscle force generation. When the knee is excessively flexed, the contraction of leg muscles is restricted, affecting the force generation effect of the muscles. This not only reduces the athlete's athletic performance but also increases the risk of knee joint injuries.

3.1.2. Excessive toe abduction

Excessive toe abduction is also one of the common incorrect postures in badminton. Firstly, excessive toe abduction easily causes the knee joint to twist and bear additional torsional force, which may lead to knee ligament injuries. Statistics show that approximately 20% of knee joint injuries in badminton players are caused by excessive toe abduction. Secondly, excessive toe abduction affects the body's stability, which may cause athletes to lose balance when hitting the ball or moving, increasing the risk of injury. In addition, excessive toe abduction may also lead to muscle imbalance. The force generation of leg muscles will be uneven, also increasing the risk of knee joint injuries.

3.2. Risks of exercise intensity and frequency

The intensity and frequency of badminton are crucial for athletes who have recovered from ACL surgery. Unreasonable exercise intensity and frequency may pose potential threats to the postoperative knee joint.

3.2.1. Excessive exercise intensity

Excessive exercise intensity is one of the important factors leading to reinjury of the knee joint. When athletes engage in high-intensity badminton, the pressure on the knee joint may be several times or even dozens of times that during normal activities. Prolonged exposure to high-intensity exercise makes the cartilage, ligaments, and other tissues of the knee joint prone to wear and tear. High-intensity exercise can also lead to muscle fatigue and decreased strength. After high-intensity exercise, athletes may experience leg muscle soreness and weakness. If they continue to exercise at this time, the probability of knee joint injuries will increase significantly.

3.3.2. Frequent exercise

Frequent exercise can not only affect muscle recovery and growth but also lead to mental fatigue. For athletes who have recovered from ACL surgery, the psychological state is also very important for the rehabilitation process. If they exercise frequently, athletes may feel mentally fatigued, affecting their rehabilitation enthusiasm and compliance, thus affecting the rehabilitation effect.

In conclusion, it is essential for badminton players who have recovered from ACL surgery to avoid incorrect sports postures and maintain appropriate exercise intensity and frequency. At the same time, they should pay close attention to their physical condition during exercise and adjust the plan in a timely manner.

4. Protection measures

4.1. Physical therapy

Physical therapy plays an important role in knee joint rehabilitation. Among these, ultrasound therapy can promote local blood circulation, enhance tissue metabolism, reduce inflammation and relieve pain, lower the tension around the joint and ligaments, improve the nutrient supply to articular cartilage, and repair damaged cartilage. For example, a study shows that after using ultrashort-wave irradiation therapy with a working frequency of 40.68 MHz, a wavelength of 730 cm, an electrode area of 27.0 cm × 18.5 cm, a skin gap of 2–3 cm, placed in opposition before and after the knee joint, at a warm heat level, once a day, 20 minutes per session, 15 times as a course of treatment, with an interval of 5 days between each course, for a total of two courses of treatment, the Lequesne index of patients was significantly lower than before treatment. Interferential current therapy can promote local blood circulation and relieve pain through the cross-action of currents of different frequencies on the human body. Deep myofascial percussion gun therapy can relax muscles, relieve

muscle tension, promote blood circulation, and accelerate rehabilitation. Shockwave therapy can stimulate tissue repair, promote new blood vessel formation, and relieve pain. Compression pants therapy can promote blood circulation and reduce swelling by applying pressure to the legs.

4.2. Muscle training

Muscle groups such as the quadriceps femoris and hamstrings play a key role in the stability of the knee joint. Strong quadriceps femoris can extend the knee joint, prevent excessive knee flexion, and reduce the pressure on the anterior cruciate ligament. Research shows that enhancing the strength of the quadriceps femoris can reduce the pressure on the knee joint by approximately 25%. The hamstrings can flex the knee joint and work in coordination with the quadriceps femoris to maintain knee joint stability. In addition, gluteal muscle training cannot be ignored. Strong gluteal muscles can provide hip joint stability and reduce compensatory movements of the knee joint. For example, when an athlete performs a jumping shot in badminton, strong gluteal muscles can stabilize the hip joint and reduce the torsion and pressure on the knee joint. Balance training and proprioceptive training can also improve the athlete's perception of the knee joint position and prevent injuries.

