On-the-Field Resistance-Tubing Exercises for Throwers: An Electromyographic Analysis

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Abstract

Context: Athletes who throw commonly use rubber-tubing resistance exercises in the field setting to assist with warm-up before throwing. Yet no researchers have described which muscles are being activated or which exercises are most effective during rubber-tubing exercises used by throwers for warm-up.

Objective: To describe the effectiveness of 12 rubber-tubing resistance exercises commonly used by throwers in activating the shoulder muscles important for throwing.

Design: Descriptive research design.

Setting: An applied biomechanics research laboratory.

Patients or Other Participants: Fifteen physically active male subjects with no history of shoulder injury.

Main Outcome Measure(s): Subjects randomly performed 12 rubber-tubing resistance exercises while we assessed muscle activation of the subscapularis, supraspinatus, teres minor, and rhomboid major by indwelling electromyography. Activation of the sternal portion of the pectoralis major, anterior deltoid, middle deltoid, latissimus dorsi, serratus anterior, biceps brachii, triceps brachii, lower trapezius, and infraspinatus muscles was assessed by surface electromyography.

Results: Performance of 7 exercises (external rotation at 90° of abduction, throwing deceleration, humeral flexion, humeral extension, low scapular rows, throwing acceleration, and scapular punch) resulted in the highest level of muscle activation of all muscles tested.

Conclusions: These 7 exercises exhibited moderate activation (>20% maximal voluntary isometric contraction) in each muscle of the rotator cuff, the primary humeral movers, and the scapular stabilizer muscles. The results suggest that these exercises are most effective in activating the muscles important to the throwing motion and may be beneficial for throwers during their prethrowing warm-up routine.

Keywords: shoulder, injury prevention

Baseball is one of the most popular sports in the United States, with an estimated 20 million individuals participating as amateurs across the country.[1,2] Accompanying this high participation rate is a high rate of injury, with more than 50000 injuries per year in players ranging from youth league to the professional level.[3] Injuries in the throwing arms of pitchers comprise a large portion of these reported injuries, with nearly 50% of all pitchers experiencing sufficient shoulder or elbow pain to prevent participation at some point in their careers.[3,4] Overuse injuries of the shoulder and elbow resulting from the cumulative soft tissue microtrauma associated with the overhead throwing motion are the most common injuries seen in pitchers. Yet many of these overuse injuries are preventable.[5,6]

Strategies for injury prevention in throwers include adherence to safe pitch counts,[7] modification of faulty pitching mechanics,[6,8] long-toss programs,[9,10] maintenance of range of motion and flexibility,[11,12] progressive resistance exercises to facilitate strength and endurance of the dynamic stabilizers,[12,13] and proper warm-up.[6,13,14] Fortunately, each of these strategies can be conveniently implemented on the field by athletic trainers, coaches, and athletes.

One approach that throwers commonly use to assist in injury prevention is to include rubber-tubing resistance exercise programs in their prethrowing warm-up routines. These programs typically include several exercises believed to facilitate activation of the muscles important in the throwing motion. These programs, with a piece of rubber resistance tubing, are conveniently administered in the bullpen, dugout, or locker room or on the sidelines. Despite the benefits of rubber-tubing resistance programs recognized by athletes, coaches, and sports medicine clinicians, no researchers to date have validated such rubber-tubing warm-up programs used by throwers. It is not known which muscles are actually being targeted and which exercises are most effective in facilitating activation of the shoulder muscles important for throwing.

Our purpose was to use electromyography (EMG) to describe 12 rubber-tubing resistance exercises commonly used by throwers as part of their prethrowing warm-up routines. Our goal was to specifically describe which exercises are most effective in facilitating activation of the shoulder muscles believed to be important for the throwing motion (ie, rotator cuff, scapular stabilizers, and humeral movers). We did not aim to determine which exercise was best for a particular muscle but rather which exercises facilitate the most activation in the most muscles. From these results, clinicians, players, and coaches can implement the exercises that result in high levels of activation of the muscles important to throwing as part of prethrowing warm-up routines.

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MATERIAL AND METHODS

Subjects

Fifteen male subjects (age = 24.53 ± 2.77 years, height = 1.77 ± 0.08 m, mass = 78.31 ± 8.20 kg) participated. All were physically active individuals who performed some type of training or sport activity at least 3 times per week. There were no exclusion restrictions based on sport participation. Thus, the study group included a combination of both recreational overhead and nonoverhead athletic activity participants. Subjects with a history of shoulder instability, significant limitation of shoulder and elbow motion, or previous injury or surgery on the upper extremity were excluded.

