Bone and Arthrosurgery Science, 2025, Volume 3, Issue 4
http://ojs.bbwpublisher.com/index.php/BAS
Online ISSN: 2981-8222
Print ISSN: 3083-4856

Research on Sport-Specific Adaptive Training Programs Following Repair of Upper Limb (Rotator Cuff and Elbow Joint) Impact Injuries in Rugby

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Abstract: Rugby is a highly competitive sport with unique functional demands on the upper limbs, resulting in a high incidence of impact injuries to the rotator cuff and elbow joint. After the repair of such injuries, conventional rehabilitation training often fails to meet the specialized athletic requirements for athletes returning to competition, which can easily lead to secondary injuries or a decline in athletic performance. Based on the specialized mechanisms of upper limb impact injuries in rugby and the core needs after repair, this paper constructs a three-stage specialized adaptive training program: "clinical rehabilitation - specialized transition - competitive adaptation," along with proposing individualized adjustment strategies and risk prevention measures. The aim is to provide a scientific basis for the Basketball and Rugby Sports Management Center to formulate rehabilitation plans for athletes after injury, enhance rehabilitation efficiency, and ensure the safe return of athletes to competition.

Keywords: Rugby; Rotator cuff injury; Elbow joint impact injury; Specialized adaptive training; Rehabilitation program

Online publication: September 10, 2025

1. Introduction

In rugby, the upper limbs are crucial for executing core technical movements such as passing, tackling, blocking, and ball-carrying breaks. The rotator cuff and elbow joints are subjected to repetitive traction, valgus stress, and instantaneous impact forces, leading to a high incidence of impingement injuries. According to statistics, upper limb injuries account for 35%–40% of all sports injuries among rugby players, with impingement-related injuries such as rotator cuff impingement syndrome, ulnar collateral ligament injuries of the elbow, and lateral epicondylitis of the humerus comprising over 60% of these cases [1]. After surgical or conservative treatment and repair, if conventional rehabilitation methods such as range-of-motion recovery and basic strength training are solely employed, athletes may achieve "functional recovery." However, upon returning to competition, they often experience limited power output and distorted movements due to inadequate load tolerance of the upper limbs for

specialized movements and uncoordinated movement patterns, resulting in a secondary injury risk that is 2-3 times higher than that of the general population [2]. The Basketball and Rugby Sports Management Center bears the core responsibility of ensuring athlete health and enhancing athletic performance, necessitating the establishment of a rehabilitation system that integrates both "clinical healing principles" and "specialized sports demands." Therefore, it is essential to explore specialized adaptive training programs for upper limb (rotator cuff, elbow joint) impingement injuries in rugby following repair.

2. Specialized mechanisms and core rehabilitation needs of upper limb impingement injuries in rugby

2.1. Specialized injury mechanisms of rotator cuff impingement injuries

The rotator cuff muscle group (supraspinatus, infraspinatus, teres minor, and subscapularis) is the core structure for maintaining dynamic stability of the shoulder joint. In rugby, the following specialized movements are prone to inducing impingement injuries: First, overhand passing. During passing, the shoulder joint needs to complete a coherent sequence of "extension-abduction-internal rotation," and the supraspinatus tendon repeatedly traverses the subacromial space. Studies have shown that the pressure in the subacromial space can reach 300–400 kPa during this process. If the athlete has a Type II/III acromion morphology (hooked acromion) or insufficient scapular stability, it can easily lead to repeated friction between the tendon and the acromion and coracoacromial ligament, triggering subacromial impingement syndrome. During high-intensity passing, the rotator cuff needs to withstand a pulling force of 3-4 times the body weight. If the repaired tendon has not adapted to this load, it is prone to re-tearing. Second, tackling and blocking [3].

During a frontal tackle, the upper limbs need to extend forward and resist the reactive force of the opposing player. The rotator cuff must rapidly undergo eccentric contraction to maintain shoulder joint stability. If the timing of force application is inappropriate or there is an imbalance in rotator cuff muscle strength (such as the infraspinatus being weaker than the subscapularis), it can easily lead to eccentric tendon injury [4]. During lateral blocking, the shoulder joint is subjected to lateral impact forces, which may trigger compound impingement between the rotator cuff muscle group and the joint capsule, exacerbating the extent of injury.

