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Common Knee Injuries and Preventive Measures for Adolescent Badminton Players During Training

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Abstract: In recent years, an increasing number of enthusiasts have embarked on badminton, particularly adolescents who have chosen as a career path in hopes of achieving excellent results on the court. However, due to variations in badminton coaching standards and differing instructional philosophies, many adolescent badminton players are repeatedly plagued by various injuries throughout their careers, with lower limb injuries being particularly prevalent (accounting for approximately 58% of all injuries). Among these lower limb injuries, more than half involve the ankles and knees, significantly impacting their careers. This paper focuses on common knee injuries experienced by adolescent badminton players, such as anterior cruciate ligament tears, meniscus injuries, and muscle strains. To effectively prevent these injuries, a series of scientific and systematic training recommendations are proposed. These include functional training of the muscles surrounding the knee joint, such as single-leg Romanian deadlifts and Bulgarian split squats, which help improve knee stability and thereby reduce the risk of injury. Additionally, functional training of the core deep stabilizing muscles, such as diaphragmatic breathing exercises and the Dead Bug exercise based on diaphragmatic breathing, is recommended to enhance the strength and stability of the core musculature and improve body balance, thereby lowering the incidence of knee injuries and achieving preventive effects. The aim is to provide effective preventive measures for knee injuries to adolescent badminton players, reducing their risk of injury and promoting the healthy development of the careers, provide a useful reference for scientific training and rehabilitation in badminton.

Keywords: Badminton, adolescent, knee injuries.

1. Introduction

Badminton, as a highly anticipated competitive event in the Olympic Games, has not only attracted numerous enthusiasts worldwide but has also become a popular sport among the masses in recent years, fueled by robust economic growth and people's increasing pursuit of health. At the family level, an increasing number of parents choose to introduce their children to badminton, aiming to enhance their physical fitness and athletic abilities. Consequently, a large number of adolescent badminton players have emerged, dedicating themselves to long and arduous professional training in hopes of shining on the competitive stage in the future.

However, the unique technical characteristics of badminton, involving numerous and frequent actions such as lunges, single-leg jumps, and rapid stops and turns, exert significant impact and strain

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on the lower limbs, particularly the knee joints [1]. A survey of knee injuries among adolescent badminton players in Wenzhou City revealed an injury rate exceeding 30% [2]. Additionally, statistics from hospital records of badminton players in New Zealand between 2006 and 2011 showed that the incidence of lower limb injuries reached 66%, with knee injuries accounting for as much as 65%, making them the most common injury site. Of particular concern, lower limb injuries among adolescents (aged 10-19) accounted for up to 22% [3].

Adolescent athletes are in the prime stage of growth and development, with imperfect neural coordination and muscle contraction balance mechanisms, unstable motor skills, weak muscles around the joints, loose ligaments, insufficient lower limb muscle strength, and poor joint stability. These intrinsic factors all contribute to their susceptibility to sports injuries. Furthermore, due to their relatively short training duration and insufficient competitive levels, adolescent badminton players often struggle to cope effectively with high-intensity and challenging training tasks, thereby further increasing their risk of injury. For adolescent badminton players, excessive injuries not only seriously impact their training and competition but may also have long-term negative effects on their growth and development. Therefore, conducting in-depth research on common types of knee injuries and their causes in badminton training, and exploring scientific and effective preventive measures, is of great significance for ensuring the healthy growth and improving the competitive level of adolescent athletes.

This paper aims to analyze common types of knee injuries in adolescent badminton training and elaborate on their risk factors. Based on the injury mechanisms, it provides a series of scientific and effective training programs to offer proactive preventive measures for reducing knee injuries, thereby laying a solid foundation for the healthy growth and athletic development of adolescents.