Instrumentation

Subjects performed all exercises with a modified Arm Strong Basix (DH Sports Inc, West Chester, PA) strength trainer system for throwers. The system consists of rubber surgical tubing (9.1 kg) connected to a standard baseball that rotates around a fixed axis of rotation (Figure 1). The system was modified by adding a TLL-500 (Transducer Techniques Inc, Temecula, CA) tension-only load cell (226.8-kg capacity). The load cell was used to secure the rubber-tubing apparatus to a stable base of support and measure the force generation produced during each exercise.

A subject performing the scapular row (high) exercise

We collected EMG data by using the Noraxon Telemyo (Noraxon, Scottsdale, AZ) EMG system. All EMG signals were passed through a single-ended amplifier (gain = 500) to two 8-channel frequency-modulation transmitters. Receiver units collected the telemetry signals from the transmitter, where the receiver amplified (gain = 500) and filtered (15- to 500-Hz band pass Butterworth filter, common mode rejection ratio of 130 dB) the signals. Signals from the receiver were then converted from analog to digital data via a DT3010/32 (32-channel, 24-bit) A/D board (Data Translation Inc, Marlboro, MA) at a rate of 2400 Hz. We collected all EMG data with the analog data acquisition package of Peak Motus Software (version 7.2; Peak Performance, Englewood, CO).

Procedures

Each subject attended 1 testing session and consented to participate as required by the university's institutional review board. Each subject was then prepared for surface and fine-wire EMG.[15] A combination of surface and fine-wire EMG was used to reduce the invasiveness of the testing session for the subjects. Thus, all muscles with a superficial orientation were assessed with surface electrodes. We prepared single fine-wire electrodes constructed with 0.05-mm nickel chromium alloy wire insulated with nylon (California Fine Wire, Grover Beach, CA) according to published recommendations[16–18] and inserted them intramuscularly via a 1.5-in (3.81-cm) 25-gauge needle into the subscapularis, supraspinatus, teres minor, and rhomboid major muscles.[19,20] We inserted 2 single-wire electrodes into each muscle at an interelectrode distance of 1 cm.[16] Insertion sites were sanitized with 70% isopropyl alcohol and an iodine solution before insertion.

We used silver-silver chloride surface electrodes (Medicotest Inc, Rolling Meadows, IL) to measure superficial muscle activity. We placed 2 surface electrodes side by side and perpendicular to the orientation of the muscle fibers, with 2 cm separating the center of each electrode.[21,22] Muscles assessed included the sternal portion of the pectoralis major, anterior deltoid, middle deltoid, latissimus dorsi, serratus anterior, biceps brachii, triceps brachii, lower trapezius, and infraspinatus. Correct positions of all electrodes were confirmed by real-time visual inspection of the EMG signals on an oscilloscope during manual muscle testing that isolates activation in each muscle tested.[15,21]

Before testing, each subject performed a 5-second maximal voluntary isometric contraction (MVIC) for each muscle assessed for the purposes of EMG trial normalization. We chose the positions for MVIC performance to best isolate each respective muscle based on standard muscle strength testing positions.[15,21]

Testing consisted of each subject performing 12 rubber-tubing resistance exercises in randomized order. We chose these exercises on the basis of the recommendations of several certified athletic trainers, coaches, and players affiliated with baseball. All subjects were positioned and each exercise was performed so that tension within the rubber tubing was uniform (ie, no visible sag within the tubing) (see Figure 1). Each exercise consisted of 10 repetitions at a standardized tempo of 2 seconds per repetition (aided by a metronome). We provided a 2-minute rest period between exercises to control for any fatigue effect, and we collected EMG and load cell data during all repetitions. The 12 rubber-tubing resistance exercises were as follows.

Shoulder Extension

The subject stood facing the stable base. With the elbow extended and the forearm in a neutral position (thumb pointing upward), the exercise began with the shoulder flexed to 90°. The exercise consisted of moving the shoulder toward maximum extension and then returning to the starting position of 90° of shoulder flexion while maintaining both elbow extension and the forearm-neutral position. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's fingertips with the shoulder fully flexed in a standing position (high fixation position).

Shoulder Flexion

The subject stood facing away from the stable base. With the elbow extended and the forearm in a neutral position, the exercise began with the subject's shoulder fully extended. The exercise consisted of moving the arm into full shoulder flexion and then returning to the starting position while maintaining both elbow extension and the forearm-neutral position. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's fingertips from the ground while standing in anatomical position (low fixation position).