4.3. Rehabilitation training

Rehabilitation training can be divided into the following stages (**Table 1**):

The first stage (0–4 weeks after surgery): The goal is to control swelling and pain and protect the surgical site. At this stage, passive joint mobility training can be carried out, such as knee joint flexion and extension activities performed by a rehabilitation therapist. At the same time, some simple muscle activation training, such as ankle pump exercises and quadriceps femoris isometric contractions, can be done. The training intensity is low, and the training time each time should not be too long, generally 15–20 minutes.

The second stage (4–8 weeks after surgery): The goal is to increase joint mobility and muscle strength [5]. At this stage, active joint mobility training can be gradually increased, such as straight leg raises and side leg raises. At the same time, some light resistance training, such as using elastic bands for resistance training of the quadriceps femoris and hamstrings, can be carried out. The training intensity is moderate, and the training time each time can be increased to 30–40 minutes.

The third stage (8–12 weeks after surgery and beyond): The goal is to restore motor function and improve athletic performance [6]. At this stage, some functional training, such as wall squats, step exercises, and single-leg balance, can be carried out, but attention should be paid to controlling the intensity and difficulty. At the same time, some badminton-specific training, such as net shot exercises and racket swinging exercises, can be gradually introduced. The training intensity is high, and the training time each time can reach 45–60 minutes. However, during the training process, close attention should be paid to physical reactions. If any discomfort occurs, the training plan should be adjusted promptly.

Table 1. Rehabilitation training plan

Training items	Training contents	Training steps	Step 1	Step 2	Step 3
Treatment	Physical therapy	Ultrasound, etc.	√	√	√
	Myofascial release	Large muscle groups of the lower limbs	√	√	√
	Joint mobilization	Knee joint flexion and extension angle	√	√	√
Activation training	Muscle activation	Hip perimeter activation	√	√	√
		Activation of small muscles in the lower limbs	√	√	√

Table 1 (Continued)

Training items	Training contents	Training steps	Step 1	Step 2	Step 3
Balance and stability	Static balance	Static balance		√	√
		Unstable plane training		√	√
	Dynamic balance	Soft cushions, bosu balls		√	√
		Weight-bearing stability		√	√
Functional recovery	Movement patterns	Correction of lower limb force line			√
		Jumping and landing patterns			√

5. Conclusions

This study focuses on the formulation of sports protection and training plans for badminton players recovering from ACL surgery. By analyzing the risk factors in badminton that may cause re-injury to the knee joint, personalized training plans are developed, with the training intensity, frequency, and content being gradually adjusted to ensure that athletes can restore their best sports state under safe conditions.

In terms of sports protection, correcting incorrect sports postures, such as avoiding excessive knee flexion and excessive toe abduction, can effectively reduce the risk of knee joint injuries. Reasonably controlling exercise intensity and frequency and avoiding overtraining are also the keys to preventing reinjury.

In terms of the training plan, rehabilitation training should be carried out in stages. In the early stage, the focus is on controlling swelling and pain and protecting the surgical site, with passive joint mobility training and simple muscle activation training. In the middle stage, joint mobility and muscle strength are increased, with active joint mobility training and light resistance training. In the later stage, motor function is restored and athletic performance is improved, with functional training and badminton-specific training. At the same time, the training intensity and frequency are gradually adjusted according to the recovery progress, following the principles of gradual progress and individual differences.

In conclusion, through scientific and reasonable sports protection measures and training plans, badminton players recovered from ACL surgery can quickly restore their best sports state under safe conditions, reduce the risk of re-injury, and continue to pursue their dreams on the badminton court.

Disclosure statement

The author declares no conflict of interest.

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