2. Causes of common knee injuries

2.1. Technical characteristics of badminton movements

The technical characteristics of badminton involve rapid turns, stops, and numerous sudden changes in speed to gain an advantage on the court. Additionally, movements such as lunges and single-leg jumps are commonly used techniques in badminton [4]. Research has shown that lunges can lead to anterior tibial translation and significant tibial internal rotation [5]. Large-scale tibial internal rotation may result in severe muscle strains and increase the potential risk of knee injuries [6]. On the other hand, large-scale tibial internal rotation can also cause femoral external rotation to counteract the internal rotational force, leading to prolonged tension in the gluteus maximus and gluteus medius muscles, which can result in muscle fatigue. Under such circumstances, if the training load is heavy, muscle compensation is highly likely to occur, leading to muscle strains. Furthermore, when large-scale tibial internal rotation is combined with femoral external rotation, it generates a significant torque on the knee joint, placing considerable stress on the cruciate ligaments and meniscus, thereby greatly increasing the risk of cruciate ligament ruptures and meniscus tears.

The repeated use of these movements and the cumulative pressure on the knee joint can lead to various overuse injuries, such as patellar tendinopathy or patellofemoral pain syndrome [7,8]. For adolescent badminton players, whose muscles, bones, and nervous systems are not fully developed, these factors significantly elevate the risk of knee injuries.

2.2. Excessive training volume and intensity

Research indicates that there is still no consensus on the optimal training volume and training intensity distribution (TID) for elite athletes [9]. For non-professional athletes, achieving this ideal state is even more challenging.

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In traditional training paradigms, coaches often adhere to the belief that more training leads to greater ability. When planning training sessions, they tend to maximize the training load to fully tap into the athletes' physical potential. This often leads coaches to overlook the importance of training intervals, resulting in excessively short recovery periods. During training, athletes' muscles and energy systems (glycogen) do not have sufficient time to recover, and the energy supply gradually shifts from aerobic to anaerobic metabolism. Consequently, athletes experience muscle lactate accumulation, muscle soreness, and a rapid increase in fatigue [10].

Among adolescent badminton players, whose muscles and bones are not fully developed, the risk of sports injuries significantly increases when they are in a state of high physical fatigue. For instance, they may experience leg weakness during lunging movements, leading to ankle sprains. As previously mentioned, muscle strains, particularly in the hamstrings, are also common when muscles are highly fatigued. Most seriously, muscle fatigue can compromise knee stability. When performing lunging movements, the torque on the knee joint becomes more intense, potentially causing irreversible damage to the cruciate ligaments and meniscus.

2.3. Inadequate recovery

During training, muscles often experience fatigue and soreness. Failure to provide sufficient recovery and rest periods can adversely affect glycogen synthesis and storage rates, inflammatory processes, and metabolic balance. Specifically, if muscles are not properly relaxed and recovered after training, they may remain tense or even become stiff during the next day's training, leading to decreased muscle elasticity and reduced joint flexibility. For example, performing numerous lunges, step-overs, and other movements can cause frequent contraction of muscles such as the hamstrings, gluteal muscles, and quadriceps, resulting in muscle tension and stiffness.

Furthermore, muscle soreness may also impact athletes' sleep quality, preventing the body from obtaining adequate rest and recovery. If pre-training fatigue is not fully resolved and daily warm-up activities lack appropriate adjustments, it will be difficult to effectively activate the muscles and allow them to function optimally. This not only affects athletes' mental state but also increases their physical fatigue index, subsequently reducing athletic performance.

Additionally, if training intensity and volume are not adjusted accordingly to provide athletes with sufficient rest and buffer periods, muscle fatigue and tension will gradually accumulate, creating a vicious cycle. In such cases, the risk of knee injuries significantly increases.

In summary, reasonable recovery and rest arrangements, adequate warm-up activities, and scientific adjustments to training intensity and volume are crucial for preventing muscle fatigue and soreness and reducing the risk of sports injuries.

