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Return to Throwing after Shoulder or Elbow Injury

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Abstract

Purpose of review Throwing places high demands on the human body, and specific characteristics are developed over time unique to these athletes. When returning to throw after injury, it is important to follow a criterion-based progression that allows the body to be prepared appropriately for the stresses that throwing will require. There is currently a void in the literature for criteria-based progression that helps these athletes return to the highest level of play.

Recent findings As injury rates continue to rise in baseball, there is increased evidence showing contributions of the core and lower extremity to the baseball pitch. There is also additional data showing pitcher specific characteristics such as range of motion and scapular position in this unique population. The rehab professional should take into account every phase of the pitch starting from balance through ball release when designing a comprehensive return-to-throwing program.

Summary Returning an athlete back to a throwing sport can be an overwhelming task. The rehabilitation specialist must have a sound understanding of the throwing motion as well as any biomechanical implications on the body, contributions throughout the kinetic chain, range of motion, and strength characteristics specific to the thrower as well as proper tissue loading principles. It is important that these athletes are not progressed too quickly through their programs and that a criteria-based progression is followed. They should have normalized range of motion, strength, and scapular mechanics, followed by a sound plyometric progression. Once this is achieved, they are advanced to an interval throwing program with increasing distance, effort, and volume which should be tracked for workload, making sure they do not throw more than their body is prepared for.

Keywords Return-to-throw · Return-to-play · Plyometrics

Introduction

Throwing a baseball is one of the most highly dynamic skills in all sports producing a tremendous amount of force across multiple joints. Shoulder and elbow injuries in baseball are unfortunately not uncommon. Conte [1] showed that pitchers' injuries accounted for 56.9% of disabled list days over a 10-year period. After enduring an injury, returning an athlete back to play at the same level of performance is the ultimate goal. Return-to-play rates after ulnar collateral ligament reconstruction have been favorable, with an overall return-to-sport rate of 86.2% [2,3,4]. Many studies show a high return-to-sport rate at an elite level; however, return-to-similar performance and workload are not as high with significant decline in earned run average (ERA) and walks and hits per inning pitched (WHIP) [2]. Klouche et al. [5] performed a meta-analysis of return to sport after rotator cuff repair. When including both recreation and professional athletes they reported an overall 84.7% return to sport rate. However, only 49.9% of professional and competitive athletes returned to the same level of play. Return to throwing after surgical treatment for superior labral lesions is even more debilitating and sometimes unattainable. Fedoriw et al. [6] showed only 48% of pitchers were able to return to play, and only 7% were able to return to their prior level of performance. When helping guide patients back to throwing activities, a criteria-based algorithm (Fig. 1) should be followed that encompasses all physical characteristics of the overhead athlete.

This article is part of the Topical Collection on *Injuries in Overhead Athletes*

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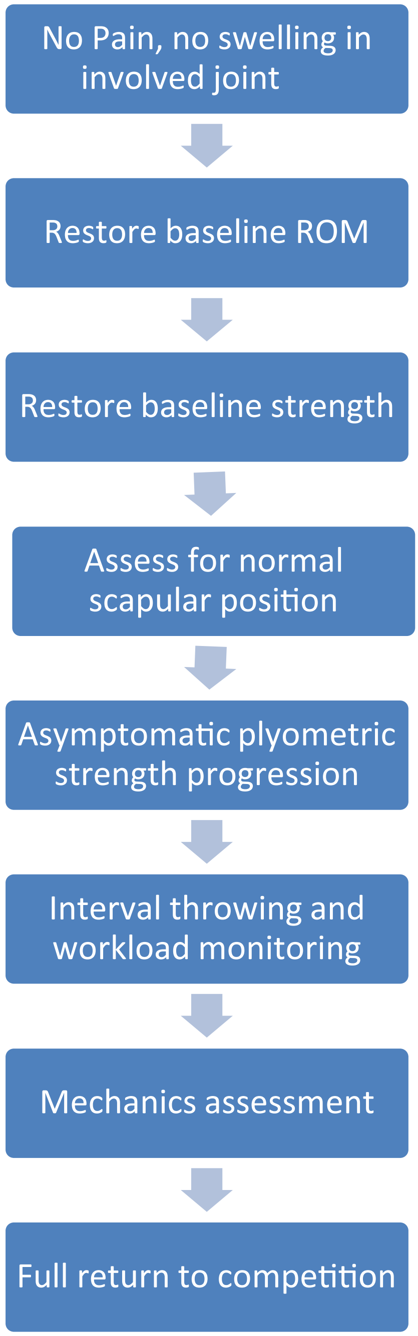