2.2. Specialized injury mechanisms of elbow joint impingement

The elbow joint serves as a crucial hub for force transmission in rugby, and its impingement injuries are mostly related to "valgus stress" and "repeated flexion and extension." The specific mechanisms are as follows:

During passing, the elbow joint needs to rapidly extend from a 90° flexion position to nearly full extension. The origin of the common extensor tendon at the lateral epicondyle of the humerus is subjected to repeated traction, which, over time, can easily lead to lateral epicondylitis ("tennis elbow"). When breaking through with the ball, the elbow joint needs to resist the pulling force of the opposing player. The anterior bundle of the ulnar collateral ligament is subjected to continuous valgus stress, which can reach 200–250 N. When this stress exceeds the tolerance limit of the ligament, it can easily lead to strain or partial tearing.

When an athlete falls to the ground and supports their body with the palm of their hand, the elbow joint instantaneously bears an axial impact force (which can reach 5-6 times the body weight). This can lead to the impact between the articular surfaces of the olecranon process of the ulna and the trochlea of the humerus, potentially causing cartilage damage or osteophyte formation. This, in turn, may induce osteoarthritis of the elbow joint and increase the risk of subsequent impact injuries [5].

2.3. Core specialized needs after repair

After the repair of rotator cuff and elbow joint impingement injuries, the rehabilitation needs of athletes should go beyond "basic functional recovery" and focus on the specialized characteristics of rugby. Specifically, these needs include: restoring the "stabilizing strength" of the rotator cuff muscle group (to maintain dynamic stability of the shoulder joint and prevent joint instability and impingement during passing) and the "explosive strength" of the muscle groups surrounding the elbow joint (to meet the demands of rapid force generation during passing and resistance during tackling); rebuilding the coordinated force generation pattern of the upper limbs and trunk (such as the linkage between the shoulder, waist, and hip during passing) to avoid secondary injuries caused by compensation from a single body part [6]; gradually adapting to the "repetitive loads" (such as 10-15 consecutive passes) and "impact loads" (such as the instantaneous resistance during tackling) encountered in rugby; and conducting targeted training for specialized movements such as overhand passing, tackling, and blocking to ensure standardized and efficient movements and reduce the risk of injury recurrence.

3. Design of a specialized adaptive training program after repair of upper limb impingement injuries in rugby

3.1. Phase 1: Clinical rehabilitation period - tissue protection and basic functional activation

3.1.1. Training objectives

Maintain the repair environment of tissues surrounding the rotator cuff and elbow joint to prevent adhesion; activate the basic functions of the rotator cuff muscle group and the elbow joint flexor-extensor muscle group, and restore joint range of motion (shoulder flexion ≥ 120°, abduction ≥ 90°, elbow flexion-extension ≥ 135°/0°); and alleviate postoperative/post-injury pain (VAS pain score ≤ 2 points).

3.1.2. Core training content

(1) Range of motion training: The rehabilitation therapist assists in passive shoulder flexion and abduction (avoiding overhead movements), and uses resistance bands for passive elbow flexion and extension. Each movement is held for 15-20 seconds, with 3 sets per session and 1 session per day, laying the foundation for subsequent specialized movements.

(2) Muscle activation training: Perform isometric contractions of the rotator cuff while standing against a wall (with the upper arm against the torso and external rotation against the wall), and isometric contractions of the elbow flexors/extensors while seated (with the forearm on a table and resisting hand pressure). Each contraction is held for 10 seconds, followed by a 5-second relaxation, with 15 repetitions per set and 2 sets per session, activating stabilization functions.

(3) Core stability training: Perform prone planks with knees on the ground (30 seconds per set, 3 sets) and glute bridges (15 seconds per repetition, 12 repetitions per set) to strengthen the core and provide a stable foundation for specialized movements.

3.1.3. Intensity control and precautions

All movements should be performed under the premise of "pain-free." If pain occurs (VAS score > 3), the exercise should be stopped immediately. Avoid active overhead movements (such as raising the arm above shoulder level) to prevent excessive strain on the rotator cuff tendons. A rehabilitation therapist should be present to provide

guidance, correct issues such as "shrugging" and "compensatory force generation," and ensure proper movement form.

