PREVENTING SHOULDER INJURIES IN THROWERS & POLE VAULTERS

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INTRODUCTION

Track and field athletics is globally popular and represents a featured core of most multi-sport international events like the Olympic games. From an injury prevention perspective, nearly 80% of injuries in track and field are related to the lower extremity secondary to the predominance of running and jumping events. Based on this, many injury prevention programs and research studies have targeted those athletic populations and overlooked the events and athletes whose sports have a higher upper extremity load and demand that leads to an elevated risk of shoulder injuries. When we change and limit our focus to upper extremity demanding events such as shot put, hammer, discus, javelin, and pole vault, the risk of shoulder injuries and upper extremity injuries is much higher and the need to include upper extremity injury prevention protocols becomes more critical to keep the athlete on the competition field for not only an event but for their career.

EPIDEMIOLOGY

Specifically, when examining upper extremity injuries in track and field athlete throwers, 70% of injuries involved the shoulder followed by elbow (15%), and hand/wrist (7% each)[1]. Thirty percent of all injuries in javelin throwers are related to the shoulder. Of these injuries, 33% were ligamentous, 31% tendinous, 20% muscular, 8% joints, 6% bones, and 2% nerves[2]. When comparing injury patterns between athletic throwing sports, the lowest percentage of total injuries were seen amongst discus throwers (0.6%) while the highest percentage was seen in javelin (3%). In women's collegiate track and field, pole vaulting accounted for the largest percentage of injuries amongst all field athletes (6%) while discus (1.5%), javelin (2%), shotput (3%), and hammer throw (1.5%) accounted for substantially fewer injuries[3]. Admittedly, the pole-vaulting risk was not limited to the upper extremity and included a myriad of other traumas related to the risk related to height of the event. Interestingly, while 78% of upper extremity injuries in throwers occurred during practice rather than competition, a higher percentage of competition injuries led to time-loss from sport leading to an average 10.1 ± 12.0 days missed[4].

In order to target the prevention of throwing injuries in athletes we must not only recognize that the problem exists, but we must also understand the pathomechanics of why it occurs and the specific pathoanatomy of injury so that injury prevention programs can be most effective. This emphasis will be particular important as we target injury prevention in track and field throwing athletes and pole vaulters because their events are different and place different and unique loads across the shoulder. Like most injuries in sports medicine, a key underlying cause of shoulder injuries in track and field athletes is overuse and loading[5]. Careful attention to training intensity and repetition counts will go a long way in reducing injury risk.

BIOMECHANICS/MECHANISMS OF INJURY

The various throwing techniques utilized by field athletes share some common fundamentals of the kinetic chain[6]. The shared kinetic chain mechanics seen in javelin, discus, shotput, and hammer throw begins with ground reaction forces generated by the lower extremities. This energy is transferred from the feet through the lower extremities and pelvis into the torso across the scapulohumeral complex into the shoulder and down the

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Image: Javelin.

arm, elbow, wrist, and hand. A successful throw requires optimal strength, flexibility, and coordinated muscle activation about the shoulder to transfer the energy to the hand and sports equipment. A breakdown in any of the links along the kinetic chain predisposes the athlete to injury in the downstream segments of the chain[7].

Each throwing action of the various field sports impose significant abduction and external rotation forces on the shoulder. During this extreme movement, forces are transmitted through the muscles and tendons of the rotator cuff. Adaptive changes can mirror those seen in overhead throwing athletes including increased external rotation (ER) range of motion (ROM), decreased internal rotation (IR) ROM, tightening of the posterior joint capsule, hypermobility of the anterior joint capsule, and increased overall capsular laxity. With increased ER, there is increased stress on the inferior glenohumeral ligament complex, leading to an elevated risk of anterior and translation of the humeral head and functional instability. Posterior capsular and posterior rotator cuff tightness occur secondary to chronic repetitive loading and represent the major pathologic process in glenohumeral internal rotation deficit (GIRD). GIRD is defined as a loss of >20° of IR compared to the contralateral shoulder. It is thought to only become pathologic when total rotational ROM of the shoulder is decreased by >5° compared to the contralateral arm. GIRD has been associated with posterior superior labral tears, partial articular-sided supraspinatus (PASTA) tears, and superior labral anterior-to-posterior (SLAP) tears in overhead throwers.

