

# The Prevalence and Management of Overuse Injuries Among Adolescent Swimmers in China

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## Abstract

Overuse injuries are a significant concern among adolescent swimmers, particularly in countries with growing competitive sports participation like China. This paper explores the prevalence, risk factors, and management of common overuse injuries such as swimmer's shoulder, patellofemoral pain syndrome (PFPS), and lumbar spine stress injuries. Adolescent swimmers are highly susceptible to these conditions due to their intense training regimens and ongoing physical development. The study emphasizes the importance of early diagnosis through clinical assessments and imaging, along with athlete monitoring systems for tracking injury risk. Effective management strategies, including short-term interventions like rest and physical therapy, and long-term approaches such as education and psychological support, are discussed. Finally, preventive measures focusing on optimizing training loads, improving stroke techniques, and promoting recovery practices are highlighted to reduce the risk of injury and support sustainable athletic performance.

**Keywords:** adolescent swimmers, overuse injuries, swimmer's shoulder, patellofemoral pain syndrome

## 1. Introduction

Competitive swimming has seen a remarkable surge in popularity among Chinese adolescents in recent years. This trend is fueled by a combination of factors, including increased government investment in youth sports, widespread public health campaigns, and the rising prominence of Chinese athletes on the international stage. Swimming is often perceived as a comprehensive form of exercise that not only promotes cardiovascular health but also enhances muscular strength and endurance. Consequently, many young athletes are encouraged to specialize in swimming from an early age, participating in intensive training

programs and competitions at local, national, and even international levels.

However, with this increased participation comes a corresponding rise in the incidence of overuse injuries, a growing concern in youth sports. Unlike acute injuries, which result from sudden trauma, overuse injuries develop gradually due to repetitive stress on specific body parts. In competitive swimming, the repetitive nature of stroke mechanics, coupled with high training volumes and inadequate recovery periods, places significant strain on muscles, tendons, and joints. Over time, this can lead to a range of injuries, including swimmer's shoulder, patellofemoral pain syndrome (PFPS),

and lumbar spine stress injuries.

The implications of these injuries extend beyond the immediate discomfort and functional limitations. For young athletes, such injuries can disrupt their athletic development, leading to periods of inactivity or even premature dropout from the sport. Furthermore, if not properly managed, overuse injuries can result in long-term health issues, such as chronic pain and early onset of osteoarthritis. From a performance perspective, injuries can hinder skill acquisition and compromise competitive results, affecting not only the individual athlete but also their team's overall performance.

Given these risks, understanding the prevalence and management of overuse injuries in adolescent swimmers is crucial. This research seeks to shed light on the underlying causes of these injuries, identify effective diagnostic and management strategies, and propose preventive measures that can be integrated into training programs. Addressing these issues is vital for safeguarding the health of young swimmers and ensuring their sustained success in competitive sports.

## **2. Common Overuse Injuries in Adolescent Swimmers**

### *2.1 Swimmer's Shoulder*

Swimmer's shoulder, a term commonly used to describe a spectrum of overuse injuries in the shoulder, is particularly prevalent among adolescent swimmers due to the high frequency and intensity of their training regimens. This condition encompasses several issues, including rotator cuff tendinitis, impingement syndrome, and biceps tendinopathy. The rotator cuff muscles and tendons play a crucial role in maintaining shoulder stability during repetitive overhead movements, which are central to swimming strokes like freestyle, butterfly, and backstroke. The constant repetition of these movements, often performed under high training loads, leads to microtrauma in the soft tissues, which, if not given adequate time to heal, accumulates and results in overuse injuries.

The risk of developing swimmer's shoulder is heightened during adolescence due to several biomechanical and physiological factors. During periods of rapid growth, imbalances between bone development and muscle strength are common. This can lead to a temporary decrease in joint stability and increase the likelihood of improper stroke mechanics. Poor stroke

techniques, such as crossing the midline during freestyle or inadequate body rotation, further exacerbate shoulder stress by forcing the rotator cuff to work harder to stabilize the joint. Additionally, inadequate warm-up routines and insufficient strength in the scapular stabilizers, which are essential for proper shoulder alignment, contribute to the onset of this condition.

Symptoms of swimmer's shoulder typically begin as mild discomfort that worsens with activity, particularly during overhead arm movements. Early signs include pain or a feeling of tightness in the front or side of the shoulder, reduced range of motion, and a decline in performance due to discomfort. As the condition progresses, swimmers may experience night pain, muscle weakness, and difficulty lifting the arm above the head. In severe cases, the injury can progress to chronic inflammation, rotator cuff tears, or even labral injuries, all of which require more intensive interventions and longer recovery periods.

