The Physician and Sportsmedicine

ISSN: 0091-3847 (Print) 2326-3660 (Online) Journal homepage: http://www.tandfonline.com/loi/ipsm20

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To cite this article: Kevin E. Wilk, A. J. Yenchak, Christopher A. Arrigo & James R. Andrews (2011) The Advanced Throwers Ten Exercise Program: A New Exercise Series for Enhanced Dynamic Shoulder Control in the Overhead Throwing Athlete, The Physician and Sportsmedicine, 39:4, 90-97, DOI: 10.3810/psm.2011.11.1943

To link to this article: https://doi.org/10.3810/psm.2011.11.1943

The Advanced Throwers Ten Exercise Program: A New Exercise Series for Enhanced Dynamic Shoulder Control in the Overhead Throwing Athlete

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Abstract: The overhead throwing motion is a high-velocity, extremely stressful athletic movement. Its repetitive nature places tremendous demands on the entire body, frequently resulting in injury to the throwing shoulder. Such injuries, whether managed nonoperatively or surgically, require a multiphased approach beginning with exercises to restore muscular strength and proprioception, and advancing to more demanding exercises to improve power, endurance, and dynamic control. This article presents a new and innovative approach to the rehabilitation of the overhead throwing athlete, The Advanced Throwers Ten Exercise Program. This expanded program incorporates throwing motion-specific exercises and movement patterns performed in a discrete series, utilizing principles of coactivation, high-level neuromuscular control, dynamic stabilization, muscular facilitation, strength, endurance, and coordination, which all serve to restore muscle balance and symmetry in the overhead throwing athlete. This program is a continuation of the Throwers Ten Exercise Program, which has been utilized with excellent results in clinical practice and in athletic performance training. This unique combination of advanced exercise techniques bridges the gap between rehabilitation and training, facilitating a kinetic linking of the upper and lower extremities and providing a higher level of humeral head control necessary for the overhead throwing athlete's symptom-free return to sports.

Keywords: baseball; glenohumeral joint; pitching rehabilitation; thrower's shoulder; Throwers Ten

Introduction

The thrower's shoulder, particularly in overhand pitchers, is a common site of injury[1–3] and requires a unique, dynamic, and aggressive rehabilitative approach in order to facilitate the return of the athlete to competition following injury or surgery. The glenohumeral joint exhibits more motion than any other articulation in the body, creating a propensity toward laxity and the potential for instability,[4] both of which are precariously balanced in the overhead throwing athlete. Wilk et al[4] proposed the concept of the "thrower's paradox," in which the throwing shoulder must be sufficiently loose in order to throw but have enough stability in order to prevent symptoms. Glenohumeral stability comes from the continuous interplay and coordinated equilibrium between the capsuloligamentous structures of the shoulder and the combined neuromuscular control of the entire upper extremity. The repetitive forces and loads placed on the glenohumeral complex in combination with the excessive motion required for throwing necessitate challenging, dynamic, and specific rehabilitative interventions for successful functional restoration of the injured shoulder in the overhead throwing athlete. The exercise program should gradually increase the demands on the thrower's shoulder, ulti-

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mately producing the enhanced dynamic strength, endurance, and neuromuscular control that is integral to maintaining symptom-free sustained activity through the rigors of a competitive season. For several years, the Throwers Ten Exercise Program has been performed to enhance shoulder strength in the athlete. The exercise program discussed in this article is designed to build on the Throwers Ten Exercise Program to create a higher level of strength, endurance, and dynamic stability. This will ultimately translate to the shoulder, scapular region, and core working synergistically to produce the necessary force to initiate and endure the repetition of the throwing motion. The article presents an advanced throwers exercise program that will enhance dynamic shoulder stabilization, muscular coactivation, strength, and endurance in the throwing shoulder.

Biomechanics of Dynamic Glenohumeral Stability

The throwing motion is dependent on the synchronicity between the glenohumeral joint and scapulothoracic complex as they work concurrently to control the powerful movement pattern. The interplay between the osseous configuration and soft tissue structures of the upper quarter creates the mobility necessary to throw while preserving the stability required to avoid injury. This inherent hyperlaxity in the shoulder is juxtaposed with the tremendous joint forces and exceedingly high angular velocities produced during overhead throwing. The acceleration phase of throwing that occurs from the fully externally rotated cocking position to ball release is the fastest functional movement pattern recorded.[5–7] This internal rotation (IR) moment is produced in 0.03 seconds at angular velocities of 7250° per second.[6,7] In addition, throwing results in anterior shear forces across the glenohumeral joint that are 0.5 times that of the thrower's body weight and distraction forces that can equal 1.5 times the thrower's body weight.[5,6]