Fig. 1 RTP Algorithm

Range of Motion and Flexibility

In order for the athlete to progress into a return-to-throw program, minimum criteria must first be met. The athlete must demonstrate 0/10 pain rated on numeric pain rating scale (NPRS), have no swelling or inflammation around the involved joint, and report pain-free activities of daily living. Once these criteria have been met, range of motion must be normalized in the involved extremity.

Due to the exceptional demands on the body of the overhead thrower and the forces imparted on individual joints, these athletes display unique range of motion profiles. Numerous papers show a decrease in elbow extension that is normal for the overhead athlete ranging from 5 to 7.9° [7, 8•]. This is an important finding as end-range stretching on these individuals may not be warranted and may result in bony impingement and potentially irritation to the elbow. Shoulder range of motion deficits, specifically decreased external rotation and flexion, has been cited as predictor of elbow injury, and normal values for the overhead thrower should be restored [8•]. Shoulder flexion, external and internal rotation at 90° abduction, and horizontal adduction should all be examined. Wilk and colleagues [9] published ROM characteristics of professional baseball players including dominant arm ER at 90°, $132 \pm 11°$; IR at 90°, $52 \pm 12°$; total rotational motion, 184°; and horizontal adduction, 42 ± 8. Wilk also examined shoulder flexion on the throwing shoulder in 296 professional pitchers showing an average of 177.7° [10]. Significant side to side differences have been shown consistently in the literature which suggests that comparing motion to the non-dominant side may be inappropriate.

Scapular Position/Assessment

The scapula has been identified as an important link in the kinetic chain and is routinely examined in the throwing athlete. As an athlete prepares to return to throw, there should be a comprehensive assessment of the scapula. Burkhart and colleagues coined the term SICK (Scapular malposition, Inferior medial border prominence, Coracoid pain, and dysKinesis of scapular movement) scapula as they noticed abnormalities in the throwing shoulder [11]. It is important to recognize that baseball pitchers have particular adaptations which have developed over time and are unique to their sport. Kibler has described the role of the scapula in overhead throwing. The scapula's primary function is to serve as a stable base for shoulder motion during the overhand throw. It must retract as the arm is cocked back, then has to rapidly protract around the thoracic wall as the arm accelerates and finally decelerates. Lastly, the scapula must upwardly rotate which allows for elevation of the acromion and prevention of shoulder impingement during the throw [12]. Throwing athletes may display increased scapula upward rotation, internal rotation, and retraction compared to the non-dominant limb [13]. It is believed that increased upward rotation can help reduce subacromial impingement, especially in the throwing athlete. Alterations in upward scapular rotation have been noticed in patients with subacromial impingement [14]. Increased scapular internal rotation was also noticed in the throwing population, which clinically could be interpreted as scapular winging in a non-throwing population but potentially a normal adaptation for the throwing athlete.

Static and dynamic scapular assessments must be made when examining the overhead thrower. In the static position, no gross winging should be noted in the medial or inferior border. Although scapular position on the throwing side may not be symmetrical to the non-throwing side, the presence of winging should be noted. During an active elevation test, the scapula is observed for elevation and upward rotation. The authors also prefer to observe the scapula during sport specific movement. In order to achieve this, the athlete is asked to slowly replicate an overhead throw. During this time, the scapula is being observed for full retraction during cocking position and full protraction during the acceleration phase.