Javelin

Pathoanatomy: Rotator cuff secondary to impingement or overuse, anterior capsule and labrum secondary to cocking leading to anterior instability, posterior capsule tightness secondary to traction and repetitive overload leading to GIRD and internal impingement

Biomechanics:

The javelin throw consists of 5 distinct steps: the approach, sideways crossover steps, single support, abrupt stop, and finally the follow-through. The javelin is initially held in the palm of the thrower's hand, parallel to the ground and over the throwing shoulder with the forearm supinated and the elbow flexed to roughly 90 degrees. As the approach phase begins, the thrower starts running with their hips facing the direction in which they are throwing, allowing them to gain momentum. The crossover steps then stretch the trunk and throwing muscles to build up potential energy. During this phase, the javelin is held behind the throwing shoulder with the shoulder abducted and externally rotated and the elbow partially extended. During the single support phase, the athlete transitions from running into the throwing motion. The abrupt stop involves a transfer of momentum from forward motion to the overhead throw of the javelin, culminating in its release. Finally, during the follow-through phase, the thrower completes the throwing motion and regains balance as he or she decelerates. As there is significant force driving the arm forward after release, the stabilizers of the shoulder (i.e. rotator cuff) must be highly active to decelerate the arm in the follow-through phase. With regards to the shoulder, the biomechanics of the javelin throw closely resemble the biomechanics of throwing a baseball.

Shot Put

Pathoanatomy: Rotator cuff secondary to impingement or overuse, acromioclavicular injury secondary to repetitive compressive load, pectoralis injury secondary to load and overuse, posterior capsule laxity and instability secondary to posterior directed forces during pre-release phases of throwing.

Biomechanics:

The shot put can be conceptualized as a complex pushing movement. Two techniques are commonly used for shotput: the glide technique and the rotational technique. The glide technique consists of several phases. In the first phase, the upper body remains relatively passive as the thrower drives with the nondominant leg momentarily becoming airborne as the back foot briefly lifts off of the ground. In the power position, the dominant leg touches the ground first followed by the nondominant leg. Meanwhile, the upper body remains passive with the shot held over the back leg and close to the body. The front leg then applies significant force to the toe board as the throwing motion is initiated. As the throwing arm begins its forward arm strike, the shoulder remains adducted and the elbow moves from a flexed to an extended position. The front hip remains behind the knee as both legs extend. Both legs then lift off the ground as the shot is finally released. The rotational technique stems from the concept of rotational inertia. The thrower spins using a long sweeping motion of the free leg. During the spin, the upper body is rotated opposite the lower extremities which builds torque through stretching of the core muscles. This potential energy is eventually transferred from the core through the shoulder and arm and finally to the shot for release. In both of these techniques, the energy produced by the lower extremities while keeping the upper body back and passive creates the effect of loading a spring. This energy is transferred through the kinetic chain and ends with rapid flexion and adduction of the shoulder, extension of the elbow, and flexion of the wrist. Given that the primary function of the clavicular head of the pectoralis major is forward flexion of the arm, this final step places tremendous stress on the pectoralis major, placing these athletes at high risk of pectoralis major strain.

Image: Shot Put.

Discus Throw

Pathoanatomy: Rotator cuff secondary to impingement or overuse, pectoralis overuse secondary to chronic loading, anterior capsule and labrum injury or laxity secondary to cocking which risks anterior instability

Biomechanics:

The discus throw is composed of five phases. The initial double support phase represents the time between maximum backswing and the takeoff of the right foot. During this phase, the trunk is rotated, loading the core to store potential energy while both arms are extended to provide counterbalance. The single support phase begins as the right foot is lifted off the ground. The trunk rotates while keeping the arms extended until the initiation of the flight phase when the left foot is picked up and the body accelerates forward within the circle. The thrower then lands on the right foot, which plants and pivots. The body leans forward with knees bent to lower the center of mass. The second double support phase begins as the left foot plants with the thrower's body perpendicular to the direction of the throw. During the release phase, the stored energy is transferred through the kinetic chain from the pelvis to the trunk then the chest, and finally the throwing arm and discus. The release of the discus represents the final step, the delivery phase.