These forces place tremendous demands on the dynamic stabilizers of the glenohumeral complex. Functional stability of the shoulder is achieved through a delicate balance of several mechanisms that, when coupled, play a critical role in enhancement of shoulder function. These dynamic functional stabilizing mechanisms include joint compression, dynamic capsuloligamentous tension, and scapular positioning, and as well as neuromuscular control. Applied clinical concepts related to enhancing glenohumeral stability and scapular control using these mechanisms have produced successful outcomes in treating pathologies unique to the overhead throwing athlete.[4,8–13]

Wilk et al[14] noted that glenohumeral joint compression is achieved through muscular co-contractions of the rotator cuff, creating a balance of muscular forces that serves to center the humeral head within the glenoid fossa. This dynamic joint compression mechanism has a significant stabilizing effect on the glenohumeral articulation. Likewise, dynamic capsuloligamentous tension is created during muscular contraction of the rotator cuff.[14] Anatomically, the rotator cuff blends with the joint capsule anteriorly, and muscular contraction results in reduced capsular stress as the shoulder is excessively externally rotated during the throwing motion.[15]

The scapula serves as a foundation, or stable base, of support from which the arm functions in space. During arm movements, it systematically aligns itself with the humerus to create the most advantageous muscular length tension relationship for scapulohumeral and scapulothoracic muscles, thereby helping to control glenohumeral stability throughout the throwing motion.[16] Scapular positioning and control enhance shoulder dynamic stability via the scapular concavity effect, whereby force couples around the scapula result in specific orientations that are necessary to create a synergistic effect between the glenohumeral joint and scapulothoracic complex.[16,18] Most significant are the force couples produced via the upper trapezius, serratus, and lower trapezius muscles, which play a crucial role in producing a posterior tilt, elevation, and upward rotation of the scapula necessary to accommodate the overhead throwing motion.[16,17]

An additional form of dynamic shoulder stability is neuromuscular control, which is the efferent motor response to sensory information provided via proprioception and kinesthesia. Proprioceptive elements that contribute to joint stability include the conscious and unconscious appreciation of joint position, the awareness of joint position and movement, and any postural, positional, or kinetic information provided to the central nervous system by sensory receptors within the muscles, tendons, or joints.[14] The kinesthetic components to stability are the sensation of joint motion or acceleration and the sensation of active movement produced via muscular contraction. Lephart et al[9,18,19] and Myers and Lephart[20] reported that proprioceptive and kinesthestic training methods were integral to enhancing both midrange and end-range shoulder complex stability in the late cocking phase of the throwing motion.

Numerous studies have shown that the overhead throwing athlete is at higher risk for shoulder and/or elbow injuries while pitching when fatigued.[21–27] Using kinematic and kinetic motion analyses, Murray et al[25] documented how fatigue affected the entire body during pitching. When the

thrower was fatigued, shoulder external rotation decreased and ball velocity diminished, as did lead lower extremity knee flexion and shoulder adduction torque.[25] It has been reported that pitching while fatigued is the primary cause of shoulder pain in youth baseball pitchers.[22,26] Lyman et al[22] determined that the predisposing factor that correlated with the highest percentage of shoulder injuries in Little League pitchers were complaints of muscle fatigue while pitching. Olsen et al[26] noted that continuing to pitch while fatigued places youth pitchers at 36 times higher risk for injury.

There is a documented relationship between muscle fatigue and diminished proprioception, resulting in up to a 78% loss in glenohumeral proprioception when fatigued.[28,29] Chen et al[30] demonstrated superior humeral head migration on initiation of arm elevation when the rotator cuff muscles were fatigued. This superior migration can lead to impingement of the subacromial tissues. Therefore, an exercise program designed to improve muscular strength and endurance can aid in injury prevention.

Advanced Throwers Ten Exercise Program

Exercises for the throwing shoulder that focus on strengthening the glenohumeral joint and the thrower's arm have not drastically changed in the past 25 years. In 1982, Jobe and Moynes[31] introduced a formal basic isotonic strengthening program for the shoulder complex. Jobe and Bradley[32] expanded this program in 1988. In 1991, Wilk et al[33] established an evidence-based isotonic exercise program for the overhead throwing athlete that specifically addressed the vital muscles involved in the throwing motion, called the Throwers Ten Exercise Program. This exercise program was developed based on the collective information derived from the electromyographic research of numerous investigators[24,34–40] and focused on traditional isotonic movements that are commonly utilized today. Escamilla et al[41] recently reported that participating in the Throwers Ten Exercise Program increases ball velocity by approximately 2% within 6 weeks of training, demonstrating the effectiveness of these exercises in enhancing athletic performance. This improvement in ball velocity using the Throwers Ten Exercise Program was similar to that observed in functional and plyometric-based training programs.[41]

A specialized and challenging rehabilitation program is required to return the overhead throwing athlete to unrestricted competitive participation. A 4-phased rehabilitation approach, paired with the clinician's knowledge of the sequential principles related to the restoration of strength, dynamic stability, and neuromuscular control in the overhead throwing athlete, is paramount to the management of injuries in this unique population. These 4 rehabilitative phases and their specific goals are outlined in Table 1. Each phase represents a progression, with exercises becoming more aggressive and demanding. The stresses applied to the shoulder complex are sequentially intensified in a controlled, systematic manner to allow the athlete to return to unrestricted activity. For a detailed description of the entire rehabilitation program for the overhead throwing athlete, the reader is referred to work by Wilk et al[42] on shoulder injuries in the overhead throwing athlete.