Lower Extremity

The pitching motion is very complex and requires coordination and activation of both lower and upper extremity muscles. A few studies have described lower extremity muscle activation during pitching [15,16]. From the point of stride foot contact through the moment of ball release, the highest level of EMG activity was noticed in both lower extremities. These muscles include gastrocnemius, vastus medialis, gluteus maximus, rectus femoris, and biceps femoris. Transitioning from the balance phase to stride foot contact, there is high-EMG activation of the trail leg as it generates linear momentum. Muscle activation in the stride leg is very high after ball release as these muscles work to stabilize and decelerate the trunk [16]. Oliver et al. [15] showed significant relationships between bilateral gluteus medius and scapular stabilizer activations which support the valuable contribution of the lower extremity during the throw as well as its relationship to scapular stabilization.

A screen of lower extremity strength can be conducted in the clinical setting. A single-leg squat and forward lunge can give the clinician an idea of lower extremity strength and stability. During these movements, the leg being tested is observed for valgus and hip deviation as well as good eccentric control.

Upper Extremity Strength/Plyometrics

Return-to-throwing rehabilitation program of the overhead athlete typically involves transitions from a strength phase to a plyometric phase and finally into the beginning stages of a throwing program. Literature cites the use isokinetic testing as criterion for progression from a strengthening phase to the plyometric phase [17] by testing for upper extremity symmetry at 180° and 300°/s as well as appropriate shoulder external rotation to internal rotation strength ratios at the same testing speeds. Many rehabilitation facilities are not equipped with isokinetic machines due to cost and space constraints. The authors of this article offer considerations to physiological strength training principles as supplemental guidelines for the strength phase transition to the plyometric phase of overhead athlete rehabilitation.

Early phases of upper extremity rehabilitation involve the restoration of joint ROM and the initiation of low levels of strengthening. Muscle force generation is the greatest with eccentric contractions followed by isometric and last by concentric contractions [18•]. Applying exercise to healing tissue in the rehabilitation setting should take into consideration these factors. Safe methods of application include submaximal isometrics in mid ranges progressing towards end ranges, concentric movements followed by loaded eccentric movements. Caution should be maintained with respect to the principles of tissue healing taking into account tissue type (tendon, muscle, ligament, cartilage) when introducing and progressing exercise.

Eccentric exercise alone has demonstrated benefits to healing tissue and has been used in the treatment of tendinosis [19] and hamstring injury rehabilitation. With a focus on muscle remodeling, eccentric strength training has been advocated in the rehabilitation of hamstring injuries. On a physiological level, eccentric exercise has been shown to improve tensile strength to musculoskeletal units and maximize cross-bridge formation through slow loading. Eccentric strength training following a hamstring injury may effectively restore optimum musculotendon length for active tension to normal [20]. Towards the end of the strength phase, once sufficient healing and exercise volume tolerance have been established, eccentric emphasis can provide the benefits described above as well as prepare the tissue and neurological system necessary for the advanced plyometric phase of the program. In addition, an increase in tendon stiffness has been seen in response to resistance training which can assist the muscle's ability to generate force rapidly [19].

During the strength phase of the rehabilitation program for overhead athletes, the authors of this article view the concepts associated with the force-velocity curves as critical to its progression. Simply put the force-velocity curve states force and velocity are inversely related. The greater the force generated, the slower the movement or muscle contraction and conversely a smaller contracted force will produce a faster velocity of movement.