Image: Hammer Throw.

Hammer Throw

Pathoanatomy: Rotator cuff secondary to impingement or overuse, pectoralis overuse secondary to chronic loading, anterior/posterior capsule laxity secondary to repetitive traction loads, scapular dyskinesia/dysfunction secondary to repetitive traction loads, bicipital tendinopathy secondary to repetitive eccentric traction loads followed concentric contraction during delivery

Biomechanics:

The hammer throw entails the generation of centrifugal force to hurl a metal ball attached to a steel wire. The throwing technique is quite complex and involves coordinated arm swings coupled with 3 to 5 full body turns before release. During the first 2 or 3 swings, the thrower rotates the hammer over their head. These swings place the hammer into orbit, providing inertia for the turns. Each turn is divided into a double support phase where both feet are contacting the ground as the hammer is accelerated, and a single support phase in which one foot is lifted in order to turn. Finally, with both feet on the ground, the thrower extends their knees and hips while simultaneously rotating their upper body just before releasing the hammer. There is a paucity of research regarding the specific forces placed on the athlete's shoulder during the hammer throw; however, it is clear that the shoulder is placed through extremes of motion increasing the risk of impingement, it requires power increasing the risk of cuff, pectoralis, and scapular muscle overuse and strains, and it places high traction loads across the glenohumeral joint and scapular thoracic joint increasing the risk of instability and muscle strains.

Pole Vaulting

Pathoanatomy: Rotator cuff secondary to impingement or overuse related to pulling body weight up and over the pole, anterior capsule and labrum laxity secondary to cocking and body weight leading to anterior instability, trauma secondary to awkward falls or missed protective cushions, posterior capsule laxity secondary to posterior loading during pole planting.

Biomechanics:

Pole vaulting, while not categorized as an overhead throwing discipline, necessitates a sophisticated orchestration of kinetic energy transmission from the lower extremities to the glenohumeral joint to achieve success. The pole vault comprises seven discrete phases: the approach run, arm elevation and transition, take-off with pole planting, the pendulum-like swing phase, the rock-back motion, the inverted posture, and the critical bar clearance. During the take-off phase, the dominant shoulder plays a pivotal role in sustaining arm elevation while withstanding ground-induced forces acting on the bending pole. This phase imposes the greatest stress on the glenohumeral joint, placing it in a potentially unstable position, thus rendering subsequent shoulder instability incidents not unusual in pole vaulting

TARGETED INJURY PREVENTION PLANS

Following the van Mechelin model of injury prevention, we have now laid out the extent of the problem and better understand the mechanism and anatomy of injury in at risk track and field sport[8]. The next step is to create targeted prevention programs for healthy athletes in javelin, shot put, hammer throw, discuss and pole vault. Well-known risk reduction programs for throwers include Throwers 10 program and FIFA 11+ shoulder injury prevention program[9-11].

The FIFA 11+ shoulder injury prevention program is aimed at football goalkeepers and has three main components: 1) Warm up, 2) Strength and balance of shoulder, elbow, wrist and finger muscles and 3) core stability and muscle control. The Throwers 10 was original designed with baseball players in mind and includes not only shoulder functional and rotational exercises but also includes exercises for the elbow and wrist to complete the path of the kinetic chain. Valuable information can be found in the 2022 Bern Consensus Statement on injury prevention[12]. Rehabilitation and return to sport for athletes at all participation levels recommends building prevention program targeting 1. range of motion/motor control, 2. Plyometrics and 3. Open/closed kinetic chain exercises. The Bern statement recommends implementation of prevention programs twice weekly and exercises should be in sport-specific positions. Implementing these programs isn't a simple matter of prescribing generic exercises, rather they need to be tailored to the individual's needs which will vary according to their current levels of preparation and wellness. In this regard, the athlete's irritability will guide their rehabilitation and injury prevention progressions.

So how, where, and what to start for track and field throwers or pole vaulters?