3.2. Phase two: Specialized transition period-muscle strength enhancement and establishment of basic specialized movements

3.2.1. Training objectives

Enhance concentric/eccentric strength of the rotator cuff muscles (especially the supraspinatus and subscapularis), and isotonic strength of the elbow flexors/extensors; establish a "simplified movement pattern" for rugby-specific actions (such as half-range passing and non-contact tackling simulations); restore the range of motion to normal levels (shoulder flexion ≥ 160°, abduction ≥ 120°, elbow flexion/extension ≥ 145°/0°).

3.2.2. Core training content

(1) Muscle strengthening training: For the rotator cuff muscle group, use elastic band shoulder abduction (0–90°), internal/external rotation (upper arm against the torso), 3 sets per session, 2 sessions per day [7]; for the elbow joint muscle group, perform dumbbell forearm flexion/extension (0.5–1 kg) and elastic band elbow flexion/extension, 12 repetitions per set, 3 sets per session, 2 sessions per day; for the scapular stabilizing muscle group, conduct prone "fly" exercises and elastic band pull-downs, 10 repetitions per set, 3 sets per session, 2 sessions per day.

(2) Prototype training for specialized movements: Standing and holding a soft ball for half-range passing simulations (15 repetitions per set, 2 sets per session), facing a foam dummy for non-contact tackling simulations (10 repetitions per set, 2 sets per session), and holding a rugby ball for ball-carrying breakthrough simulations (8 repetitions per set, 2 sets per session).

(3) Coordination training: Seated while holding a ball, perform shoulder extension and forward push passing in coordination with breathing, while tightening the abdomen, 12 repetitions per set, 3 sets per session, 1 session per day.

3.2.3. Intensity control and precautions

Gradually increase the load during muscle strength training, ensuring that muscle soreness does not persist for more than 24 hours after each training session (to avoid excessive fatigue that may hinder healing); use soft training equipment (such as soft balls and foam dummies) for specialized movement simulations to reduce impact loads on the upper limbs; conduct joint range of motion and muscle strength assessments once a week, and promptly adjust the training program if there is a stagnation in muscle strength growth or a decrease in joint range of motion.

3.3. Phase three: On-Field adaptation period—load tolerance and specialized confrontation adaptation

3.3.1. Training objectives

The primary objectives of this phase are to enhance the upper limb's tolerance to rugby-specific loads (such as continuous passing and confrontational tackling); optimize the power efficiency of specialized movements to restore athletic performance (such as passing speed and tackling stability); and establish awareness of secondary injury prevention, mastering self-protection movements for unexpected situations on the field.

3.3.2. Core training content

During this phase, the core training content primarily encompasses three aspects: First, specialized load tolerance training. This involves coordinated passing drills with teammates over progressive distances of 5 to 15 meters (3 sets per session, 2 sessions per day), gradually increasing the passing frequency; engaging in light-intensity tackling drills against padded teammates (3 sets per session, 1 session per day), progressively increasing resistance; and conducting medicine ball overhead throws for distance and elastic band-assisted passing drills (10 repetitions per set, 3 sets per session, 1 session per day). Second, specialized movement optimization training. This includes correcting passing techniques through video playback, simulating falling scenarios to train self-protection movements, and performing specialized movements on different playing surfaces to enhance environmental adaptability. Third, organized comprehensive confrontation training in the form of 3v3 and 5v5 small-sided games (with restrictions on high-intensity collisions), conducting specialized training under fatigue conditions, and simulating late-game scenarios.

3.3.3. Intensity control and precautions

The intensity of confrontation training should be gradually increased, with the initial confrontation game intensity not exceeding 50% of the game intensity, and subsequent weekly increases of 10% to 15%. After each training session, apply ice packs to the upper limbs (15 minutes each for the rotator cuff and elbow joints) to alleviate muscle fatigue and inflammatory responses. A team doctor should be present on-site. If any upper limb pain, numbness, or abnormal force generation occurs during training, immediately suspend the training and conduct an assessment.

4. Evaluation and individualized adjustment of specialized adaptive training programs

4.1. Multidimensional evaluation system

To ensure the effectiveness and safety of the training program, an evaluation system combining "stage assessment + dynamic monitoring" has been established, with specific indicators outlined in **Table 1** below.