As indicated in the force-velocity curve (Fig. 2), maximum strength training should involve 90–100% of one rep max producing the slowest speeds of movement while maximum velocity or speed training should involve loads of < 30% of one rep max thereby producing the highest contraction velocities. There is a training continuum between the two ends of the curve that extend from maximum strength to strength-speed, to speed-strength, and to maximum velocity. As stated previously, reduced loads will allow greater speeds of movement. Finally, the strength-training principle that should be considered is the concept of power output: Power = force × velocity [21•]. Manipulating either of these variables will allow changes in power output. In the rehabilitation setting, beginning stages

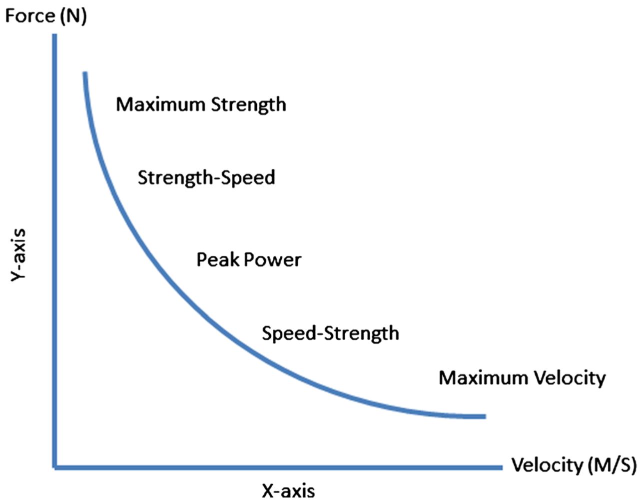

Fig. 2 Force-velocity curve

of strengthening should be used to develop a base-work capacity and incorporate strength more indicative of the left side of the force-velocity curve. Loads approaching maximum lifts should be avoided and coincide more with loads in the strength speed region of the curve to respect the healing tissue involved. Characteristics should include slower resistance speeds with progressive muscle tension to maximize cross-bridge formation. Once adequate work volume has been built, exercise can be progressed by dropping muscular tension and performed at higher speeds to prepare for the higher velocities necessary for plyometric movements (right side of the force-velocity curve). The authors of this article note that much of the research on the force-velocity curve is with healthy, non-injured subjects and do not explicitly apply to the rehabilitation setting. Soft tissue healing times must be respected following an injury or surgery and are suggested by the authors to train an overhead athlete in the middle ranges of the force-velocity curve and avoid the extreme end ranges of the curve (max strength or max velocity). A "mixed method" approach of strength training and higher velocity work for power development has been viewed as optimal [22,23]. This includes use of combination of strength-speed with speed-strength training.

Overhead-throwing sports require significant high-velocity demands of the upper extremity in a short period of time requiring significant tolerance to torques generated around the joints involved in the kinetic chain namely the shoulder and elbow. Maximum speeds of internal rotation during the acceleration phase of throwing range from 7000 to 9000° per second at ball release, occurring often times in less than 1 s [18•, 24]. Upper extremity plyometrics has been used in the final phase of the rehabilitation process prior to initiating a throwing program as a means to prepare the upper extremity for the high-velocity demands of throwing [25]. The strengthening phase of the rehabilitation program should serve as the building block for higher level upper extremity plyometrics. Components of the plyometric exercises can be broken down and trained individually in the strength phase in order to implement them safely and effectively in the plyometric phase. Davies et al. [18•] stated that "if a muscle cannot function normally in an isolated pattern then it cannot function normally in an integrated pattern".

Plyometric exercise has been defined as a powerful muscular contraction after the dynamic loading or stretching of the same muscle group [24]. Plyometric training consists of three phases: the eccentric phase, the amortization phase, and the concentric phase. The three phases utilize the stretch-shortening cycle (SSC) as a means to achieve this task at higher speeds and with greater force. The eccentric phase involves the loading and lengthening of a given muscle while the concentric phase involves a forceful concentric contraction of the same muscle group. The amortization phase is the intermediate phase between the two defined as the time between the ending of the eccentric contraction and the initiation of the concentric contraction of that same muscle group [18•]. The stretch-shortening cycle has been shown to facilitate a greater concentric force production through a faster rate of eccentric loading [17]. The faster the muscle is stretched, the greater the force produced, and the more powerful the muscle movement. In addition, the smaller the amortization phase, the greater the force production, therefore using excessive loads in plyometrics can result in too long of an amortization period. A lengthened amortization phase results in an inefficient SSC potentiation, directly influencing the concentric muscle contraction associated with it [26]. One key aspect of plyometric training is to reduce this amortization phase in order to maximize force production.