Preventing swimmer's shoulder requires a multifaceted approach that includes both physical and technical strategies. Proper warm-up and cool-down routines, incorporating dynamic stretches and shoulder mobility exercises, are essential to prepare the muscles and joints for the demands of swimming. Strengthening programs that target the rotator cuff and scapular stabilizers can help build resilience against the repetitive stress of swimming. Furthermore, regular biomechanical assessments can help identify and correct faulty stroke techniques before they lead to injury. Coaches and medical professionals play a crucial role in monitoring training loads, ensuring swimmers do not exceed safe thresholds, and promoting adequate rest and recovery periods.

Early intervention is critical in managing swimmer's shoulder. Once symptoms appear, reducing training intensity and modifying stroke techniques to alleviate shoulder stress are immediate priorities. Physical therapy is often employed to address underlying muscle imbalances, improve flexibility, and restore full range of motion. In some cases, anti-inflammatory treatments, such as ice therapy or medication, may be recommended to reduce pain and swelling. Swimmers are encouraged to gradually return to full training only after symptoms have resolved and proper

mechanics have been re-established. Failure to address swimmer's shoulder promptly can lead to chronic issues, potentially ending an athlete's career prematurely. Therefore, ongoing education and injury prevention strategies are paramount for sustaining long-term athletic development in adolescent swimmers.

## 2.2 Patellofemoral Pain Syndrome (PFPS)

Patellofemoral pain syndrome (PFPS), commonly referred to as "runner's knee," is a prevalent overuse injury in adolescent swimmers, particularly those who specialize in strokes that heavily rely on kicking, such as the breaststroke. Although swimming is generally classified as a low-impact sport due to the reduced gravitational force on the joints, the repetitive nature of swimming motions still places considerable stress on specific areas of the body. In the case of PFPS, the repetitive flexion and extension of the knee joint during vigorous kicking motions lead to irritation and inflammation of the patellofemoral joint.

This joint, where the kneecap (patella) articulates with the femur, is especially prone to misalignment and uneven pressure distribution during repetitive activities. Improper technique, such as excessive outward splaying of the knees (valgus positioning) or inward motion (varus positioning) during breaststroke kicks, increases the mechanical load on the joint. This improper alignment can cause the patella to track incorrectly along the femoral groove, resulting in pain and dysfunction.

In adolescent swimmers, PFPS is often compounded by inherent physical factors such as muscular imbalances. Weakness in the quadriceps, particularly the vastus medialis oblique (VMO), or tightness in the hamstrings and iliotibial band, can disrupt the patellar tracking mechanism. Adolescents undergoing rapid growth spurts are particularly susceptible, as changes in bone length can outpace muscle development, further exacerbating joint instability.

The hallmark symptom of PFPS is anterior knee pain, which may worsen during swimming, particularly with breaststroke kicking, or after prolonged periods of inactivity, such as sitting with the knees bent. If not managed effectively, PFPS can progress to chronic knee instability, limiting an athlete's ability to participate fully in training and competition. Intervention strategies often include strengthening exercises aimed at

improving the muscular support of the knee joint, particularly focusing on the quadriceps and hip abductors. Stretching routines to enhance flexibility in the hamstrings and iliotibial band, as well as modifications in training load and technique, are also essential components of management. Rest and temporary reduction in training intensity allow the joint to recover and minimize inflammation, while the refinement of kicking techniques ensures proper alignment and reduces stress on the patellofemoral joint.

## 2.3 Lumbar Spine Stress Injuries

Lumbar spine stress injuries are increasingly recognized as a critical issue among adolescent swimmers, reflecting the high biomechanical demands placed on the lower back during specific strokes and training practices. These injuries primarily include stress fractures, such as spondylolysis, and disc-related conditions, such as bulging or herniated discs. The repetitive hyperextension of the lumbar spine, which occurs frequently in strokes like butterfly and freestyle, significantly contributes to these injuries. During these strokes, swimmers hyperextend their backs to maintain streamline positions and generate maximum propulsion, placing undue mechanical stress on the vertebrae and intervertebral discs.

Flip turns, an essential component of competitive swimming, and powerful starts off the blocks further amplify the compressive and shear forces exerted on the lumbar region. These dynamic movements require rapid flexion and extension, which, when performed repetitively without adequate recovery, increase the risk of microtrauma to the spinal structures. Over time, these microtraumas can accumulate, leading to more severe conditions such as spondylolysis—a stress fracture in the pars interarticularis of the vertebra. If left untreated, this can progress to spondylolisthesis, where one vertebra slips forward over another, causing instability and nerve impingement.