The critical component to the advanced strengthening phase is the Advanced Throwers Ten Exercise Program (Table 2), which combines the principles of dynamic stability, coactivation, high-level neuromuscular control, endurance, rotator cuff facilitation, proper posture, core strength/endurance, and coordination in a specific manner designed to enable an athlete to progress seamlessly into an interval throwing program and prepare him or her for a return to sport participation. The exercises in this program demand high levels of proprioceptive and neuromuscular control bilaterally, serving to enhance the dynamic stability characteristics of the upper quarter, trunk, lumbopelvic complex, and lower extremity. The shoulder external rotator, scapular retractor, protractor, and depressor muscles frequently receive focus because of their identifiable weaknesses in the overhead throwing athlete.[4,8,11–13,39,42]

The Advanced Throwers Ten Exercise Program outlined in this article contains alterations to a previously outlined Throwers Ten Exercise Program by Wilk et al,[33] placing higher demands on the shoulder. This new program emphasizes progressive challenges to the postural muscles and the endurance/fatigability of the musculature via the application of sustained holds and alternating arm movements with sustained hold sequences. Muscle fatigue has been associated with a decrease in neuromuscular control.[28] Carpenter et al[28] observed the ability to detect passive motion of the shoulder when positioned at 90° of abduction and 90° of external rotation (ER), noting a decrease in the detection of both IR and ER movements. The Advanced Throwers Ten Exercise Program emphasizes endurance training not only of the shoulder and scapulothoracic musculature but also of the stabilizing musculature responsible for maintaining appropriate trunk and lower extremity position during throwing. This ensures that progressive demands are continually applied during the rehabilitative process in order to adequately challenge the overhead throwing athlete. The

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Table 1. Rehabilitation of the Overhead Athlete: Phases and Goals

Phase 1: Acute Phase
Goals
- –Diminish pain and inflammation
- –Normalize motion
- –Delay muscular atrophy
- –Reestablish dynamic stability (muscular balance)
- –Control functional stress/strain

Exercises and modalities
- –Cryotherapy, iontophoresis, ultrasound, electrical stimulation
- –Flexibility and stretching for posterior shoulder muscles to improve shoulder IR and horizontal adduction
- –Rotator cuff strengthening (especially external rotator muscles)
- –Scapular muscles strengthening (especially retractor and depressor muscles)
- –Dynamic stabilization exercises (rhythmic stabilization)
- –Weightbearing exercises
- –Proprioception training
- –Abstain from throwing

Phrase 2: Intermediate Phase
Goals
- –Progress strengthening exercises
- –Restore muscular balance
- –Enhance dynamic stability
- –Control flexibility and stretches

Exercises and modalities
- –Continue stretching and flexibility (especially shoulder IR and horizontal adduction)
- –Progress to isotonic strengthening
  - • Complete shoulder program
  - • Throwers Ten program
- –Rhythmic stabilization drills
- –Initiate core lumbopelvic region endurance program
- –Initiate leg lower extremity program

Phase 3: Advanced Strengthening Phase
Goals
- –Aggressive strengthening
- –Progress neuromuscular control
- –Improve strength, power, and endurance

Exercises and modalities
- –Flexibility and stretching
- –Rhythmic stabilization drills
- –Advanced Throwers Ten program
- –Initiate plyometric program
- –Initiate endurance drills
- –Initiate short-distance throwing program

Phase 4: Return-to-Activity Phase
Goals
- –Progress to throwing program
- –Return to competitive throwing
- –Continue strengthening and flexibility drills

Exercises
- –Stretching and flexibility drills
- –Throwers Ten program
- –Plyometric program
- –Progress interval throwing program to competitive throwing

Abbreviation: IR, internal rotation.

alternating movement patterns incorporated in this advanced throwers program challenges shoulder and scapular neuromuscular control, while facilitating the rotator cuff by using alternating dynamic and sustained-hold sequences as the athlete performs the exercise. These exercise activities not only address strength, dynamic stability, and proprioception but also promote the type of high-level endurance required to facilitate an athlete's to return to a high-demand, repetition-based sporting activity, such as throwing.