There is currently little data on the power development and training of the upper body, but research has shown that the addition of plyometric exercise to a strong foundation of strength training can improve power outputs when compared to strength-training alone [27]. This premise can be used when designing return-to-play programs in the rehabilitation setting for the overhead athlete. When transitioning from the strength-building program to a plyometric program, a base level of power and high velocities of movements, acceleration, and deceleration are all necessary components. The athlete's throwing motion requires rapid acceleration from a position of maximum shoulder ER until ball release and rapid deceleration in the follow-through phase.

The following section is a progressive resistance program within the strength phase of an upper extremity rehabilitation program. The first 6 weeks of a strengthening program for an untrained healthy athlete typically involves neuromuscular system. At 6–8 weeks, muscular hypertrophy changes typically begin. A periodized rehabilitation program involves 4-week blocks progressing from ROM to strengthening to plyometric (power) to an interval sport program. As described above, phases overlap within a rehabilitation program. For example, pre-plyometric components are introduced at the end of the strength phase while strengthening still occurs within the plyometric phase [Appendix].

Interval Throwing and Workload

After successful completion of a plyometric progression program, an interval throwing program can commence. Recently, with a rise in elbow injuries in baseball, there has been concern about the efficacy of pitch and inning limits and whether or not they allow for individualization. Individual workload may be a better way to track stress on the throwers elbow. A recent study suggested that MLB pitchers, who require revision UCL reconstruction after returning to play, pitch at workloads greater than their pre-injury level. They also suggested that pitchers should be counseled on individual workload restrictions and that they should be cautioned if they approach pre-injury workloads [28]. With the availability of wearable technology, this is now possible. Elbow force along with other useful performance metrics can be captured and tracked on an individual basis which allows for more specific progressions. Using a simple acute:chronic workload ratio (ACWR), (Fig. 3) may be a useful mechanism in preparing an athlete for return to competition. In this model, acute workload is defined by a rolling 7-day workload and chronic workload as rolling 28-day workload. Spikes in acute workload, relative to chronic workload which results in a high acute:chronic ratio, were significantly associated with increased risk of injury [29]. The benefit of using this ratio model is that it takes into account the workload that the player has performed relative to the workload that the player has been prepared for [30•]. Changes in weekly training loads must also be monitored. Weekly increase of 5–10% in training load resulted in less than 10% risk of injury; however, when week to week training loads were increased by greater than 15%, risk escalated between 21 and 49% [31]. It is important that during training, acute workload does not far exceed chronic workload thresholds. Gabbett showed that ratios above 1.5 times (current week workload was 1.5 times greater than what athlete was prepared for) increased risk of injury by 2–4 times [31].

Consideration needs to be made regarding distances thrown and the medical condition or surgery involved. Studies have shown that long tossing produced greater elbow and shoulder torques with the arm in the cocked position [32]. Maximum distance throws should be avoided initially in procedures such as UCL reconstruction to prevent excessive valgus force on the elbow. Maximum distance throws also exhibited the greatest elbow extension velocity [33]. Longer distance throws should be delayed in posterior medial osteophyte removal minimizing the posterior-medial elbow stress in the rehabilitation process. In addition, shoulder torques have demonstrated the greatest levels with longer throwing distances and no changes in velocity when compared to shorter distances making long tossing after labrum repair questionable in the early stages of throwing [32]. Limiting long toss distances may need to be considered when an individual has a history of shoulder labral tears. Early stages of throwing may require higher volumes at shorter distances to build a greater work capacity and arm strength. Future research should be performed to find the most efficient distances with workload to maximize training effect while minimizing arm stresses.