Adolescents are at heightened risk due to their ongoing skeletal development. Rapid growth during puberty can lead to imbalances between bone strength and muscular support, leaving the spine more vulnerable to stress injuries. Common symptoms include persistent lower back pain that is exacerbated by physical activity, particularly during swimming, and alleviated with rest. Swimmers may also experience

stiffness, reduced flexibility in the lower back, and in severe cases, nerve-related symptoms such as numbness or tingling in the lower extremities.

Managing lumbar spine stress injuries requires a comprehensive approach. Early diagnosis through clinical evaluation and imaging, such as MRI or X-rays, is crucial to prevent further progression. Treatment typically involves rest and cessation of activities that exacerbate the injury, allowing the affected structures to heal. Core-strengthening exercises are fundamental in improving spinal stability and distributing mechanical loads more effectively. Additionally, adjustments to training regimens, including reduced intensity and modified stroke mechanics, help minimize recurrent stress on the lumbar spine. Preventive strategies, such as regular monitoring of training loads and biomechanical assessments, are critical in reducing the long-term risk of spinal injuries and ensuring the overall well-being of adolescent swimmers.

### 3. Risk Factors

#### 3.1 Physical Growth and Muscle Imbalances During Adolescence

Adolescence is a critical period of physical development marked by rapid growth spurts and hormonal changes, which can significantly affect an athlete's musculoskeletal system. During this phase, bone growth often outpaces muscle development, resulting in temporary imbalances in strength and flexibility. This mismatch can lead to increased stress on joints, tendons, and muscles, making adolescent swimmers more susceptible to overuse injuries.

In swimming, the repetitive nature of stroke mechanics places high demands on specific muscle groups. For instance, the shoulder rotator cuff and scapular stabilizers are heavily utilized in all strokes, while the lower extremities endure substantial strain during kicks. When muscle imbalances occur—such as weak rotator cuff muscles coupled with tight pectoral muscles—the body compensates by relying on incorrect movement patterns. This not only diminishes efficiency but also heightens the risk of injuries like swimmer's shoulder or patellofemoral pain syndrome (PFPS).

Furthermore, the rapid changes in body proportions during adolescence can temporarily alter an athlete's biomechanics. Changes in limb length and joint angles can disrupt previously

established stroke techniques, increasing the likelihood of improper joint loading. Without appropriate adjustments to training and technique, these biomechanical shifts can further exacerbate the risk of injury. Recognizing and addressing these developmental factors through targeted strength and flexibility programs is crucial in minimizing injury risk during this vulnerable stage.

#### 3.2 High Training Volume and Poor Recovery Management

High training volume is a hallmark of competitive swimming, where adolescent athletes often spend several hours in the pool daily, completing thousands of strokes. While such rigorous training is necessary for skill and performance development, it also significantly increases the risk of overuse injuries. Repetitive motions, compounded by inadequate recovery periods, do not allow sufficient time for tissue repair and adaptation, leading to microtrauma accumulation in muscles, tendons, and joints.

Poor recovery management further exacerbates this issue. Many adolescent swimmers underestimate the importance of rest and recovery, often focusing solely on training intensity and frequency. Factors such as inadequate sleep, poor nutrition, and insufficient rest between training sessions hinder the body's ability to repair and strengthen itself. This not only compromises physical health but also leads to fatigue and decreased performance.

Moreover, external pressures from coaches, parents, and competitive environments often push young swimmers to prioritize performance over recovery. Ignoring early signs of discomfort or pain can result in chronic overuse injuries, forcing athletes to take prolonged breaks or even prematurely end their athletic careers. Implementing structured recovery protocols, including adequate sleep, balanced nutrition, and active recovery strategies, is essential for maintaining the health and performance of adolescent swimmers. Training programs should also incorporate periodization techniques to balance workload and recovery, ensuring long-term athletic development without compromising well-being.

### 4. Diagnostic and Monitoring Approaches

#### 4.1 Clinical Assessments and Imaging Tools for Early Detection



Early detection is a cornerstone of effective injury management in adolescent swimmers, as it helps prevent minor injuries from escalating into severe conditions. Clinical assessments form the first line of defense, relying on thorough physical evaluations conducted by sports medicine professionals. These assessments typically include a range of motion tests, strength evaluations, and pain response analyses. For instance, in diagnosing swimmer's shoulder, clinicians assess shoulder mobility, focusing on internal and external rotation, and examine scapular stability during dynamic movements. Painful arcs or signs of impingement during these tests often indicate early-stage overuse injuries.