An athlete is typically instructed to perform 10 repetitions of each sequence (movement pattern) for all exercises outlined in the Advanced Throwers Ten Exercise Program (Table 2). The sequence described below for each exercise is performed twice. These exercise sets are performed without rest between sets. The pattern incorporated when participating in the program follows a sequential progression that integrates 3 specific movement patterns. First, the athlete performs a bilateral isotonic movement set, then a unilateral isotonic movement of the involved arm with a contralateral sustained hold of the uninvolved arm, and finally alternate repetitions between a sustained isometric hold and an active isotonic movement pattern from arm to arm. Incorporating sustained holds will challenge the athlete to maintain a fixed elevated-arm position while the opposite arm performs isotonic dumbbell or resistance tubing exercise movements.

A stability ball is used during the participation in The Advanced Throwers Ten Exercise Program to continue to challenge the athlete's position on an unstable surface. While performing each exercise repetition, the athlete is positioned in good sitting alignment on a stability ball, sitting over the

Table 2. Advanced Throwers Ten Exercise Program

- –IR/ER tubing at 0° of abduction seated on stability ball[a]
- –Full can seated on stability ball[a]
- –Lateral raise to 90° of abduction seated on stability ball[a]
- –Side-lying external rotation[a]
- –T raises prone on stability ball[a]
- –Y raises prone on stability ball[a]
- –Prone row into ER on stability ball[a]
- –Lower Trapezius 5 Series
  - • Shoulder extension in ER seated on stability ball
  - • Shoulder extension at 45° in ER seated on stability ball
  - • Standing wall circle slides
  - • Standing low row
  - • Standing table press-downs with scapular depression
- –Biceps curls/triceps extensions seated on stability ball
- –Wrist flexion/extension and supination/pronation

[a]Exercises in which sustained holds are utilized. Exercises are performed incorporating 3 sets of 10 repetitions. Exercises are performed (3-set sequence) 2 times.
Abbreviations: ER, external rotation; IR, internal rotation.

ischial tuberosities, with feet planted shoulder-width apart and abdominals engaged. Proper posture and positioning, especially of the scapula, is essential for successful completion of the exercises. Maintaining a posteriorly tilted, externally rotated, and retracted scapular position is a continual focus. Frequently, athletes are cued until scapular positioning is maintained with all exercises. Manual resistance can also be employed to any of the seated stability ball exercises to increase muscle excitation, co-contraction, and dynamic stability, as well as promote endurance and challenge the fatigability of the rotator cuff muscles (Figure 1).

The Advanced Throwers Ten Exercise Program begins with IR and ER tubing exercises at 0° of abduction with a towel roll between the individual's arm and side while the athlete is seated on a stability ball. The towel roll is used to promote greater electromyographic activity of the posterior cuff musculature, as described by Reinold et al.[39] This is followed by the athlete performing the same seated exercises in conjunction with a sustained contralateral isometric hold at 90° of abduction. The weight used to perform any sustained hold is one that the individual can comfortably hold throughout the duration of the exercise without pain or a break in the holding position.

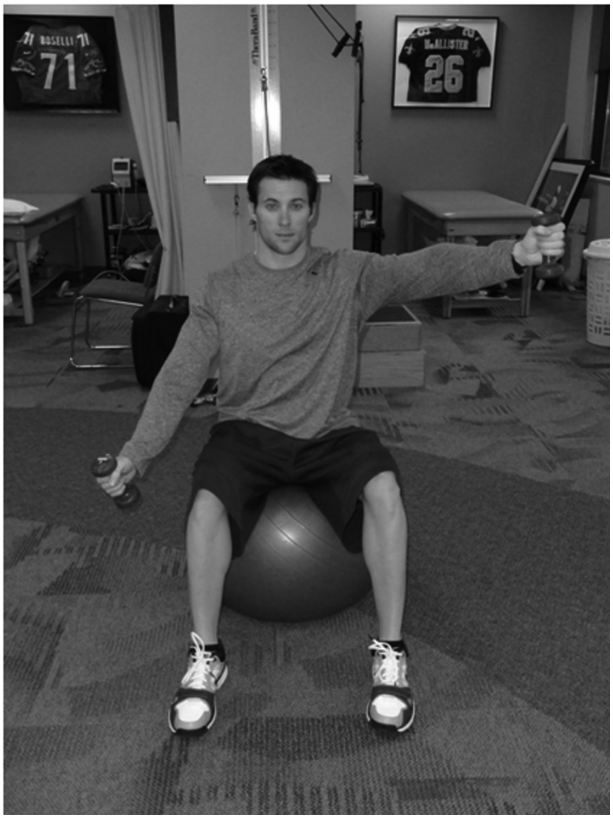
Similarly, the first set of the full-can exercise begins with the athlete seated on a stability ball with both arms at the side, elbows straight, and thumbs up. The athlete is instructed to raise both arms to shoulder level at 30° angles in front of the body, holding for 2 seconds at the apex of the movement and slowly lowering to the starting position (Figure 2). In the second set, the athlete raises both arms to shoulder level in the scapular plane and the involved arm returns to the patient's side and repeats the motion for 10 repetitions, while the uninvolved arm sustains the elevated position for the duration of the set. The third set incorporates raising both arms to shoulder level in the scapular plane and then alternately returning each arm to the side while the opposite arm sustains its position at shoulder level for the duration of the set. This is followed by shoulder abduction to 90° while the athlete is seated on a stability ball, with the athlete performing 1 bilateral set, followed by a set utilizing a sustained contralateral hold, and then a set of alternating movements with sustained holds in the manner previously described.

