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Research Progress on Land-Based Rehabilitation Training for Rotator Cuff Injuries in Swimmers

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Abstract

Swimmer's shoulder, medically referred to as rotator cuff injury in competitive swimmers, is one of the most prevalent and performance-limiting musculoskeletal disorders in aquatic sports. Its protracted course and high recurrence rate pose persistent challenges to both training adherence and career longevity. Although a variety of clinical interventions are available, the multifactorial nature of its pathogenesis—encompassing biomechanical overload, anatomical impingement, and neuromuscular dyscoordination—directs therapeutic priorities toward pain modulation, strength restoration, and dynamic chain reconditioning. Land-based rehabilitation training, characterized by controllable load, standardized movements, and high reproducibility, has become the cornerstone of rotator cuff rehabilitation and has been endorsed by multiple clinical guidelines. However, consensus regarding the optimal training protocol—including modality, frequency, intensity, and timing—remains lacking. This review synthesizes contemporary evidence on land-based rehabilitation training for rotator cuff injuries in swimmers, with a focus on three primary modalities: land-based strengthening, blood flow restriction training, and traditional Chinese Daoyin exercises. It evaluates their respective intervention characteristics, clinical evidence, and stage-specific applicability, aiming to inform the development of individualized rehabilitation protocols in clinical practice.

Keywords

swimmer's shoulder, rotator cuff injury, land-based rehabilitation training, blood flow restriction training, rehabilitation nursing

1. Introduction

As one of the most widely practiced physically demanding sports globally, the intensity of competitive training in swimming is steadily increasing. Elite swimmers can train up to 60,000 to 80,000 meters on the water per week [1]. Pink et al. [2] reported that nearly 90% of the swimming propulsion force is generated by the upper limbs. Based on the calculation of 8 to 10 arm strokes per 25-meter swimming pool, the unilateral shoulder joint needs to complete about 30,000 rotations a week, which makes the shoulder joint bear huge cumulative stress [2]. It is this highly repetitive and high-load sports characteristics that make the shoulder joint the joint with the largest load on the body and the highest risk of injury for swimmers. Shoulder pain is also one of the most common training-related complaints for swimmers [3]. Swimmer's shoulder injury refers to a type of rotator cuff tendon lesions and secondary subacromial impingement syndrome that occurs in the group of swimmers, mainly manifested by pain around the shoulder joint, limited extension and internal

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rotation, and muscle weakness during exertion. The injury site usually involves the supraspinatus tendon, the subscapularis tendon and the biceps long head tendon. The course of the disease can be acute attacks or chronic accumulation, the latter is especially common in elite swimmers [4]. According to the epidemiological survey, the incidence of shoulder injury in swimmers is as high as 40% to 91%, among which the rotator cuff-related lesions are the most prominent, and there is a significant upward trend with age and years of training [5] [6]. Among elite swimmers, more than half of them are interrupted training or their performance declines due to shoulder pain. Rotator cuff injury has become the primary bottleneck that restricts the improvement of competitive performance [6].

From the perspective of Western medicine's pathophysiology, the core injury mechanism of the swimming shoulder can be attributed to the superposition effect of "internal degeneration" and "external impact" [7]. In terms of internal factors, repeated overhead swimming strokes (especially free swimming and butterfly swimming) cause the rotator cuff tendon to suffer continuous eccentric loading and friction stress in the subacromial space, resulting in the accumulation of tendon collagen micro-damage and reduced blood vessel distribution, which in turn causes tendon degeneration and even partial tear; In terms of external factors, the abnormal dynamics of the scapula (insufficient downward angle back tilt and reduced upper rotation) causes the humerus to move forward under the acromion. The static structure further narrows the gap under the acromion, aggravating the impact of the coracoacromial arch on the outlet area of the supraspinatus tendon [7]. In addition, the common imbalance of the anterior and posterior muscle strength of the shoulder joint of swimmers (the endorsal rotation muscle group is overdeveloped and the external rotation and the posterior scapular muscle group is relatively weak), which makes it difficult for the humerus to maintain a normal trajectory in dynamic movement, further accelerating the wear process of the rotator cuff [7]. The theory of tendon injury in traditional Chinese medicine classifies the swimming shoulder into the category of "shoulder bi syndrome" and "tendon disorder". It is believed that the disease is caused by long-term water training, which is caused by pathogenic wind, cold, and dampness, invading the shoulder meridians. In addition, the repeated top pulling makes the shoulder meridians secretly consume the tendons, qi and blood, and the tendons become insufficiently nourished. Pain results from insufficient nourishment of the tendons; Local blood stasis is blocked, pain results from obstruction of qi and blood circulation. The two cause and effect each other, forming a mixed pattern of deficiency and excess [8]. From the perspective of modern medicine, tendon micro-injury and ischemic degeneration [9] are just in line with the pathology of traditional Chinese medicine's "qi and blood deficiency, tendon and vein loss" [10] to form a pathological echo between traditional Chinese medicine and Western medicine.

