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Integrated Rehab Strategies for Shoulder Injuries in Swimmers

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Abstract. Shoulder injury is a common overuse injury among elite swimmers, especially in the high-load training strokes such as freestyle and butterfly. This paper analyzes the application mechanism of comprehensive rehabilitation programs in the rehabilitation of shoulder injuries in elite swimmers, and explores in depth the intervention mode of combining traditional physical therapy with functional training. The focus is on studying the role of this mode in restoring scapular control, core activation, proprioceptive sensation and sports-specific mechanics. The paper results of this article indicate that this comprehensive rehabilitation program can not only effectively improve chronic shoulder pain and functional impairment, accelerate the rehabilitation process, but also reduce the risk of reinjury, supporting the transformation of the sports rehabilitation field (especially for the swimmers) towards interdisciplinary, function based models that simultaneously consider the physiological and psychological factors of injury, which is of a great significance for improving rehabilitation effectiveness and sports performance.

Keywords: Shoulder rehabilitation, functional training, swimmers, overuse injury, neuromuscular re-education

1. Introduction

Shoulder pain remains one of the leading time-loss causes among elite swimming populations, with greater than 50% incidence among competitive swimming populations [1]. Athletes who undergo high-capacity training for a long time (60-70 kilometers per week) and repetitive head water strokes can gradually accumulate minimally invasive injuries in the rotator cuff and scapular muscle tissue, leading to a series of problems such as scapular movement disorders, joint instability, and limited range of motion (ROM). Especially for competitive swimmers who start high-load training from a young age, if they lack sufficient land training support or reassessment of technical movements, they are more likely to develop long-term overuse injuries, leading to a vicious cycle of delayed recovery and re-injury

Currently, traditional physical therapy (PT) methods still dominate in the rehabilitation of shoulder injuries, with a core focus on symptom relief, such as reducing local inflammation and promoting tissue healing through cryotherapy, ultrasound, and other methods [2,3]. Although these methods can improve symptoms in the short term, for high-level swimmers, it is often difficult to

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restore their required joint function and neuromuscular control ability, and they cannot fundamentally solve the problem of functional impairment [4].

In recent years, functional training (FT) has gradually gained attention as a supplementary or alternative strategy for sports rehabilitation. Compared with traditional PT, functional training places more emphasis on the integration of the motor chain, trunk stability, and proprioceptive retraining. Relevant studies have shown that swimmers who receive functional training not only have a faster recovery speed but also have better long-term prognosis, including improved motor learning ability and reduced recurrence rate [5-7]. However, in China, the comprehensive rehabilitation model of combining traditional PT with functional training has not been fully applied, and most rehabilitation institutions still rely on passive treatment plans, which have a significant gap with international advanced rehabilitation concepts. Therefore, promoting the transformation of rehabilitation practice for elite water athletes towards evidence-based and functional models has become an urgent problem to be solved. This paper aims to provide a practical model for interdisciplinary sports rehabilitation, verify the effectiveness of the personalized and phased "PT+FT" comprehensive plan in the rehabilitation of shoulder injuries in swimmers, and provide theoretical and practical references for promoting the optimization of rehabilitation models for elite swimmers in China.

2. Principles and treatment of comprehensive rehabilitation

2.1. Pathophysiology of injuries in elite swimmers

Shoulder pain is the most common overuse injury in elite swimming populations, with incidence rates higher than 50% in competition groups [1]. Freestyle and butterfly strokes specifically create excessive repetitive loading on the glenohumeral joint as a result of their cycle of overhead movement, with an average of 8,000–10,000 strokes per training session [2]. This repeated movement creates significant shear force and compression loading in specific phases of the movement cycle, namely the pull-through and catch phases, where there is translation of the humeral head anteriorly and superiorly. Poor scapular positioning or late rotator cuff activation increases subacromial impingement risk [3,8].

These biomechanical stresses over time will result in a continuum of pathologies ranging from rotator cuff tendinopathy through labral fraying and glenohumeral instability to posterior capsular tightness [6]. Internal impingement, also a typical mechanism in swimmers, results when the posterior-superior rotator cuff is squeezed between the glenoid rim and humeral head during late cocking and results in microtrauma and localized pain [5]. Chronic exposure with an insufficient neuromuscular adaptation leads to functional instability—a condition where passive stabilizers of the joint are preserved while dynamic stability is lost [4].