2.4. Unscientific configuration of coaching teams

From the perspective of sports medicine, an efficient and comprehensive coaching team typically encompasses a diverse range of professional roles, including head coaches, physical trainers, physiological and biochemical analysts, rehabilitation specialists, physiotherapists, nutrition consultants, and others. These professionals each fulfill their respective duties, collectively providing athletes with comprehensive support from training to recovery. However, for non-professional adolescent badminton players, assembling such a complete coaching team is nearly impossible. Consequently, crucial tasks such as optimizing athletic performance, preventing and recovering from muscle injuries, monitoring sleep quality, adjusting nutritional intake, and maintaining mental well-being can only rely on coaches and athletes themselves.

Adolescent badminton players often lack comprehensive and scientific knowledge regarding training methods and recovery strategies. Therefore, they need to invest more time and effort in

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studying how to improve performance on the court, how to translate daily training into winning strategies in competitions, and how to devise countermeasures against opponents with different characteristics.

Meanwhile, coaches also face significant challenges. In the absence of professional equipment and team support, it is difficult to comprehensively and accurately monitor athletes' physiological and biochemical indicators, such as blood lactate concentration and heart rate changes, thereby making it challenging to develop personalized training plans and recovery strategies. Furthermore, due to the large number of athletes and limited number of coaches, coaches often struggle to accommodate the individual differences and needs of each athlete in practical operations, resulting in a significant reduction in training effectiveness.

Therefore, a complete and scientific training team is crucial for the growth and development of adolescent badminton players. It can provide athletes with comprehensive and professional training guidance and recovery support, helping them better cope with the challenges in training and competitions, reducing the risk of sports injuries, and improving athletic performance levels. In situations where it is not feasible to assemble a complete team, it is necessary to integrate existing resources as much as possible, strengthen the professional training of coaches and athletes, and enhance the scientificity and effectiveness of training. Additionally, modern technological means, such as remote monitoring and data analysis, can be considered to compensate for the lack of team resources.

3. Prevention measures

In response to the aforementioned common causes of knee injuries, the following are recommendations for preventive measures tailored to adolescent badminton players.

3.1. Enhancing the function of key muscle groups

In badminton, technical movements such as lunges and step-over strides place significant demands on the functionality of athletes' gluteal muscles, hamstrings, and quadriceps. To enhance the function of these crucial muscle groups and strengthen knee joint stability, a series of scientific and systematic functional training programs have been designed in this paper.

Firstly, to improve knee joint stability and strength, a range of specific strength training exercises such as single-leg hard pulls, bulgarian split squats, squats, and half squats can be arranged. These exercises not only strengthen the muscles surrounding the knee joint but also improve joint flexibility and stability, thereby effectively preventing acute injuries and chronic strains during exercise. Meanwhile, coaches can personalize and optimize the training exercises based on individual differences among athletes, such as muscle strength, flexibility, and coordination, to maximize training effectiveness.

Secondly, to further enhance knee joint stability and coordination in different directions, training tools like bosu balls, yoga balls, and soft mats can be utilized to introduce instability into the training. These tools simulate the complex terrains and movement variations encountered during competitions, enhancing athletes' adaptability and balance. For instance, conducting footwork training on soft mats or sand beaches can exercise athletes' mobility and stability on different surfaces. Performing balance exercises on a bosu ball with one leg and engaging in single-leg hopping drills (including left-right and forward-backward directions) can exercise knee joint stability and coordination in various directions, further improving athletes' performance.

Furthermore, the stability of the core muscle group is also crucial for overall athletic performance. In particular, the deep core stabilizer muscles, such as the diaphragm, transverse abdominis, pelvic floor muscles, and multifidi, when strengthened, can improve athletes' stability and endurance during

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competitions. Core muscle training can be divided into two stages: basic training and advanced training. Basic training includes movements like abdominal breathing exercises, the dead bug, and the superman pose, aimed at activating and strengthening the basic functions of the core muscles. Advanced training, utilizing unstable factors like bosu balls and yoga balls, involves exercises such as plank holds and side planks, further improving core muscle stability and coordination while enhancing athletes' core strength and explosive power. During the training process, athletes' training responses should be closely monitored and evaluated to promptly identify and correct any abnormal movement patterns or muscle imbalances.