Targeted intervention combined with continuous athlete monitoring is a useful approach. The program will need buy-in from athletes and coaches to be successful as it will need to be integrated into normal practice/training routines and can't be seen as impairing performance. The program should be sport and event specific. Indeed, athletes will respond better to the program if you know and understand the unique demands of their sport.

Most shoulder and elbow injuries in track and field throwers and vaulters are thought to be related to poor technique or the aggressive increase in training load (number of repetitions, intensity, or a combination of both)[7]. Collaboration with coaches to ensure proper technique, and dialing in a safe and progressive training load with and exercise prescription is a critical key to preventing elbow and shoulder injuries. For example, if a javelin thrower is unable to maintain the correct throwing form and unable to keep the elbow in an elevated position secondary to improper technique or fatigue, the athlete is likely to put greater amount of stress on the shoulder and elbow. It's noted that as athletes fatigue, they can be prone to "dropping their elbow" (reducing shoulder abduction) below shoulder level and then losing external range of motion. These factors are thought to then overload the shoulder and elbow. Accordingly, it's important for the coach to maintain close monitoring of the athlete's fatigue levels during a session. Typically, they will notice

> ***Ultimately, every rehabilitation and return to play program for track and field throwers should be personalized and sports specific accounting for the unique demands and needs of that athlete within their sport.***

a worsening of throwing form before an athlete will report any sensation of tiredness, and the coach may need to stop a session early, or change the focus of the session when they notice poor form that can't be easily corrected. Occasionally sessions will need to be stopped early when athletes are inappropriately making maximum effort throws – throwing close to their personal bests – and the coach may need to step in to protect the athlete's arm. The International Olympic Committee consensus statement on loading in sport recommended a balanced approach of load and recovery which included careful monitoring of symptoms, effort, repetitions and pyschologic readiness to optimize an athlete's ability to optimize performance and avoid injury[5].

Examples of measures to monitor workload in field athletes and throwers include; an assessment of number of throws or repetitions and number of throws at given distance; a strength assessment including external or internal rotation strength either isokinetically or with handheld dynamometer. An athletic shoulder test that assesses rate of force development analysis can also be of benefit. A recommended toolkit for assessment should include an inclinometer or goniometer for ROM measurements, a hand-held dynamometer for strength measurements, and wearables and questionnaires for documentation of effort and recording perceived effort is critical for reproducible monitoring. Continuous monitoring over time is the smart way to go with the ability to adapt or progress sessions as indicated.

Regarding psychological readiness to train and return to sport, the player should feel comfortable throwing and their feedback should be encouraged throughout the return to play process. A good coach/athlete relationship is also key to determining and enhancing psychological readiness. This relationship extends to the parents/guardians in younger athletes. Recognizing and managing external pressures from parents / guardians on the younger athlete especially after injury needs to be managed accordingly.

The following are examples of targeted techniques in rehabilitation can optimize recovery and improve performance in track and field throwers and pole vaulters.

Figure 1a and b: ROM/Motor control for all athletes – ER powerband behind back and under arm (focus on end ROM ER and elevation) can be particular effective in javelin throwers. Pull overs in tension arc position mimics the arc of motion for javelin throwers. (Begin with limiting flexion ROM and progress to more close to end range of motion).

Figure 2a and b: Plyometric – Yo-yo with weight and powerband can be effective in all overhead throwers.