2.2. Neuromuscular deficits and kinetic chain dysfunction

Beyond structural pathology, functional impairments play a central role in the perpetuation of shoulder symptoms in swimmers. Functional movement screening (FMS) frequently reveals scapular dyskinesis, characterized by asymmetrical or delayed upward rotation, protraction, or anterior tilting during overhead tasks [9]. Weakness in scapular stabilizers—particularly the lower trapezius and serratus anterior—compromises the scapulohumeral rhythm, leading to increased humeral head migration and altered joint loading [7].

Thoracic spine hypomobility, usually secondary to extended prone swimming posture, decreases the ability of the swimmer to reach proper overhead alignment. Core muscle delays, especially of

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the transverse abdominis and obliques, break the kinetic chain and require compensation of the shoulder for force transmission loss between the trunk and the extremity. In the current example, the athlete displayed restricted thoracic extension and decreased trunk rotation, verified using FMS rotary stability tests. The efficiency of the kinetic chain is of paramount importance in swimming mechanics. Freestyle and butterfly strokes entail sequential production of force from the lower limbs and are transmitted through a rigid core and culminate in proper upper-limb propulsion. Any compromise along the chain adds strains on the glenohumeral joint's load, accelerating fatigue and risk of injury [10].

2.3. Principles and mechanisms of Physical Therapy (PT)

Classic PT continues as an integral part of the initial rehabilitation process, especially within the subacute and acute settings. Cryotherapy is one of the first-line PT interventions and decreases focal metaboreflex activity through vasoconstriction of peripheral vessels and a decrease in secondary hypoxic damage during high-intensity exercise [6]. Cryotherapy has been found to decrease joint effusion and exercise-related soreness in overhead sports [2]. Ultrasound therapy, while contentious in literature, is applied to enhance local circulation and healing of soft tissue through deep tissue heating and acoustic microstreaming [5]. Manual therapy of posterior glide mobilizations and myofascial release corrects capsular stiffness and enables joint translation on overhead motions [4]. In the current athlete, selective manual therapy of the subscapularis and posterior capsule enhanced range of external rotation and alleviated posterior shoulder stiffness. But PT as an individual intervention does not fix neuromuscular deficits nor restore ideal stroke mechanics. While it decreases symptoms, the risk of recurrence is great unless dynamic stability and kinetic chain reintegration are reestablished [9].

2.4. Principles and mechanisms of Functional Training (FT)

Functional training (FT) aims to restore movement quality, proprioception, and sport-specific neuromuscular control. Traditional strengthening programs involve exercise on single muscle groups in an isolated manner, while FT combines multi-joint, multiplanar drills that mirror swimming mechanics [7]. Key principles include progressive resistance to improve muscular endurance, proprioceptive neuromuscular facilitation (PNF) to enhance coordinated movement patterns, and movement re-education to refine stroke-specific motor control . In this case, exercises such as resisted pull-throughs, plank-to-rotation, and scapular push-ups simulated the demands of water propulsion, reinforcing trunk-to-limb sequencing. FT also emphasizes eccentric control of the rotator cuff and scapular stabilizers, critical for decelerating the arm in the recovery phase of the stroke. Enhanced proprioception from closed-chain drills, such as quadruped weight shifts and stability ball wall slides, reduces the risk of maladaptive motor patterns that predispose to reinjury.

2.5. Rationale for an integrative PT+FT model

An integrated PT and FT rehabilitation model takes into consideration symptomatic relief and causative correction [1,8]. PT controls pain, inflammation, and movement limitation so that early FT initiation does not worsen symptoms. FT then restores sport-specific stability, strength, and movement control and decreases the risk of recurrence and accelerates return to performance. This combined approach is particularly beneficial in elite swimming, where rapid return to training is essential for maintaining competitive conditioning. In the present case, pain scores decreased from

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7/10 to 2/10 within three weeks of initiating FT, with concurrent improvements in external rotation (+18°) and scapular control. Competition readiness was achieved in 7.5 weeks—significantly faster than the typical 10–12 week recovery reported in literature [8]. The research confirms that athletes following combined PT+FT programs recover their pre-injury performances sooner, with fewer long-term limitations and reinjury occurrences [6]. In addition, collaboration between the therapist and coach ensures combined land and pool training burdens are compatible and don't overtax the healing shoulder while preserving cardiovascular fitness.