Side-lying ER is performed with a dumbbell in a standard 3-set isotonic fashion. This exercise is progressed to the side-lying plank position to maximally challenge the athlete's

Figure 1. External rotation tubing seated on stability ball with superimposed manual resistance.

The patient is seated on the stability ball with trunk perpendicular to the floor. The patient is cued to retract and depress scapula while the therapist applies manual resistance against external rotation. A towel roll is placed underneath the affected arm to enhance excitation of the rotator cuff.

Figure 2. Full can seated on stability ball.



The patient is instructed to sit with the trunk in an upright position, with scapulae retracted and depressed for initiation of the movement. The first sequence involves raising both arms in the scapular plane to 90° of shoulder flexion. The second sequence begins with the right arm remaining in the scapular plane held at 90° while the left arm performs concentric/eccentric flexion for 10 repetitions. The same sequence is repeated for the right shoulder. The third sequence involves alternating arm concentric/eccentric movements with the left and right arm for 10 repetitions. A total of 30 repetitions is performed for the exercise. An additional 30 repetitions involving the same sequence will follow to complete the exercise.

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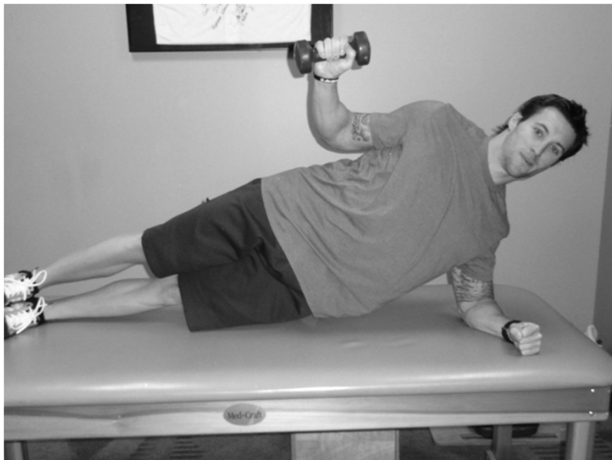
position (Figure 3). Caution must be exercised to ensure that the athlete is capable of exhibiting excellent dynamic stability on the supported arm while holding a neutral spine position when performing plank side-lying ER.

Prone horizontal abduction (T raises), prone horizontal abduction at 105° of abduction with full ER (Y raises), and rows into ER prone on a stability ball are all performed in the previously described 3-set manner, incorporating bilateral movements, contralateral holds, and alternating holds with active movements (Figures 4, 5). Performing these exercises with sustained holds and alternating-arm/sustained-hold sequencing further challenges the endurance of the posterior rotator cuff, periscapular, lumbar extensor, and gluteal musculature in a kinetic linking of the upper and lower extremities.

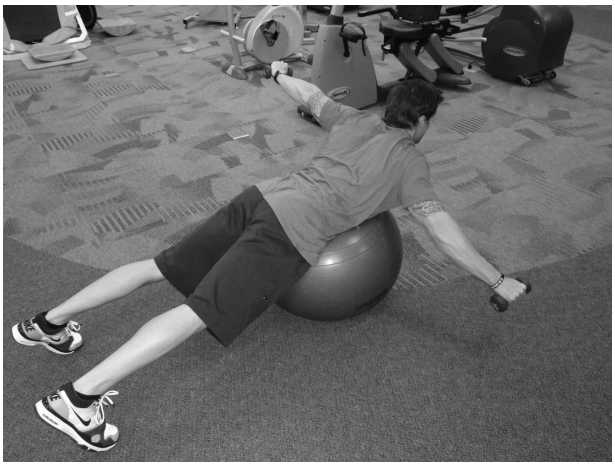
The next portion of the program is referred to as the Lower Trapezius 5 Series. The exercises in this series have been chosen based on the electromyographic findings of multiple authors and emphasize scapular control and lower trapezius isolation.[24,34,37–40] These exercises include shoulder extension in 20° of abduction with the arms externally rotated, shoulder extension at 45° of abduction with the arms externally rotated, wall circle slides, low rowing in standing position, and table press-downs with scapular depression (Figure 6). Each exercise in this series is performed for 3 sets of 10 repetitions. In addition, scapular neuromuscular control exercises (ie, therapist applying manual resistance into protraction, retraction, elevation, and depression) are performed to train the synchronicity of muscle firing for the scapulothoracic muscles. The athletes can perform these exercises sitting on a stability ball or side-lying on a table. Cools et al[43] reported that a lack of scapular muscle synchronicity, particularly of the lower trapezius and middle trapezius, is a key factor evident in shoulder pain in the overhead throwing athlete. In addition, bicep curls and triceps extensions are performed with sustained holds on the stability ball. Because

Figure 3. Side-lying external retotation in plank position.



