

Research Progress on Rhythmic Gymnastics-Specific Training and Meniscal Injuries in Athletes

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Abstract

Rhythmic gymnastics is a competitive sport characterized by technical difficulty and aesthetic expression, requiring flexibility, balance, coordination, and explosive power. In sport-specific training, a large number of jumping, rotation, landing, knee bending and other movement modes make athletes' knee joints bear high load, high shear force and impact for a long time. Meniscal injury has become a high-incidence type of sports injury in rhythmic gymnastics. This article summarizes the pathogenesis characteristics, injury mechanism of sport-specific training, new training intervention methods and rehabilitation treatment research progress of rhythmic gymnastics athletes by reviewing the literature on sport-specific training, epidemiology of sports-related meniscal injury, injury intervention and rehabilitation training in recent years. It analyzes the shortcomings of current research and looks forward to the future research direction, aiming to provide theoretical reference for sport-specific injury prevention, scientific training, and injury rehabilitation in rhythmic gymnastics.

Keywords

rhythmic gymnastics, sport-specific training, meniscal injury, sports injury, rehabilitation intervention

1. Introduction

Rhythmic gymnastics takes the completion of various difficult technical movements with bare hands or hand-held equipment as the core, which has very high requirements for the joint stability, limb control ability and joint flexibility of athletes [1]. The meniscus is a fibrocartilaginous structure between the tibia and the femur of the knee joint. It plays an important role in shock absorption, load distribution, maintenance of knee stability, and reducing joint wear. It is the core protective structure for the motor function of the knee joint. Unlike conventional sports, rhythmic gymnastics-specific training includes a large number of specific movements such as continuous rotation, airborne jumps, single-leg landings, and deep knee flexion, etc. The knee joint continues to be under force in the state of repeated bending and extension, twisting and weight-bearing. As an important cushioning and stabilization structure of the knee joint, the meniscus is very prone to chronic strain or acute injury [2]. Meniscal injury will not only directly reduce the training quality and competitive level of athletes, but also may even end an athlete's competitive career in severe cases. At the same time, it is easy to cause sequelae such as knee joint degeneration and joint pain [2].

In recent years, with the continuous improvement of the difficulty of rhythmic gymnastics competition, the intensity and training density of sport-specific training have continued to increase, and the risk of lower limb sports injuries of athletes has increased significantly. The prevention, treatment and rehabilitation of meniscal

injury have become a research hotspot in the fields of sports training and sports medicine. At present, domestic scholars have carried out a lot of research on the epidemiological characteristics of meniscal injury, special balance training in rhythmic gymnastics, strength training, injury intervention and rehabilitation treatment of meniscal injury [1, 3]. This article systematically integrates the existing research results, sorts out the intrinsic relationship between the sport-specific training of rhythmic gymnastics and meniscal injury, summarizes the research progress of injury prevention and control and rehabilitation means, and provides a basis for the construction of a scientific and safe rhythmic gymnastics sport-specific training system.

2. Epidemiology and Pathogenesis of Sports-Related Meniscal Injuries

2.1 Epidemiological Characteristics of Sports-Related Meniscal Injuries

Yang Yuan et al. [2] carried out epidemiological research on sports-related meniscal injuries through systematic evaluation, clarifying the high-incidence movement mode, susceptible population and age characteristics of this kind of injury, and providing an epidemiological basis for the study of meniscal injury of rhythmic gymnasts. Judging from the injury-induced action, the incidence of sports-related meniscal injury is concentrated in competitive sports that require frequent knee bending, rapid rotation, jumping, and weight-bearing landing. Such repetitive and high-load lower limb torsion and impact movements are the core triggers of sports-related meniscal injuries. In terms of the incidence of the disease, female athletes and adolescent athletes are the core susceptibility groups, and the injury detection rate is significantly higher than that in the general physically active population and adult male athletes. From the analysis of age characteristics, athletes who begin sport-specific training at an early age and train systematically for a long time have a higher risk of injury. The continuous load of the knee joint brought about by children's early sport-specific training will gradually increase the probability of chronic meniscal injury. According to the epidemiological characteristics of rhythmic gymnastics, it is shown that the meniscal injuries of athletes in this event are mainly chronic strain-type injuries, and the proportion of acute traumatic injuries is relatively low. The injuries are mostly caused by the accumulation of chronic risk factors such as long-term irregular sport-specific movements, weak core stability of the lower limbs, and insufficient landing buffer control ability, which is consistent with the injury patterns observed in adolescent female athletes undergoing specialized training.