When scheduling these training sessions, full consideration should be given to athletes' individual differences and training needs. Generally, the training plan can be divided into 2-3 sessions per week, with each session lasting between 1.5 and 2 hours. One session can focus on functional training for large muscle groups and knee joint stability training, while another can focus on core muscle training and further enhancement of knee joint stability. Additionally, based on athletes' training progress and physical condition, the content and intensity of the training plan should be adjusted in a timely manner to ensure maximum training effectiveness.

Such training arrangements can effectively enhance badminton athletes' muscle function and knee joint stability, providing robust support for adolescents to excel in competitions. Simultaneously, they can strengthen athletes' core strength, coordination, and endurance, laying a solid foundation for long-term development. Moreover, they can significantly reduce athletes' risk of injuries during training and competitions, enhancing their athletic longevity and competitive level.

3.2. Rational training program arrangement

In the training process of adolescent athletes, coaches play a crucial role, as they need to scientifically and rationally devise training programs based on the athletes' actual capabilities. To ensure the effectiveness and safety of training, coaches must comprehensively consider multiple factors to accurately assess whether the training volume is appropriate and adjust the training plan in a timely manner.

Firstly, when observing signs such as movement distortion, decreased coordination, muscle tremors, or obvious fatigue among most athletes during training, these may be direct indications of excessive training volume. These phenomena are often associated with muscle fatigue, energy depletion, and central nervous system inhibition. Therefore, coaches should closely monitor athletes' training performance, promptly capture these signals, and adjust the training intensity and duration accordingly.

Secondly, athletes' subjective feelings are equally important. When most athletes express feelings of fatigue, it often means that their bodies have already borne significant training loads and require more rest and recovery time. Meanwhile, even if only a few athletes express fatigue, coaches should pay sufficient attention, as this may reflect individual differences or potential health issues. In such cases, coaches can make slight adjustments to individual athletes' training programs to ensure their training loads match their capabilities.

To effectively manage training loads, coaches also need to focus on athletes' rest and recovery time. During training, rest periods allow athletes to engage in brief recovery and adjustment, thereby avoiding overtraining and the occurrence of sports injuries. Additionally, sufficient intervals should be left between training sessions to enable athletes to fully recover their physical strength and prepare for the next stage of training. The arrangement of these rest and recovery periods should be comprehensively considered based on factors such as athletes' individual differences, training goals, and competition schedules.

Furthermore, the arrangement of exercise intensity is also a vital aspect of the training plan. Coaches should allocate high, medium, and low-intensity training days based on the arrangement of

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rest days and the proximity of competition days. Through scientific and reasonable intensity arrangements, not only can athletes' training effectiveness be improved, but the risks of overtraining and sports injuries can also be effectively avoided. Additionally, coaches should understand the impact of different intensity levels on athletes' physical functions to better formulate personalized training plans.

Lastly, to ensure athletes' physical and mental well-being and training effectiveness, coaches also need to supervise athletes' muscle relaxation and sleep quality after training. Athletes must ensure their muscles are adequately relaxed and obtain sufficient sleep time to facilitate body recovery and repair. This can be achieved through professional relaxation techniques, massages, hot compresses, and other methods. At the same time, sleep quality can be improved by adjusting sleep habits and optimizing the sleep environment.

In summary, when devising training programs for adolescent athletes, coaches should comprehensively consider athletes' capabilities, the assessment of training volume, the arrangement of rest and recovery time, the rational allocation of exercise intensity, as well as muscle relaxation and sleep quality. By formulating more scientific, reasonable, and personalized training plans, a solid foundation can be laid for the long-term development of adolescent athletes.

3.3. Adequate recovery and rest

Recovery strategies and rest strategies constitute two indispensable components in the post-training recovery process of athletes [11].