Beyond physical examinations, specialized tests, such as the Neer and Hawkins-Kennedy impingement tests, can help identify shoulder pathologies. For patellofemoral pain syndrome (PFPS), clinicians may observe knee alignment during weight-bearing activities, such as squats or step-down tests, to identify improper patellar tracking or valgus knee positioning. Similarly, for lumbar spine stress injuries, physical assessments focus on spinal alignment, flexibility, and signs of localized tenderness along the lower back.

When clinical signs suggest more serious injuries or when a definitive diagnosis is required, imaging tools come into play. X-rays are commonly used for detecting bony abnormalities such as stress fractures, particularly in the lumbar spine (e.g., spondylolysis). For soft tissue injuries, more advanced imaging techniques like magnetic resonance imaging (MRI) and ultrasound are preferred. MRI provides a detailed view of muscles, tendons, and ligaments, enabling the detection of inflammation, partial tears, or other soft tissue damage. Ultrasound, on the other hand, is a cost-effective and dynamic imaging method, allowing real-time observation of soft tissue structures under load or movement.

Early identification through these methods is critical. By detecting injuries at their nascent stages, clinicians can implement targeted interventions, reducing recovery times and preventing chronic complications. Moreover, regular clinical check-ups, even in the absence of symptoms, can help uncover asymptomatic injuries, providing an opportunity for early management.

#### *4.2 Athlete Monitoring Systems for Tracking Injury Risk*

The evolution of technology in sports science has introduced advanced athlete monitoring systems, which are becoming essential tools in managing the health and performance of swimmers. These systems utilize a combination of wearable devices, software applications, and self-reported data to provide a comprehensive understanding of an athlete's workload, recovery status, and injury risk.

Wearable devices, such as heart rate monitors, GPS trackers, and motion sensors, are widely used to gather swimming-specific data. For instance, these devices can track key metrics like stroke count, stroke rate, lap time, and swimming velocity. This data offers insights into the efficiency and intensity of each training session. By analyzing trends over time, coaches can detect deviations from normal performance, which may indicate fatigue or the onset of overuse injuries.

In addition to performance metrics, modern wearable technology can monitor physiological indicators, such as heart rate variability (HRV), which reflects the body's recovery status. A consistent decline in HRV, for example, may signal overtraining or insufficient recovery, prompting adjustments to the training schedule. Some systems also measure sleep quality and duration, which are crucial for physical recovery and injury prevention.

Another key component of athlete monitoring is the collection of self-reported data, such as perceived levels of fatigue, muscle soreness, and stress. Many systems use mobile applications to allow athletes to log their subjective experiences daily. When combined with objective data from wearables, this self-reported information provides a holistic view of the athlete's condition, enabling personalized training and recovery plans.

The integration of these monitoring systems into regular training programs offers several benefits:

- 1) **Injury Prevention:** By identifying early warning signs, such as increased fatigue or changes in biomechanics, these systems allow for proactive interventions to prevent injuries before they occur.
- 2) **Performance Optimization:** Detailed

data on stroke mechanics and workload helps coaches refine training techniques and maximize performance.

- 3) **Data-Driven Decision Making:** Coaches and medical staff can make informed decisions about modifying training intensity, scheduling rest periods, or initiating rehabilitation based on real-time data.

Furthermore, athlete monitoring systems can be linked to broader team management platforms, facilitating communication between athletes, coaches, and healthcare providers. These platforms enable the tracking of historical data, allowing for longitudinal studies of injury trends and the effectiveness of various training and recovery strategies. As these systems continue to evolve, they will play an increasingly vital role in safeguarding the health and optimizing the performance of adolescent swimmers.

## 5. Management Strategies

Effective management of overuse injuries in adolescent swimmers requires a multifaceted approach that addresses both the immediate symptoms and the underlying causes. These strategies can be divided into short-term interventions for immediate relief and long-term measures aimed at preventing recurrence and promoting overall well-being.

### 5.1 Short-Term: Rest, Physical Therapy, and Gradual Return to Training

In the acute phase of an overuse injury, the primary focus is on reducing pain and inflammation while allowing the affected tissues to heal. Rest is a critical component of this process, as continued training or competition can exacerbate the injury, prolong recovery, and increase the risk of chronic complications. Depending on the severity of the injury, rest periods may range from a few days to several weeks. During this time, athletes are often advised to avoid specific movements or strokes that aggravate the injury, such as repetitive overhead arm motions in the case of swimmer's shoulder or breaststroke kicks for patellofemoral pain syndrome (PFPS).