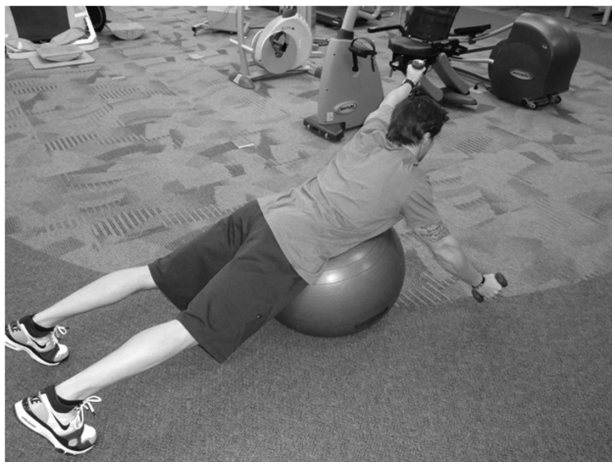
The patient is instructed to assume the body in a side-lying position on the plinth. The unaffected arm will be placed on the table, with the elbow bent at 90°. The patient is cued to lift the pelvis from the table while contracting lumbopelvic abdominal musculature to maintain a neutral spine with the liftoff. External rotation is performed for 10 repetitions or 10 seconds while preserving a neutral spine. The therapist closely monitors spine angle for signs of fatigue.

Figure 4. Prone horizontal abduction (T raise).



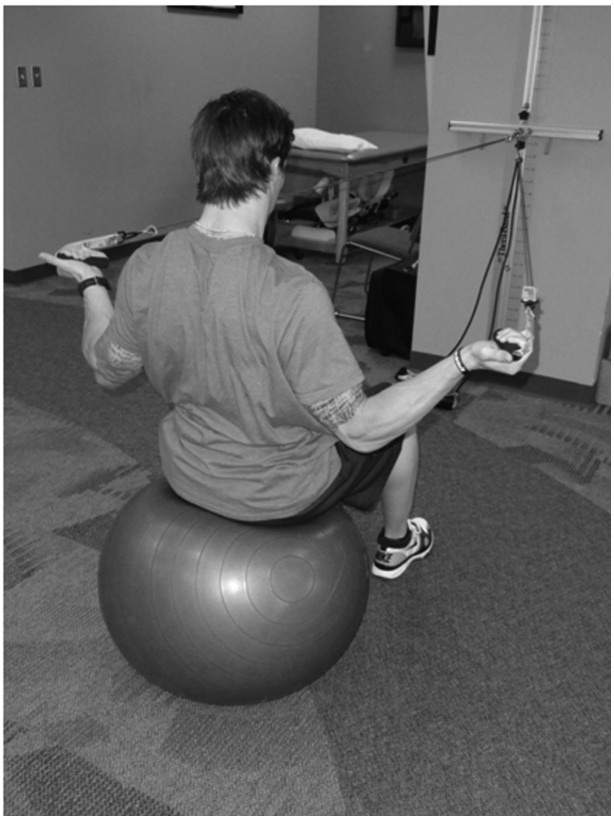
The patient is instructed to position the body prone to enable the abdomen to rest on the stability ball while the trunk assumes a parallel position to the floor. Abduction of each arm is performed for a set of 10 repetitions while the patient maintains proper positioning on the stability ball. The second and third sequences are similar to the exercise described in Figure 2. A total of 30 repetitions is performed. An additional 30 repetitions involving the same sequence will follow to complete the exercise.

Figure 5. Prone horizontal abduction at 105° with full external rotation (Y raise).



The patient assumes the same position as that described in Figure 4. The patient raises both arms in the scapular plane (creating a "Y") for 10 repetitions while maintaining the position on the stability ball. The second and third sequences are performed as described in the previous figure. An additional set of 30 repetitions will complete the exercise.

Figure 6. "W" external rotation seated on stability ball.



The patient is instructed to sit tall with the trunk perpendicular to the floor. The arms are abducted to 30° with elbows bent and forearms in neutral position. The exercise is initiated with bilateral retraction/depression of the scapulae while the patient extends and externally rotates the arms ("W" position at the end of concentric motion of arms). A total of 30 repetitions is performed to complete the exercise.

of the inherent stresses on the elbow joint during the throwing motion, elbow strengthening is also incorporated into the program to include isotonic dumbbell exercises for wrist flexion, extension, supination, and pronation.