3. Approaches towards rehabilitation and efficacy in swimmers

Shoulder overuse injuries in elite swimmers need specific rehabilitation measures that go beyond symptomatic treatment and focus on the recovery of neuromuscular control, joint stability, and sport-specific mechanics. In this research, a systematic three-phase rehabilitation program was applied that incorporated conventional physical therapy (PT) and functional training (FT) in an effort to treat both symptomatic manifestations and intrinsic movement dysfunction. This combined approach is designed for early return to competition while keeping risk of recurrence low. The first stage of treatment (0-2 weeks) is acute pain management and early activity, with the core goal of controlling inflammation and pain, and initiating safe joint activity. Cryotherapy was utilized to decrease joint effusion and manage post-exercise inflammatory involvement and thus enable early tolerance to movement [2]. At a mechanistic level, cold therapy causes vasoconstriction, lowers nerve conduction speed, and inhibits local metabolic activity and secondary hypoxic damage. Ultrasound therapy was also used to enhance localized circulation and facilitate rapid soft tissue healing [3]. Manual therapy modalities—posterior glide mobilization and myofascial release of the subscapularis and posterior capsule—were administered to enhance glenohumeral translation and reduce posterior shoulder stiffness. These interventions enabled ROM restoration in part, but control of symptoms in itself did not correct stroke mechanics or neuromuscular impairments. The second stage (3-5 weeks) is functional strengthening and neuromuscular remodeling. With pain under control, attention then focused on re-establishing core stability, scapular control, and coordinated kinetic chain action. Scapular push-ups, prone I-Y-T raises, and resisted diagonal band pulls were instructed as stroke-specific movement imitations. PNF movement patterns were utilized to ensure maximum coordinated trunk-to-arm force transfer. Anti-rotation presses, split-stance chops, and bird-dog rows retrained the deep spine stabilizers so trunk torque and upper-limb alignment on propulsive efforts were optimized. At this stage of completion, strength tests confirmed 35% increase in trunk torque and 30% increase in scapular stabilizer strength. Pain measurements dropped from 7/10 to 2/10 and active ROM approached full restoration.

The third stage (6-8 weeks) mainly focuses on specialized integration and performance optimization, with a focus on high-load specialized training. Centrifugal load exercises (such as slow lateral lift centrifugal phase and centrifugal wall sliding) maximize tendon remodeling and strength [9]. Dynamic water-simulating drills like resisted tethered swims, medicine ball rotational throws, and single-arm landmine presses fortified stroke-specific movement profiles. Video stroke analysis gave visual feedback to enhance technical proficiency and confidence. Psychological preparation was facilitated through peer modeling so that the athletes trained with other recovering swimmers. Full return to competition swimming occurred at 7.5 weeks—an elapsed time considerably shorter than the 10–12 weeks routinely documented in literature [8]. This result highlights the benefit of an integrated approach that addresses neuromuscular deficits while fulfilling sport-specific requirements.

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4. Recommendations and solutions for shoulder injuries

4.1. Athlete-centered recommendations

Successful prevention and treatment of overuse shoulder injuries in elite swimmers involves an integrated, multispecialty approach between athletes, coaches, physical therapists, and support personnel. It is recommended to divide interventions into athlete-led, coach-initiated, and system-level interventions. Competitors ought to receive regular functional movement screenings for the early detection of scapular dyskinesis, thoracic hypomobility, and instability within the core. Year-round maintenance programs involving eccentric strengthening of the rotator cuff, drills for thoracic mobility, and kinetic chain conditions decrease risk of injury. Contrast baths, active recovery swims, and mobility circuits must be customized according to training loads. Pain-monitoring protocols ensure early intervention preceding the advancement of symptoms.

4.2. Coach-led recommendations

Trainers need to be educated on red flags like pain lasting more than 48 hours, decreased efficiency of stroke, and compromised ROM. Adapting altered training loads, like substitution of butterfly sets with single-arm drills or kickboard drills, allows cardiovascular conditioning while not overloading the shoulder. Joint planning with physical therapists allows drylands and pool training to enhance tissue healing timelines. Ongoing feedback loops avoid an untimely return of high-intensity training.

4.3. System-level recommendations

Swimming programs should adopt integrated rehab pathways that combine PT and FT from the earliest injury stages. This requires establishing formal communication channels between medical staff and coaching teams. Access to underwater video analysis and biomechanical assessments allows targeted technique corrections during rehab. Establishing return-to-play (RTP) checklists—requiring pain-free full ROM, ≥90% rotator cuff strength compared to the contralateral side, and two consecutive symptom-free swim sessions—ensures objective clearance criteria. Through the adoption of these recommendations, swimming programs will be able to shorten recovery windows, decrease reinjury rates, and maximize long-term athlete output. These findings justify an integrated model in which relief of symptoms and neuromuscular correction go hand-in-hand and adhere to current sports medicine mandates for elite-level return-to-play [1,6,8].