Table 1. Multidimensional evaluation system

Evaluation Dimension	Core Metrics	Frequency	Passing Standard
Pain Assessment	VAS Pain Score	Before each session	VAS ≤ 3 during training; returns to ≤ 1 within 24 hours after training
Function Assessment	UCLA Shoulder Score (rotator cuff) MEPS Elbow Score (elbow joint)	Every 2 weeks	UCLA Score ≥ 30 (Excellent) MEPS Score ≥ 90 (Excellent)
Strength Assessment	Isokinetic Strength Test (shoulder IR/ER, elbow flexion/extension at 60°/s & 180°/s)	Every 4 weeks	Affected side strength ≥ 85% of the healthy side Strength symmetry error ≤ 10%
Sport-Specific Performance	Passing speed (radar gun) Passing accuracy (hits/10 attempts) Tackling stability (posture maintenance time under resistance)	Every 2 weeks	Passing speed ≥ 90% of the healthy side Accuracy ≥ 80% No difference in tackling stability compared to the healthy side
Imaging Evaluation	Ultrasound/MRI (rotator cuff tendon continuity, elbow ligament edema)	Pre- and post-training	Good rotator cuff tendon continuity, no re-tears No edema or worsened damage in the elbow ligaments

4.2. Individualized adjustment strategies

Based on the severity of the injury and the repair method, athletes undergoing surgery for complete rotator cuff tears should extend their clinical rehabilitation period to 8–10 weeks, while those undergoing conservative treatment can shorten it to 4–6 weeks. In terms of age, athletes under 25 years old can increase the intensity of explosive power training, while those over 30 years old should focus more on core training and extend their period of adaptation to the playing field. Regarding position, quarterbacks should intensify passing drills, while linebackers should prioritize elbow joint resistance and protective training.

5. Risk prevention and control and safeguard measures for training programs

5.1. Common risk points and response strategies

5.1.1. Risk of secondary impact

If there is a sudden worsening of shoulder cuff or elbow joint pain during training, training should be immediately suspended, and an ultrasound examination should be conducted to rule out tendon re-tearing. Response measures: Adequate warm-up before training (dynamic stretching + 5–10 minutes of light aerobic exercise), setting a "pain warning line" during training (stop if VAS score > 3), and performing static stretching for relaxation after training.

5.1.2. Risk of muscular compensation

If athletes exhibit actions such as "shrugging shoulders while passing" or "bending forward to compensate for elbow extension," it can easily lead to secondary injuries in the neck and waist. Response measures: Rehabilitation specialists should be present to observe movements in real-time, use motion capture technology to analyze movement patterns, promptly correct compensatory actions, and apply kinesiology tape for fixation when necessary.

5.1.3. Risk of overtraining

If persistent upper limb soreness lasts more than 48 hours after training or if muscle strength declines, it indicates overtraining. Response measures: Establish a training log to record the load and physical response of each training session, schedule 1–2 rest days per week, avoid continuous high-intensity training, and supplement with protein and vitamins as necessary to promote recovery.

5.2. Safeguard measures

The center should establish a collaborative team consisting of "team doctors, rehabilitation therapists, and specialized coaches." Team doctors are responsible for injury assessment and risk management, rehabilitation therapists design training programs and adjust intensity levels, and specialized coaches optimize movement details based on rugby-specific technical requirements, ensuring that training is both "safe" and "rugby-specific" [8,9]. Secondly, the center should be equipped with professional equipment such as soft training balls, resistance bands, isokinetic muscle strength training devices, foam dummies, and shoulder and elbow pads [10]. The training venue should be flat and free of debris, and grassy fields should undergo regular inspections for evenness to prevent accidental injuries caused by equipment or venue issues. Additionally, regular training sessions on upper limb injury prevention and rehabilitation knowledge should be conducted. Through case studies and movement demonstrations, athletes can understand their injury characteristics and training contraindications, enhancing their self-protection awareness and encouraging proactive cooperation with training programs.

5. Conclusion

The rehabilitation of upper limb (rotator cuff, elbow joint) impingement injuries in rugby should prioritize "safe return to the field and restoration of rugby-specific athletic abilities" as the core objective, rather than merely satisfying basic functional recovery. The "three-stage rugby-specific adaptive training program" developed in this paper can be further refined in the future by incorporating sports biomechanics technologies (such as three-dimensional motion capture and surface electromyography analysis) to optimize training details. This will provide more precise scientific support for the rehabilitation training of upper limb injuries in rugby, facilitating athletes' efficient return to the field and enhancing their athletic performance.

Disclosure statement

The authors declare no conflict of interest.

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