This program is implemented in conjunction with a stretching program, plyometrics, and the initiation of an interval-throwing program at appropriate times. Clinical trials will be necessary to determine the ultimate efficacy of this program; however, we have utilized this program for > 3 years with excellent anecdotal clinical success. Electromyographic studies and additional clinical trials are necessary to document the effectiveness of this program.

Summary

Overhead throwing athletes typically present with a unique musculoskeletal profile. The overhead throwing athlete exhibits excessive amounts of motion, which result in an inherently unstable glenohumeral complex, thus requiring the athlete to rely heavily on dynamic stabilization for high-level, symptom-free activity. This unique athletic population demonstrates distinct shoulder pathology that frequently presents challenges for the clinician. Progressively challenging exercises that emphasize the restoration of muscle balance and symmetry are required to facilitate the athlete's return to competition.

The Advanced Throwers Ten Exercise Program presented in this article provides an additional critical step for comprehensive rehabilitation of the overhead throwing athlete. It functions as a bridge, facilitating the transition from rehabilitation to return to competitive throwing by utilizing higher-level principles of dynamic stabilization, neuromuscular control, rotator cuff facilitation, and coordination in the application of throwing-specific exercises in a unique and progressive manner.

Conflict of Interest Statement

Kevin E. Wilk, PT, DPT, A.J. Yenchak, PT, DPT, CSCS, Christopher A. Arrigo, MS, PT, and James R. Andrews, MD disclose no conflicts of interest.

References

1. Conte S, Requa RK, Garrick JG. Disability days in major league baseball. *Am J Sports Med*. 2001;29(4):431–436.
2. McFarland EG, Wasik M. Epidemiology of collegiate baseball injuries. *Clin J Sport Med*. 1998;8(1):10–13.
3. Lyman S, Fleisig GS. Baseball injuries. *Med Sport Sci*. 2005;49:9–30.
4. Wilk KE, Meister K, Andrews JR. Current concepts in rehabilitation of the overhead throwing athlete. *Am J Sports Med*. 2002;30(1):136–151.
5. Dillman CJ, Fleisig GS, Andrews JR. Biomechanics of pitching with emphasis upon shoulder kinematics. *J Orthop Sports Phys Ther*. 1993;18(2):402–408.
6. Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med*. 1995;23(2):233–239.
7. Wilk KE, Meister K, Fleisig GS, Andrews JR. Biomechanics of the overhead throwing motion. *Sports Medicine and Arthroscopy Review*. 2000;8(2):124–134.
8. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology. Part III. The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy*. 2003;19(6):641–661.
9. Lephart SM, Pincivero DM, Giraldo JL, Fu FH. The role of proprioception in the management and rehabilitation of athletic injuries. *Am J Sports Med*. 1997;25(1):130–137.
10. Swanik KA, Lephart SM, Swanik CB, Lephart SP, Stone DA, Fu FH. The effects of shoulder plyometric training on proprioception and selected muscle performance characteristics. *J Shoulder Elbow Surg*. 2002;11(6):579–586.
11. Wilk KE, Arrigo CA. Current concepts in the rehabilitation of the athletic shoulder. *J Orthop Sports Phys Ther*. 1993;18(1):365–378.
12. Wilk KE, Arrigo CA. An integrated approach to upper extremity exercises. *Orthop Phys Ther Clin North Am.* 1992;1:337–360.
13. Wilk KE, Arrigo CA, Andrews JR: *Functional Training for the Overhead Athlete*. Sports Phys Therapy Home Study Course, LaCrosse, WI, 1995.
14. Wilk KE, Arrigo CA, Andrews JR. Current concepts: the stabilizing structures of the glenohumeral joint. *J Orthop Sports Phys Ther*. 1997;25(6):364–379.