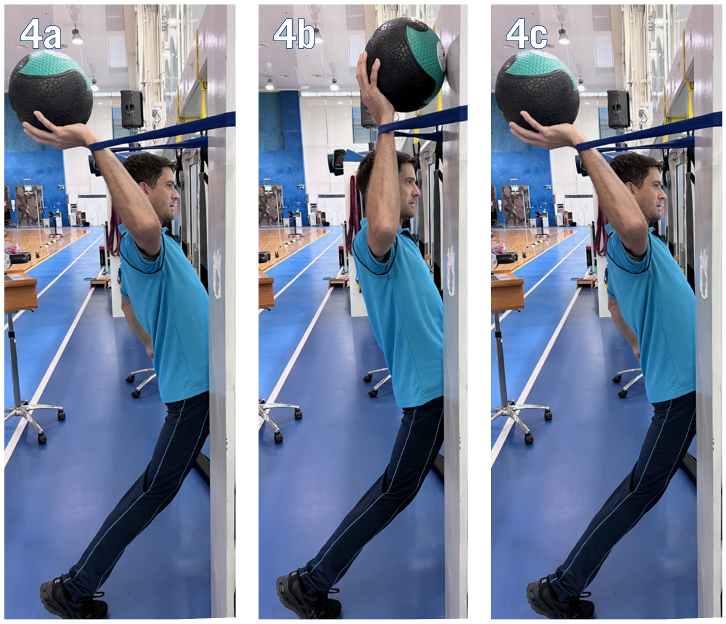
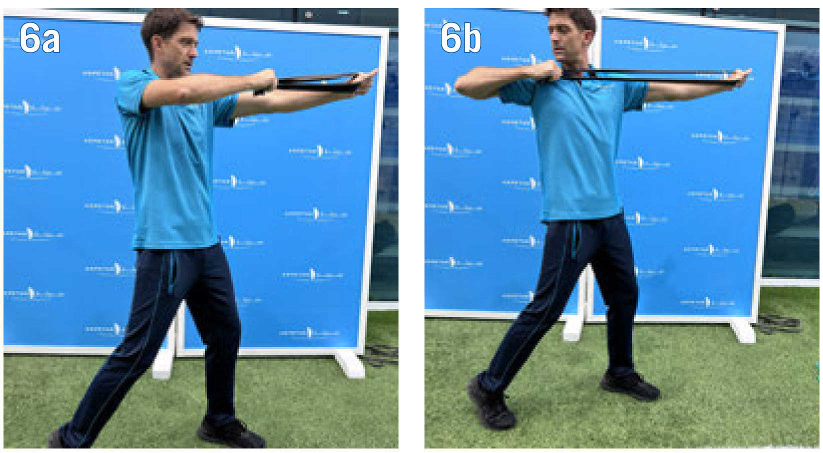


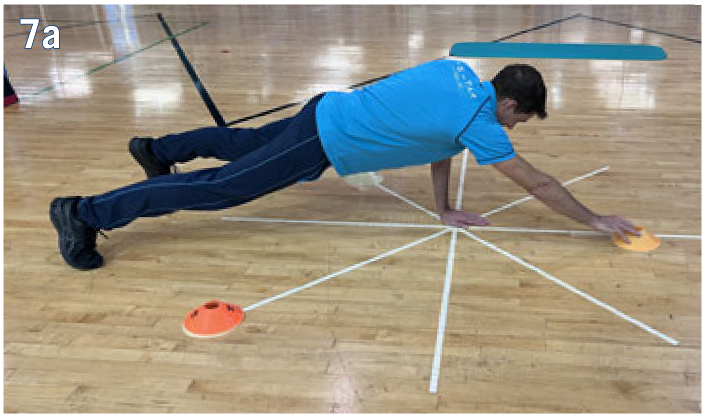
Figure 3a and b: Wall taps with elastic work both IR and ER help to both strengthen and coordinate the rotator cuff and kinetic chain in throwers.

Figure 4a, b, and c: Open/close kinetic chain – High plank with ER in 90º/90º.

Figure 5a and b: ROM/Motor control is also critical for most throwers. Archer exercise helps optimize scapular function as part of the kinetic chain.

Figure 6a and b: Plyometric – Yo-yo with weight and powerband creates dynamic loading through-out the range or motion.