4.4. Practical suggestions for coaches, clubs and committees

The success of shoulder overuse injury rehabilitation relies heavily on the level of integration among the diverse approaches used. In elite swimmers, the use of passive modalities alone provides short-term relief only and does not improve neuromuscular coordination. Here, initial utilization of ultrasound and cryotherapy effectively decreased pain and enhanced ROM, but the absence of active training restricted functional improvements—consistent with Bleakley et al.'s report of a finding that cryotherapy reduced pain but needed to be followed by active intervention if function was to be regained [2]. Manual therapy, including scapular mobilization and deep friction massage of the shoulder, brought about some gains in shoulder motion; however, in the absence of concomitant strengthening of the stabilizers of the scapula, these improvements could to be maintained under the load of freestyle swimming. Weakness of stabilizers of the scapula was shown by Hibberd and Myers to substantially delay the recovery period [6].

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Strength training of the core was a turning point in functional rehab in this case. Insufficient rotational strength of the trunk was manifested during tethered swims, and exercises like bird-dog rows, anti-rotation presses, and split-stance chops were introduced to target deep spinal stabilizer activation and improve transverse abdominis recruitment. Four weeks afterwards, strength trials revealed an improvement of 35% in rotational torque of the trunk, and concomitantly, absence of flip turn pain was experienced. The case further underscored the need for proprioception training, employing unilateral band-resisted reaches coupled with closed-chain balance holds to mimic stroke resistance and improve force output and joint position sense coordination. This corroborates Magrum and Wilder's observations that proprioception recovery is of prime importance to high-load endurance athletes [4].

Incorporating technological and technical training devices was likewise instrumental in the rehab process. Shoulder accelerometers and wearable joint angle sensors are capable of measuring fatigue indices in real time and delivering load prediction and reduced human error on an individualized basis [4]. Furthermore, the employment of aquatic resistance tools such as paddles and drag socks provides a safe method of mimicking in-water load and becoming more and more adept at building up the tolerance of the joint. In their pilot study, Riemann et al. uncovered that aqua-specialized resistance training utilized by rehabbers benefited them in reaching a recovery of swim velocity earlier in comparison to dryland exercisers [7]. In this instance of the rehab course of action, we notice the integration of multi-dimensional PT, functional neuromuscular retraining, and technological support as being not only decreasing the rehab time but radically reducing the likelihood of recurrence as well [1,9].

5. Conclusion

By systematic reassessment, the treatment strategy changed from conventional physical therapy (PT) to a functionally integrated program with an emphasis on core stability, neuromuscular control, and proprioception. Major gains were relief of pain from VAS 7/10 to 1/10, 30% improvement in shoulder abductor strength, and 35% improvement in trunk rotating torque. The swimmer was restored to competition sooner than average (7.5 weeks vs. 10–12 weeks) with improved range of movement and better stroke technique. The athlete's rehabilitation was not merely physical but psychological as well, reinforced by collaboration with the swimmer's coaches, peer support, and variable dryland/pool load coordination. It illustrates the clinician's value in applying functional training in swim rehab beyond passive treatment methodologies in an effort to correct neuromuscular deficits and biomechanical imbalances. A focus on sport-specific movement re-education with early-phase correction resulted in improved strength, pain management, and time of return-to-play, mirroring current trends in sports rehab science. But this study has shortcomings. It's a single-case investigation, after all, with non-generalizability among all swim populations. It's also limited in that it relies upon subjective reports of pain and increments in strength tests without follow-up re-injury monitoring beyond the term. Future research should take on longitudinal designs, increased sample sizes, and sophisticated monitoring instruments—like wearable movement sensors—to monitor training load, breakdowns in technique, and real-time joint stresses with greater precision. In the future, the use of artificial intelligence-directed feedback and digital fatigue models within rehab programs could allow clinicians to predict overuse patterns early and individualize recovery pacing. Multi-disciplinary rehab guidelines adopted for swimming-specifications biomechanical stresses—psychological support, as well as education of the athlete—could become the new benchmark in sustainable performance and prevention of injuries within aquatic sports.

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