Wang Jingzhi et al. [3] further supplemented the clinical research progress of meniscal injury and concluded that sports-related meniscal injury is often accompanied by complications such as knee synovitis, limited joint mobility, decreased muscle strength, etc. If not intervened in time, it will gradually develop into chronic knee injury, which will seriously affect athletes' athletic longevity. Compared with ordinary athletes, rhythmic gymnasts have higher requirements for knee joint function. Slight meniscal injury can significantly affect the completion quality of special technical movements such as rotation and jumping, and the harmfulness of injury is more prominent.

2.2 Core Mechanisms of Meniscal Injuries Induced by Rhythmic Gymnastics-Specific Training

The specificity of the movement of the sport-specific training of rhythmic gymnastics is a key factor that induces meniscal injury. First of all, the project training includes a large number of single-leg supported rotations, jump turns, and split-leap landings and other movements. Under the weight of one leg, the knee joint is in a state of flexion and internal or external rotation, and the meniscus will withstand huge shear stress and vertical pressure. Repeated loading over a prolonged period can lead to the accumulation of microdamage in the meniscal fibrocartilage, eventually resulting in degeneration and tears [1]. Secondly, the physical development of young rhythmic gymnasts is immature, and the structural stability of bones, cartilage and ligaments is insufficient. Premature and excessive specialized training will aggravate the load on the knee joint and greatly increase the risk of meniscal injury [1].

At the same time, Insufficient lower-limb balance, ankle stability, and core strength are important indirect risk factors for injury. In the process of completing the special action, if the ankle control ability is weak and the trunk stability is insufficient, it will lead to altered knee alignment when landing and rotating, the joint force is uneven, and the local stress is concentrated on the meniscus, which will cause long-term accumulation of injury [4]. The study by Guan Di [5] also confirms that the imbalance of trunk strength will lead to

compensatory loading of the lower limbs, which will not only cause lower back pain, but also indirectly increase the mechanical load on the knee joint and meniscus, which is an important cause of lower limb injury in rhythmic gymnasts.

3. Research Progress on Rhythmic Gymnastics-Specific Training Interventions and Injury Prevention

In recent years, domestic scholars have focused on the optimization of the physical conditioning of rhythmic gymnasts and explored the effect of various new training methods on the improvement of athletes' body control ability. They aim to address athletes' physical weaknesses through scientific sport-specific training, reduce the compensatory force of the knee joint, and thus reduce the risk of lower-limb injuries, including meniscal injuries. Relevant research mainly focuses on balance ability training, stability strength training, functional intervention training, etc.

3.1 Research on Sport-Specific Balance Training

Balance ability is the core foundation for rhythmic gymnasts to complete various rotations, jumps, and static balance elements. Good balance ability can effectively optimize the movement mechanics of the lower limbs, reduce the abnormal force on the knee joint, and reduce the risk of meniscal injury. At present, the research results of sport-specific training for the balance ability of rhythmic gymnasts are relatively rich, forming a diversified training system.

Gan Zhiyi [6, 7] successively explored the impact of Pamela leg training on the balance ability of students specializing in rhythmic gymnastics. A controlled experiment was conducted among students specializing in rhythmic gymnastics at Shanghai University of Sport. The results showed that the Pamela leg training can effectively strengthen the muscle strength of the lower limbs, improve the control ability of ankle and knee joints, significantly improve the static and dynamic balance ability, effectively correct the body posture of athletes when landing and rotating, reduce the stress concentration of the knee joint, and provide new training ideas for the prevention of meniscal injury. Cao Yejiao [8] studied the intervention effect of BOSU ball training and found that unstable plane training can activate the deep stabilizing muscles of the lower limbs, improve the neuromuscular control ability of athletes, enhance the dynamic stability of the knee joint, and reduce the risk of injury in sport-specific movements. Jiang Linfei [9] confirmed through the TRX suspension training experiment that suspension resistance training can effectively improve the core control and lower limb balance ability of rhythmic gymnasts, and optimize the sport-specific movement mechanics. Li Zhaoxin [4] carried out targeted research on ankle stability strength training, making it clear that ankle stability is the basis for proper lower-limb kinetic chain function. Strengthening the ankle strength can effectively reduce the compensatory force of the knee joint and thereby reduce the risk of chronic meniscal strain.

3.2 Functional Training and Injury Prevention Interventions

Functional training is an important means to prevent sports injuries for rhythmic gymnasts. Unlike conventional isolated strength training, functional training is more suitable for the sport-specific movement mode, focusing on the overall coordination of the body and the improvement of joint stability. Li Xuerui [1] specifically carried out functional training intervention research on the risk of sports injuries for young rhythmic gymnasts. Li Xuerui found that systematic functional training can effectively improve the problems of lower limb muscle imbalance and weak body control of children's athletes, significantly reduce the incidence of sports injuries at injury-prone sites such as the knee and ankle, and have a good preventive effect on chronic meniscal strain. The study clarifies the importance of scientific sport-specific training in children and provides a practical basis for the prevention and control of injuries in youth rhythmic gymnastics training.