Firstly, recovery strategies are subdivided into active recovery and passive recovery. Active recovery, such as jogging, light walking, and targeted stretching exercises, facilitates recovery by promoting blood circulation and gentle activity of muscle fibers. These activities help accelerate lactate metabolism and reduce muscle stiffness, thereby enhancing the overall recovery effect for athletes. Passive recovery, on the other hand, includes external interventions like massage, compression wear, and cold and hot compresses. For adolescent badminton athletes, methods such as foam rolling, professional massage techniques, and full-body stretching exercises are recommended. These methods are not only easy to operate and require minimal equipment but also offer high cost-effectiveness, making them well-suited for widespread promotion within adolescent badminton teams. Additionally, athletes should engage in muscle relaxation activities for at least 30 minutes after each day's training. For those with higher muscle tension, relaxation time should be appropriately extended based on individual circumstances to achieve optimal recovery effects.

Secondly, the issue of sleep within rest strategies deserves equal attention. Sleep is not only a crucial stage for physical rest and recovery but also a vital period for athletes to adjust their physical fitness and competitive status. During sleep, the body releases various growth hormones and hormone-regulating substances, such as human growth hormone (HGH) and insulin-like growth factor (IGF-1), which play important roles in promoting protein synthesis, repairing damaged muscle tissue, and enhancing immune function. Adequate sleep also helps replenish muscle glycogen reserves, providing a stable energy source for athletes. Furthermore, increased testosterone levels during sleep contribute to muscle growth and strength enhancement, while the release of anti-inflammatory cytokines and antioxidants helps reduce inflammation and oxidative stress responses, further promoting body recovery [12].

Therefore, it is strongly recommended that adolescent athletes ensure at least 8 hours of quality sleep per day. This not only promotes physical recovery and growth and development but also enhances competitive performance and mental health. To achieve this goal, coaches and athletes should work together to develop scientific sleep schedules, avoiding the negative impacts of overtraining and unhealthy habits on sleep quality. Meanwhile, coaches should strengthen

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supervision and guidance for athletes, raising their awareness of health and recovery, and ensuring they fully recognize the importance of muscle relaxation and adequate sleep after training.

In summary, by comprehensively utilizing both active and passive recovery methods and optimizing sleep strategies, a comprehensive and scientific recovery program can be provided for adolescent badminton athletes. This will not only improve the competitive level but also promote healthy growth and long-term development.

4. Conclusion

Badminton, as a sport that demands both high-level skills and physical fitness, poses significant challenges to the knee joints of adolescent badminton players, a fact that cannot be overlooked. This necessitates the enhancement of related muscle groups during training for these athletes to improve their athletic abilities and effectively reduce the risk of sports injuries.

When undergoing professional training, adolescent badminton players require not only technical and capability guidance from professional coaches but also comprehensive support from a scientific and professional sports technology team, which includes physiotherapists, rehabilitation specialists, physical fitness coaches, physiological and biochemical testers, and other personnel.

Ultimately, to ensure a healthy and effective athletic career for adolescent badminton players, it is not only essential for the athletes themselves to train diligently but also crucial for coaches to adopt a systematic approach, encompassing the coordinated development of badminton skills training, functional training, rest arrangements during training, post-training rehabilitation, on-court strategy planning, and mental preparation. Only through such comprehensive efforts can adolescent badminton players continuously grow and progress within a healthy and effective athletic career.

In summary, scientific training methods and comprehensive rehabilitation support can create a healthy and effective training environment for adolescent badminton players, laying a solid foundation for their future development.

The prevention of sports injuries among adolescent badminton players is a long-term and arduous task, necessitating further exploration into personalized and targeted training and rehabilitation plans for athletes. Additionally, there is a need to address the current situation where athletes and coaches lack adequate rehabilitation awareness and scientific training arrangements. Furthermore, efforts should be made to promote the awareness of scientific training and active rehabilitation among the general population. It is hoped that these aspects will receive greater attention in the future, with more research providing practical and theoretical foundations for the further development of injury prevention among adolescent badminton players, driving the sport towards greater professionalism and scientific rigor.

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