15. Cain PR, Mutschler TA, Fu FH, Lee SK. Anterior stability of the glenohumeral joint. A dynamic model. *Am J Sports Med*. 1987;15(2): 144–148.
16. Kibler WB. The role of the scapula in the athletic shoulder function. *Am J Sports Med*. 1998;26(2):325–337.
17. Kibler WB, Sciascia A. Current concepts: scapular dyskinesis. *Br J Sports Med*. 2010;44(5):300–305.
18. Lephart SM, Riemann BL, Fu FH. Introduction to sensorimotor system. In: Lephart SM, Fu FH, eds. *Proprioception and Neuromuscular Control in Joint Stability*. Champaign, IL: Human Kinetics; 2000:16–26.
19. Lephart SM, Warner JJP, Borsa PA, Fu FH. Proprioc eption of the shoulder joint in healthy, unstable, and surgically repaired shoulders. *J Shoulder Elbow Surg*. 1994;3(6):371–380.
20. Myers JB, Lephart SM. The role of the sensorimotor system in the athletic shoulder. *J Athl Train*. 2000;35(3):351–363.
21. Lyman S, Fleisig GS, Andrews JR, Osinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. *Am J Sports Med*. 2002;30(4):463–468.
22. Lyman S, Fleisig GS, Waterbor JW, et al. Longitudinal study of elbow and shoulder pain in youth baseball pitchers. *Med Sci Sports Exerc*. 2001;33(11):1803–1810.
23. Meister K, Andrews JR. Classification and treatment of rotator cuff injuries in the overhead athlete. *J Orthop Sports Phys Ther*. 1993;18(2):413–421.
24. Moseley JB Jr, Jobe FW, Pink M, Perry J, Tibone J. EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med*. 1992;20(2):128–134.
25. Murray TA, Cook TD, Werner SL, Schlegel TF, Hawkins RJ. The effects of extended play on professional baseball pitchers. *Am J Sports Med*. 2001;29(2):137–142.
26. Olsen SJ 2nd, Fleisig GS, Dun S, Loftice J, Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. *Am J Sports Med*. 2006;34(6):905–912.
27. Pappas AM, Zawacki RM, McCarthy CF. Rehabilitation of the pitching shoulder. *Am J Sports Med*. 1985;13(4):223–235.
28. Carpenter JE, Blasier RB, Pellizzon GG. The effects of muscle fatigue on shoulder joint position sense. *Am J Sports Med*. 1998;26(2):262–265.
29. Voight ML, Hardin JA, Blackburn TA, Tippett S, Canner GC. The effects of muscle fatigue on and the relationship of arm dominance to shoulder proprioception. *J Orthop Sports Phys Ther*. 1996;23(6): 348–352.
30. Chen SK, Simonian PT, Wickiewicz TL, Otis JC, Warren RF. Radiographic evaluation of glenohumeral kinematics: a muscle fatigue model. *J Shoulder Elbow Surg*. 1999;8(1):49–52.
31. Jobe FW, Moynes DR. Delineation of diagnostic criteria and a rehabilitation program for rotator cuff injuries. *Am J Sports Med*. 1982;10(6):336–339.
32. Jobe FW, Bradley JP. Rotator cuff injuries in baseball. Prevention and rehabilitation. *Sports Med*. 1988;6(6):378–387.
33. Wilk KE, Andrews JR, Arrigo CA, et al. *Preventive and Rehabilitative Exercises for the Shoulder and Elbow*. 5th ed. Birmingham, AL: American Sports Medicine Institute; 1997.
34. Blackburn TA, McLeod WD, White B, Wofford L. EMG analysis of posterior rotator cuff exercises. *Athl Train J Natl Train Assoc*. 1990;25(1):40–45.
35. Decker MJ, Hintermeister RA, Faber KJ, Hawkins RJ. Serratus anterior muscle activity during selected rehabilitation exercises. *Am J Sports Med*. 1999;27(6):784–791.
36. DiGiovine NM, Jobe FW, Pink M, Perry J. An electromyographic analysis of the upper extremity in pitching. *J Shoulder Elbow Surg*. 1992;1:15–25.
37. Henry TJ, Lephart SM, Stone D, et al. An electromyographic analysis of dynamic stabilizing exercises for the shoulder. *J Athl Train*. 1998;33:S74.
38. Hintermeister RA, Lange GW, Schultheis JM, Bey MJ, Hawkins RJ. Electromyographic activity and applied load during shoulder rehabilitation exercises using elastic resistance. *Am J Sports Med*. 1998;26(2):210–220.
39. Reinold MM, Wilk KE, Fleisig GS, et al. Electromyographic analysis of the rotator cuff and deltoid musculature during common shoulder external rotation exercises. *J Orthop Sports Phys Ther*. 2004;29: 574–583.
40. Townsend H, Jobe FW, Pink M. Electromyographic analysis of the glenohumeral muscles during a baseball rehabilitation program. *Am J Sports Med*. 1991;19(3):264–272.
41. Escamilla RF, Ionno M, deMahy S, et al. Comparison of three baseball-specific six-week training programs on throwing velocity in high school baseball players. *Med Sci Sports Exerc.* 2011;43(5):836–837.
42. Wilk KE, Obma P, Simpson CD, Cain EL, Dugas JR, Andrews JR. Shoulder injuries in the overhead athlete. *J Orthop Sports Phys Ther*. 2009;39(2):38–54.
43. Cools AM, Witvrouw EE, Declercq GA, Danneels LA, Cambier DC. Scapular muscle recruitment patterns: trapezius muscle latency with and without impingement symptoms. *Am J Sports Med*. 2003;31(4):542–549.