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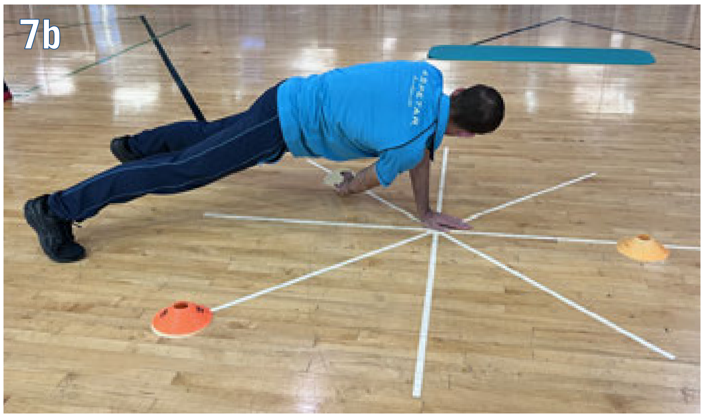
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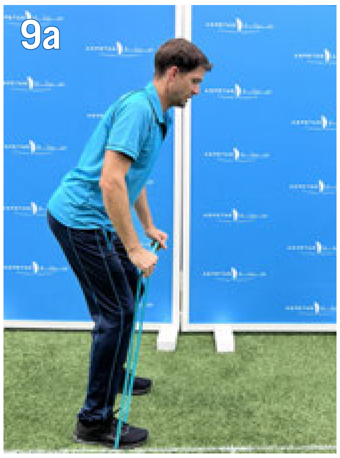
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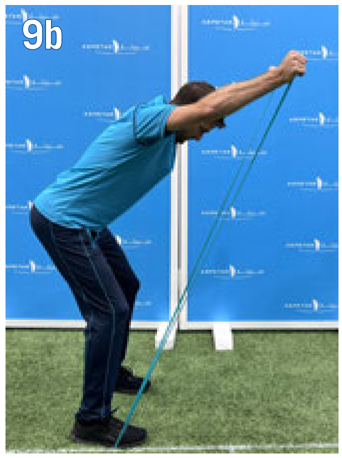
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10a


11b

Figure 7a, b and c: Open/close kinetic chain provides for dynamic loading, strengthening coordination along the upper portion of the kinetic chain. – Y-balance (emphasis on weightbearing arm).

Figure 8a and b: Push up clap is another dynamic technique for loading and training and is particular valuable in shot-putters.

Figure 9a and b: Dynamic ROM/Motor control is important for athletes that post off of their lower extremity during the thrown such as hammer and discus throwers – Bend over Y raises (Bands, dumbbells or pulley).

Figure 10a and b: Plyometric – Side-lying T's plyometrics with ball in 90 flexion position are great dynamic training for throwers.

Figure 11a and b: Open/close kinetic chain is an essential component of training for all throwers – High plank with thoracic rotation T's are good examples and have been particularly effective in pole vaulters.

Figure 12a and b: Open/close kinetic chain is an essential component of training for all throwers– High plank walk outs with legs backwards are a good example.

Ultimately, every rehabilitation and return to play program for track and field throwers should be personalized and sports specific accounting for the unique demands and needs of that athlete within their sport. An example of a progressive return to sport program or shot put or javelin is provided.

WHEN NON-OPERATIVE APPROACHES FAIL IS IT TIME TO REFER FOR SURGERY?

The goal in managing shoulder injuries of track and field throwing athletes is clear: return them to their preinjury level of sport in the most efficient and cost-effective way possible. For the majority of shoulder injuries in this cohort, conservative treatment remains first-line. However, for injuries that haven't responded to conventional rehabilitation protocols, surgery is often warranted. In these circumstances, athletes should be referred to an orthopaedic surgeon in a timely manner. Specific injuries necessitating referral include:

Rotator Cuff Tears: Complete rotator cuff tears, especially in young athletes, often demand surgical intervention for optimal function restoration. Surgery is frequently favored when conservative treatments fail to address the issue or when the tear is extensive. Seventy-five percent of these athletes were able to return to sport at a mean of 6.4±6.0 months following repair while 62% were able to return to their preinjury level of play[13].

Shoulder Instability: Labral tears, such as Bankart lesions in throwers, may require surgery to stabilize the shoulder joint and prevent further dislocations or subluxations. These injuries can significantly impact throwing performance. Recurrent shoulder instability issues, such as multidirectional instability and acute traumatic dislocation, can compromise a thrower's performance and require surgical stabilization to restore shoulder function and prevent further dislocations. Special awareness regarding the presence of posterior instability in shot putters is important[14].

Distal clavicle problems: Repetitive throwing, pole vaulting as well as weight-lifting training programs associated with high level performance can create chronic repetitive compression loads across the acromioclavicular leading to degenerative changes and pain that can be treated with surgical decompression with a high rate of return to play.