In the management strategy of rotator cuff injury for swimmers, although passive treatment (such as rest, ice, physiotherapy, local closed injection) can control acute inflammation in the short term, it cannot reverse muscle weakness and maladaptive movement patterns, and repeated injections may further weaken the mechanical strength of tendons [11]. In recent years, a number of high-quality randomized controlled trials (RCT) and systematic evaluations have shown that exercise therapy, as the core means of active rehabilitation, can not only significantly relieve shoulder pain and improve joint mobility, but also restore the scapulohumeral rhythm through neuromuscular re-education and reduce the risk of recurrence [12]. Among many exercise therapies, land rehabilitation training has received more and more attention because of its controllable load, high degree of movement standardization and independent non-water environment. The scoping review of Yoma et al. [13] also points out that the effect of open-chain sports and land training seems to be better than that of closed-chain sports and water training. However, the symptoms of rotator cuff injuries in swimmers vary greatly. Some are mainly pain-based, some are mainly weak, and some are accompanied by instability of the ovicular joint, and the disease is easy to recur due to fluctuations in training intensity. There is still a lack of a unified evidence-based framework for the indications, intervention timing and combination strategies of different land rehabilitation training methods [13]. In view of this, on the basis of reviewing relevant literature, this article focuses on the land rehabilitation training of swimmers' rotator cuff injuries, and focuses on the clinical evidence of the three main forms of land strength training, blood flow restriction training and Traditional Chinese Daoyin exercises, in order to provide reference for the sports rehabilitation of swimmers' rotator cuff injuries.

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2. Major Types of Land-Based Rehabilitation Training

2.1 Land-Based Strength Training

Land strength training is the most basic and controllable intervention method in the rehabilitation of rotator cuff injuries in swimmers. The core logic is that swimming training itself has caused a large amount of repetitive load on the shoulder joint. If high-intensity training in the water continues during the recovery period, it is not only difficult to accurately control the load dose, but also difficult to isolate specific muscle groups for targeted strengthening [14]. Land training makes up for this shortcoming. Studies have confirmed that land training is better than water training in reducing the imbalance of the rotator cuff muscle group and muscle fatigue [15].

Competitive swimmers will experience a progressive shoulder rotation strength imbalance during the season, but it is not clear whether preventive training can effectively intervene in this process. Against this background, Tavares et al. al. [16] randomly divided competitive swimmers aged 16 to 35 into weight-bearing training groups, elastic band training groups and sham control groups. After 12 weeks of preventive training (two times a week), it was found that the imbalance in the intervention group in the conventional/functional ratio of shoulder rotation force was significantly less than that of the control group. According to this study, this project can minimize the progressive imbalance of shoulder rotation force during the season of competitive swimmers. This finding suggests that the core goal of strength training is not only to “increase strength”, but also to “restore balance” - that is, to correct the overdeveloped internal rotator muscles group and the relatively weak weakness of the external rotator and scapular retractor muscles group prevalent among swimmers.

In addition, the scope summary of Yoma et al. [13] further points out that it is appropriate to have no more than 5 open-chain movements in the land training plan. Too many training actions may lead to a decrease in compliance and dilute the effect. This dose-effect relationship suggests that precision rather than quantity should be pursued when formulating training prescriptions.