In addition, the bilateral trunk training research of Guan Di [5] confirms that trunk core stability training can improve the asymmetry of athletes' trunk muscle strength, reduce the compensatory force of the lower limbs, avoid the excessive load on the knee joints caused by the imbalance of body posture, indirectly reduce the risk of meniscal injury, and improve the injury prevention and control system of rhythmic gymnastics athletes' whole-body coordinated training.

4. Research Progress on Rehabilitation and Treatment of Meniscal Injuries in Rhythmic Gymnasts

In response to sports-related meniscal injury, diversified intervention plans such as rehabilitation training, physical therapy, and combined treatment of traditional Chinese and Western medicine have been formed in the field of clinical and sports rehabilitation at this stage, which provide support for the functional recovery and return to sport after injury.

Guo Yangyang and Jia Ning [10] specifically explored the rehabilitation training plan for patients with knee meniscal injury, and put forward a phased rehabilitation training model. In the acute stage, it is mainly to reduce swelling, relieve pain, and protect the meniscus. In the recovery period, it focuses on knee muscle strengthening, restoration of joint range of motion, and balance retraining. The training system is adapted to the sport-specific demands of rhythmic gymnasts, which can effectively help injured athletes restore knee joint function and avoid injury recurrence. Wang Ping [11] verified the therapeutic effect of floss band therapy combined with electroacupuncture on chronic meniscal injuries. Research shows that the combination of traditional Chinese and Western medicine can effectively improve the blood circulation of the knee joint, relieve muscle spasms, repair damaged cartilage tissue, improve the overall function of the knee joint, and provide a new treatment for the clinical rehabilitation of chronic meniscal strain in rhythmic gymnasts.

The review research of Wang Jingzhi and others [3] further summarized the latest treatment progress of meniscal injury, pointing out that for mild and moderate meniscal injuries in physically active individuals, the effect of conservative rehabilitation intervention combined with sport-specific functional training is better than a single treatment method. While repairing the injury, it can reshape the muscle strength and joint stability of the lower limbs, adapt to the high-intensity and high-difficulty sport-specific training needs of rhythmic gymnastics, and provide theoretical support for scientific rehabilitation after injury.

5. Limitations of Existing Research and Future Perspectives

5.1 Limitations of Existing Research

A review of the existing literature reveals that there are still certain limitations in the current domestic relevant research. First, the existing research focuses mostly on the balance ability of rhythmic gymnasts and the effect of lower limb strength training. There are few studies on the specific mechanisms linking sport-specific movements to meniscal injuries, and there is a lack of quantitative analysis of the stress characteristics of the meniscus during sport-specific movements of varying difficulty and under different training loads. Second, the research on injury intervention is mainly based on universal sports rehabilitation schemes, and the personalized meniscal injury prevention and rehabilitation system for athletes of different ages has not been perfected. Third, the existing epidemiological research is mostly for the analysis of the overall sports population, and there is a lack of special research on the incidence of meniscal injuries, injury grading and recurrence characteristics of rhythmic gymnasts.

5.2 Future Research Directions

Future research can be promoted in depth from three directions. First, using biomechanical techniques, quantitatively analyze knee joint loading and meniscal stress distribution of core sport-specific movements such as rhythmic gymnastics rotation, jumping and landing, and accurately reveal the injury mechanism of sport-specific training. Second, combine the physical development and training characteristics of different groups of children, adolescents and professional athletes to develop a stratified and individualized meniscal injury prevention training system and rehabilitation plan. Third, further investigate the effectiveness of novel training methods and rehabilitation therapy combining traditional Chinese and Western medicine in the prevention and control of meniscal injuries of rhythmic gymnasts, forming a scientific system of the whole process of “training-prevention-injury-rehabilitation-returning to training”, which provides support for the safe and scientific training development of rhythmic gymnastics.

6. Conclusion

The action specificity and high-intensity characteristics of rhythmic gymnastics sport-specific training determine the high incidence and distinct characteristics of meniscal injuries in athletes. Current research has made it clear that the balance ability, core stability and abnormal sport-specific movement mechanics of the lower limbs are the core triggers of meniscal injury. All kinds of new functional training and balance training can effectively reduce the risk of injury. Combined treatment of traditional Chinese and Western medicine and phased rehabilitation training can effectively promote the recovery of knee joint function after injury. However, at present, the research on the mechanisms and personalized prevention and control systems for rhythmic gymnastics-related meniscal injuries still need to be improved. In the future, based on the characteristics of sports, combined with the multidisciplinary theories of biomechanics, sports medicine and training, it is necessary to deepen research on sport-specific injury mechanisms, improve the injury prevention and rehabilitation system, and promote safe training and the long-term athletic development of rhythmic gymnasts.

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Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgment

This paper is an output of the science project.

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