Table 1

Progressive return to throwing Javelin

Progression criteria 1. Pain free session 2. No soreness next day 3. Must feel comfortable.
Stop session when poor technique noticed by coach or fatigue reported by athlete
Recommended: Start 2x per week, followed by 3x per week.
Video sessions for monitoring progressions and visual feedback for athlete and coach.

Stage 1	***Stage 2***	***Stage 3***
Target: 4 throws Intensity: <50% Equipment: Ball (cricket, hockey of baseball)	*Target: 50 throws Intensity: <50% Equipment: Ball (cricket, hockey of baseball)*	*Target: 50 throws Intensity: <50% Equipment: Ball (cricket, hockey of baseball)*
Warm up: Active and easy throws 15m (20 throws) Rest 10min Warm up throws 15m (20 throws)	*Warm up: Active and easy throws 20m (25 throws) Rest 10min Warm up throws 20m (25 throws)*	*Warm up: Active and easy throws 30m (25 throws) Rest 10min Warm up throws 30m (25 throws)*
Progress to 3x 20hrows	*Progress to 3x 25 throws*	*Progress to 3x 25 throws*
Stage 4	***Stage 5***	***Stage 6***
Target: 50 throws Intensity: <50% Equipment: 400g Javelin	*Target: 50 throws Intensity: <50% Equipment: 400g Javelin*	*Target: 50 throws Intensity: <50% Equipment: 400g Javelin*
Warm up: Active and easy throws 15m (25 throws) Rest 10min Warm up throws 15m (25 throws)	*Warm up: Active and easy throws 20m (25 throws) Rest 10min Warm up throws 20m (25 throws)*	*Warm up: Active and easy throws 30m (25 throws) Rest 10min Warm up throws 30m (25 throws)*
Progress to 3x 25 throws	*Progress to 3x 25 throws*	*Progress to 3x 25 throws*
Stage 7	***Stage 8***	***Stage 9***
Target: 40 throws Intensity: 50% Equipment: 400g Javelin	*Target: 20 throws Intensity: 75% Equipment: 400g Javelin*	*Target: 10throws Intensity: 100% Equipment: 400g Javelin*
Warm up: Active and easy throws 50% (20 throws) Rest 10min Warm up throws 50% (20 throws)	*Warm up: Active and easy throws 75% (10 throws) Rest 10min Warm up throws 75% (10 throws)*	*Warm up: Active and easy throws 100% (5 throws) Rest 10min Warm up throws 100% (5 throws)*
Progress to 3x 20 throws	*Progress to 3x 10 throws*	*Progress to 3x 5 throws*
Stage 10	***Stage 11***	***Stage 12***
Target: 40 throws Intensity: 50% Equipment: 600g Javelin	*Target: 20 throws Intensity: 75% Equipment: 600g Javelin*	*Target: 10 throws Intensity: 100% Equipment: 600g Javelin*
Warm up: Active and easy throws 50% (20 throws) Rest 10min Warm up throws 50% (20 throws)	*Warm up: Active and easy throws 75% (10 throws) Rest 10min Warm up throws 75% (10 throws)*	*Warm up: Active and easy throws 100% (5 throws) Rest 10min Warm up throws 100% (5 throws)*
Progress to 3x 20 throws	*Progress to 3x 10 throws*	*Progress to 3x 5 throws*

Figure 1: Progressive return to sport program – distance / number of throws/weight of shot put javelin.

Traumatic Fractures & Ruptures: Fractures, particularly in the throwing arm, require prompt surgery to ensure proper healing and the ability to return to competitive throwing. This is especially true with comminuted, peri-articular, and open fractures. Ninety percent of patients undergoing pectoralis major tendon repair successfully returned to sport at a mean of 6.1 ± 1.7 months post-surgery while 74% returned to their preinjury level of sport[15].

The decision to opt for surgical management as a first-line approach is based on a thorough evaluation by a sports medicine specialist and orthopedic surgeon, taking into account the specific injury, the athlete's goals and demands, and the extent of structural damage. It's crucial to assess each case individually and consider the most appropriate treatment to optimize the athlete's function and performance.

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