Once the initial pain and inflammation subside, physical therapy plays a vital role in the recovery process. Physical therapy programs are tailored to the specific injury and athlete, often focusing on restoring flexibility, strength, and

stability. For example, therapy for swimmer's shoulder may include exercises to strengthen the rotator cuff and scapular stabilizers, as well as stretches to improve shoulder mobility. Similarly, for PFPS, exercises targeting the quadriceps, hamstrings, and hip abductors are commonly prescribed to enhance knee joint stability and alignment.

As the athlete progresses through physical therapy, the emphasis shifts to a gradual return to training. This phase involves reintroducing swimming activities at a reduced intensity and volume, carefully monitoring the athlete's response to ensure they do not experience a recurrence of symptoms. Coaches and physiotherapists collaborate to design a structured training plan that incrementally increases the workload, allowing the athlete to rebuild their endurance and performance capacity without risking re-injury. Throughout this process, ongoing communication between the athlete, coach, and medical team is essential to ensure a smooth and safe return to full training.

### 5.2 Long-Term: Education on Injury Prevention and Psychological Support

While short-term management focuses on immediate recovery, long-term strategies aim to address the root causes of overuse injuries and equip athletes with the tools they need to maintain their health and performance. Education on injury prevention is a cornerstone of this approach. Athletes, coaches, and parents are educated on the importance of proper technique, appropriate training loads, and the role of recovery in preventing overuse injuries. Emphasis is placed on the importance of warming up and cooling down, incorporating strength and flexibility training, and recognizing the early signs of overuse injuries.

In addition to physical health, the psychological well-being of adolescent swimmers is crucial for their long-term success. Overuse injuries can be mentally taxing, especially for young athletes who may feel frustrated by their inability to train or compete. Psychological support is therefore an integral component of long-term management. Sports psychologists or counselors can help athletes cope with the emotional challenges of injury, such as anxiety about losing fitness or fear of re-injury. They can also work with athletes to develop mental resilience and maintain motivation during the recovery

process.

Moreover, fostering a supportive environment within the team and family can alleviate the psychological burden of injury. Coaches play a pivotal role in maintaining open communication and encouraging a positive outlook, emphasizing that injury is a temporary setback rather than a permanent obstacle. By addressing both the physical and psychological aspects of recovery, long-term management strategies ensure that adolescent swimmers are not only physically ready to return to their sport but also mentally prepared to face future challenges with confidence.

## 6. Preventive Measures

Preventing overuse injuries in adolescent swimmers requires a comprehensive approach that addresses both physical and technical aspects of training. One of the most important strategies is optimizing training loads. Adolescent swimmers often face intense training schedules, with high volumes of repetitive movements that can lead to tissue fatigue. Periodization, a method of structuring training into phases of varying intensity and volume, helps balance workload and recovery. By incorporating lighter training phases and active rest periods, athletes can build strength and endurance without overburdening their musculoskeletal system. Additionally, cross-training is highly beneficial in diversifying the physical demands on the body. Activities like cycling or yoga engage different muscle groups, reducing the repetitive strain on the specific muscles and joints used in swimming.

Technical proficiency is another cornerstone of injury prevention. Improper stroke mechanics, such as poor shoulder alignment during freestyle or inadequate knee positioning in breaststroke, significantly increase the risk of overuse injuries. Regular biomechanical evaluations, including video analysis, can help swimmers and coaches identify and correct these technical flaws. Improving stroke efficiency not only enhances performance but also minimizes unnecessary stress on vulnerable areas like the shoulders, knees, and lower back. Core stability and body alignment also play crucial roles in maintaining proper biomechanics, ensuring that forces are evenly distributed across the body during swimming.

Recovery practices are equally critical in preventing injuries. Adequate sleep, hydration,

and nutrition are foundational elements that support tissue repair and energy replenishment. Active recovery techniques, such as light aerobic exercises, foam rolling, and stretching, promote blood flow and reduce muscle soreness. Swimmers should also be educated about the importance of listening to their bodies and recognizing early signs of overuse injuries, such as persistent discomfort or reduced performance. Encouraging open communication between athletes, coaches, and medical professionals fosters a culture where injury prevention is prioritized, allowing for early intervention when necessary.

Strength and flexibility training tailored to the demands of swimming further reduce the likelihood of overuse injuries. Exercises focusing on the rotator cuff, scapular stabilizers, and core enhance joint stability and muscular support, which are essential for sustaining repetitive movements in the water. Flexibility routines, including dynamic stretches before training and static stretches afterward, help maintain a full range of motion in critical joints. For swimmers, maintaining optimal shoulder, hip, and spinal flexibility is particularly important to avoid compensatory movements that can lead to injury. By implementing these measures, adolescent swimmers can not only improve their athletic performance but also sustain long-term participation in the sport with reduced risk of injury.

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