2.2 Blood Flow Restriction Training

Blood Flow Restriction (BFR) training is one of the most breakthrough advances in the field of musculoskeletal rehabilitation in recent years. Its core principle is to block the venous return of the limb by partially restricting venous return using a pressurized cuff so that the patient can induce the muscle hypertrophy effect under a low load of 20% to 30% 1RM, and promote the pulsed release of growth hormone. For swimmers, rotator cuff injury is often accompanied by significant muscle atrophy, and high-load resistance training is contraindicated in the early stage of injury. BFR cleverly solves this contradiction.

This contradiction prompts researchers to seek alternative means to induce muscle hypertrophy with low load. Based on previous studies, Kara et al. [17] conducted an 8-week (2 times a week) low-load BFR training intervention on 28 patients with rotator cuff tendon disease using a random and evaluator blind design. The results showed that the BFR group was significantly better than the non-BFR group in terms of biceps thickness ($P=0.002$) and shoulder rotation strength (60°/s, $P=0.040$). According to this study, low-load BFR training can effectively promote the recovery of key muscle groups. There was no significant difference between the two groups in the thickness of the supraspinatus muscle, the infraspinatus muscle, the posterior scapular retraction muscle and shoulder external rotation strength, but the pain of both groups was significantly reduced and the function was significantly improved.

The clinical significance of this study is that the advantages of BFR training are targeted. However, its application in rotator cuff rehabilitation is still in the exploration stage, and there is no consensus on the standardization of upper limb cuff width and pressurization position, training frequency and optimization of treatment course. In addition, the current research on BFR in the specific population of swimmers is still blank, and the existing evidence is mainly from the group of patients with common rotator cuff tendinopathy. Future research should focus on BFR rehabilitation RCT for swimmers and explore the combination strategy of BFR and other land training.

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2.3 Traditional Chinese Daoyin Exercises

Traditional Chinese Daoyin exercises takes the three harmony of "form, qi and god" as the core concept. Through specific limb movements combined with respiratory exhalation and thought Daoyin exercises, it achieves the purpose of dredging meridians, harmonizing qi and blood, and strengthening muscles and bones. Compared with equipment training, Daoyin exercises does not require external load and belongs to "self-weight" training, which can also be completed independently on land. For swimmers' rotator cuff injuries, the value of Daoyin exercises is not only to improve local blood circulation and accelerate the removal of inflammatory mediators, but also to restore the proprioception and dynamic stability of the shoulder joint through multi-plane and multi-angle soft movements. The following is to elaborate on the two representative skills of the Baduanjin and the Wuqinxi.

2.3.1 Baduanjin

Baduanjin is one of the most widely spread Traditional Chinese Daoyin exercises methods. Its eight movements cover the flexion, extension, rotation and pulling of the joints of the whole body. For the rehabilitation of rotator cuffs, especially the two styles of "Holding the Sky with Both Hands" and "Looking Back to Prevent Five Strains and Seven Impairments" are the most targeted: The former can effectively pull the pectoris major muscle, the small pectoral muscle and the soft tissue of the anterior shoulder by lifting the arms up and cooperating with the support of the palm root, and relieve the pectoral muscle tension and scapular extension caused by long-term swimming; The latter emphasizes that the rotation of the head, neck and spine drives the scapula to retriate, which helps to activate the lower oblique and rhombic muscles and improve the scapular rhythm [18].

Although the pathological mechanism of periarthritis and rotator cuff injury is different, they are both manifested as shoulder joint pain and limited movement. In the clinical practice of shoulder joint rehabilitation, some researchers tried to introduce Baduanjin into the treatment of periarthritis of the shoulder. On this basis, Wen Xiaoyi et al. [18] conducted a meta-analysis of a randomized controlled trial of Baduanjin in the treatment of periarthritis of the shoulder. The results showed that the clinical efficiency of the simple or combined Baduanjin test group was significantly higher than that of the control group (OR=4.05, 95% CI (2.15, 7.63), $P<0.0001$). According to this study, Baduanjin can effectively improve shoulder joint pain and mobility disorders, which provides a preliminary evidence-based basis for the application of Baduanjin in the rehabilitation of rotator cuff injury. However, at present, the research on the intervention of Baduanjin directly targeting the rotator cuff injuries of swimmers is still blank, and its combination with swimming special training, intervention timing and dosage effects still need to be explored.