When designing interval throwing programs, progression should be gradual with increases in weekly loads that do not surpass injury thresholds. Using a structured interval throwing program that gradually increases effort, distance and volume of throws should allow the athlete to safely progress back to pitching. While advancing throughout their interval throwing program, constant monitoring of workload and program modification by the primary therapist or athletic trainer can help prevent excessive forces on the elbow which may lead to re-injury.

Mechanics

As the athlete nears the completion of their throwing program and begins to pitch off of the mound, sound mechanics should be demonstrated. Some biomechanical flaws that lead to increase stress on the arm include open-foot position or angle, excessive or insufficient shoulder external rotation, and poor hip and shoulder separation timing as well as shoulder abduction angle deviating from 90° at ball release [34]. In a clinical setting, this can easily be monitored with slow motion video or any available motion capture system. Fleisig has shown that if flaws are identified, there is potential to correct them in both amateur and professional athletes. Flaws earlier in the motion near front foot contact have a better chance of being corrected than flaws later in the motion near the time of ball release [35].

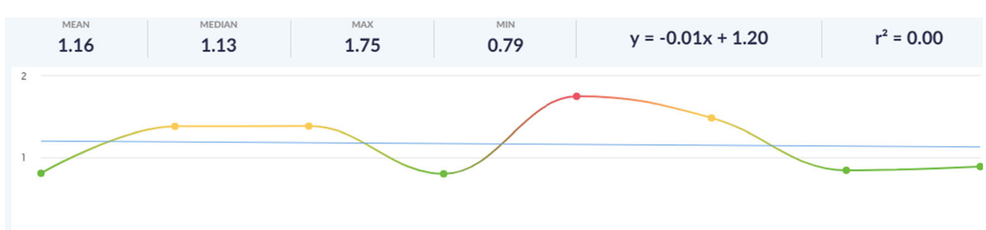

Fig. 3 Acute:chronic workload ratio

Conclusion

Following a comprehensive and criteria-based progression as outlined above and in [Fig. 2], throwers should successfully be able to return to throwing activities within reasonable time frames. It is important to develop sports and position specific player profiles so that we can continue to individualize progressions based on demands of the individual athletes. This progression should provide confidence to both the athlete and the rehabilitation provider as they advance back to maximal effort throwing.

Compliance with ethical standards

Conflict of interest Both authors declare that they have no conflicts of interest.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Appendix

Pre-plyometric and plyometric progression example

- Isometrics mid-range progressing to end ranges as ROM increases
- Resistance through full ROM, constant speed (slower to maximize recruitment)
- Increase volume of resistance to develop a good work capacity
  - ○ Up to three sets, 12–15 repetitions
  - ○ Step wise incremental increase in resistance
  - ○ Reinforce end range fatigue tolerance with perturbations (proprioception)
    - ▪ Body blade static holds at end range (Max ER @ 0 abd)
    - ▪ Manual perturbations at end range
- Begin slow eccentrics to maximize cross-bridge formation
  - ○ 90/90 tubing ER X 10 f/b 5 manually resisted eccentric with tubing
- End with drop set resistance with increasing velocity (superset)
  - ○ One set of 10 D2 flexion (high resistance/Blue) f/b 1 × 10 low resistance/high velocity (yellow)
  - ○ Add eccentrics to first set
- Perturbation exercises emphasizing the stretch-shortening cycle (SSC)
  - ○ 90/90 wall dribbles, wall clock taps
- Transition into plyometric program
  - ○ Tubing dynamic hug press—MB wall dribbles—MB plyo chest pass
  - ○ Lat pull downs—OH MB wall dribbles—OH soccer pass (rebounder)
  - ○ ½ kneel chops (tubing/double arm)—D2 extension tubing—MB chops (rebounder)
  - ○ Tubing row into ER with eccentrics—½ kneel ER flips (concentric)
  - ○ Single-arm D2 flexion/eccentric extension—eccentric plyo ball catches
  - ○ Single-arm D2 extension (tubing)—½ kneel 90/90 plyo ball throw (rebounder)

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