2.3.2 Wuqinxi (Five-Animal Exercises)

The Wuqinxi imitates the posture and charm of the five animals of tiger, deer, bear, ape and bird, among which the "bird play" has the most prominent value for the recovery of shoulder joint function. Through the spread of wings, wings, flying and other movements of the arms, the bird play makes the shoulder joints open and close on the sagittal plane and the coronal plane. This multi-plane and multi-angle movement mode just covers the main force trajectory of the rotator cuff muscle group in the swimming action [19].

Elderly patients with chronic rotator cuff injury often reduce the movement of the shoulder joint due to pain, resulting in further decline in joint stiffness and muscle strength, forming a vicious circle. Against this background, Zheng Ji et al. [19] randomly divided 60 elderly patients with chronic rotator cuff injury into the experimental group (routine rehabilitation + improved Wuqinxi) and the control group (routine rehabilitation). After 3 months of intervention, it was found that the experimental group was significantly better than the control group in terms of VAS pain score, Constant-Murley shoulder function score and patient self-strengthening evaluation scale (PEI) score ($P<0.001$), indicating that the addition of improved Wuqinxi on the basis of routine rehabilitation can significantly reduce shoulder joint pain and improve shoulder joint mobility. Although the subjects of the study are elderly patients with chronic rotator cuff injury rather than swimmers, its RCT design provides high-quality evidence for the application of Wuqinxi in rotator cuff rehabilitation. For swimmers, the "bird play" action of the Wuqinxi is highly similar to the shoulder joint activity mode of swimming and rowing. In the future, research on adaptability improvement for swimming can be carried out on this basis.

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3. Conclusions and Future Perspectives

Existing studies show that land strength training has a clear therapeutic effect in correcting the imbalance of rotator cuff muscles. Blood flow restriction training shows unique advantages in promoting muscle thickening under low-load conditions. Traditional Chinese Daoyin exercises provides useful supplements in improving shoulder joint mobility and proprioception. The three types of methods have their own strengths. In clinical practice, they can be applied sequentially or jointly according to the injury stage, muscle strength level and season arrangement of athletes.

Although the current study provides preliminary evidence, there is still a lack of verification of a large sample of RCT for rehabilitation interventions in this specific group of swimmers. There are still the following major limitations in the current research: First, most RCTs are research subjects for ordinary rotator cuff injuries or the elderly, and high-quality RCTs specifically for swimmers are still scarce. Although the research of Tavares et al. [16] is aimed at swimmers, they focus on injury prevention rather than post-injury rehabilitation, and RCT evidence in the rehabilitation stage still needs to be supplemented; Second, the dose parameters (frequency, intensity, duration, combination method) of different land training methods are quite different, and it is difficult to make a direct comparison between studies; Third, the long-term follow-up data is generally insufficient, and the long-term impact of the training program on the recurrence rate of injury and the length of exercise career is not clear; Fourth, existing studies generally lack a systematic assessment of athletes‘ training compliance. Therefore, in the future, RCT should include compliance in the formal outcome indicators to ensure the clinical generalization of rehabilitation programs.

Against this background, future research should focus on the following directions: carry out a large sample and multi-center RCT for the rehabilitation period of shoulder and sleeve injury of swimmers, and systematically compare the difference in therapeutic effect and cost-effect ratio of different land training methods; Explore the joint intervention plan of BFR and land strength training, land strength training and Traditional Chinese Daoyin exercises, and give full play to the advantages of traditional Chinese medicine and Western medicine; Establish a standardized dose-effect relationship for onshore rehabilitation training to provide a basis for the accurate formulation of clinical exercise prescriptions. Only by breaking the cognitive barriers of “Western medicine focuses on local” and “traditional Chinese medicine focuses on the whole” can we provide a solid rehabilitation and nursing guarantee for swimmers to return to the highest competitive level.

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Conflicts of Interest

The authors declare no conflict of interest.

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