Internal Humeral Rotation at 0° of Abduction

The subject stood with the stable base on the dominant side. With the elbow flexed to 90°, forearm in a neutral position, and shoulder in 0° of abduction, the exercise began with the subject's shoulder in full external rotation. The exercise consisted of moving the shoulder into full internal rotation and then returning to the starting position while maintaining the elbow-flexion, forearm-neutral, and shoulder-abduction positions. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's elbow from the ground when standing in anatomical position (middle fixation position).

External Humeral Rotation at 0° of Abduction

The subject stood with the stable base on the nondominant side. With the elbow flexed to 90°, the forearm in neutral position, and the shoulder in 0° of abduction, the exercise began with the subject's shoulder in full internal rotation. The exercise consisted of moving the shoulder into full external rotation and then returning to the starting position while maintaining the elbow-flexion, forearm-neutral, and shoulder-abduction positions. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's elbow from the ground when standing in anatomical position (middle fixation position).

Internal Humeral Rotation at 90° of Abduction

The subject stood facing away from the stable base. With the shoulder abducted and elbow flexed to 90°, the exercise began with the subject's shoulder in full external rotation. The exercise consisted of moving the shoulder into full internal rotation and then returning to the starting position while maintaining the shoulder-abduction and elbow-flexion positions. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's fingertips with the arm fully flexed in a standing position (high fixation position).

External Humeral Rotation at 90° of Abduction

The subject stood facing the stable base. With the shoulder abducted and elbow flexed to 90°, the exercise began with the subject's shoulder in full internal rotation. The exercise consisted of moving the shoulder into full external rotation and then returning to the starting position while maintaining the shoulder-abduction and elbow-flexion positions. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's fingertips from the ground while standing in anatomical position (low fixation position).

High, Middle, and Low Scapular Rows

The subject stood facing the stable base with the elbow extended and scapula fully protracted. The exercise consisted of moving the scapula into full retraction (with accompanying elbow flexion) and then returning to the starting position. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's fingertips with the shoulder fully flexed in a standing position (high fixation position), each subject's elbow while standing in anatomical position (middle fixation position), or each subject's fingertips while standing in anatomical position (low fixation position).

Scapular Punches

The subject stood facing away from the stable base with the elbow fully flexed, forearm in neutral position, and scapula fully retracted. The exercise consisted of flexing the shoulder to approximately 100°, extending the elbow, and fully protracting the scapula while punching forward and then returning to the starting position. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's elbow from the ground when standing in anatomical position (middle fixation position).

Throwing Acceleration

The subject stood facing away from the stable base. With the shoulder abducted and the elbow flexed to 90°, the exercise began with the subject's shoulder in full external rotation. The exercise consisted of moving the arm across the body (similar to the acceleration phase of throwing [D2 flexion pattern]) and then returning to the starting position. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's fingertips with the shoulder fully flexed in a standing position (high fixation position).

Throwing Deceleration

The subject stood facing the stable base. The exercise began with each subject's shoulder at 30° of flexion. The exercise consisted of pulling the tubing back so the shoulder moved into full extension and scapular retraction. At full shoulder extension, the shoulder moved to 90° each of shoulder external rotation, shoulder abduction, and elbow flexion. The exercise finished with the subject eccentrically controlling the tubing as the arm returned to the starting position of 30° of shoulder flexion. The rubber tubing-load cell apparatus was secured to the stable base at a height equal to the height of each subject's fingertips from the ground while standing in anatomical position (low fixation position).

Data Reduction

To quantify the activation that resulted from each exercise for each muscle, the start and end of each exercise repetition was first identified by the load cell within the tubing-load cell apparatus by determining the maximum and minimum force phases of each exercise of each of the middle 8 repetitions used for analysis. In addition to identifying the start and end of each repetition, we used the load cell to calculate the average force for each of the 8 repetitions during the exercise.

The EMG data were smoothed by a moving root mean square with a window of 50 milliseconds. We calculated mean activation of the middle 8 repetitions of each muscle tested to determine the overall activation of each muscle for each exercise. All muscle activation data were normalized to the mean activation of the 5-second MVIC.

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RESULTS

We calculated the mean activation for each of the 13 muscles during both the increasing and the decreasing force phases of 12 exercises and overall activation of each muscle for each exercise (Table 1). In Table 2, the mean force during both the increasing and the decreasing force phases is presented for each exercise.

Table 1
Electromyographic Activity of Each Muscle for the 12 Rubber-Tubing Resistance Exercises as % Maximal Voluntary Isometric Contraction: Mean (SD)

Table 2
Force Production (Newtons) for Each Exercise
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DISCUSSION

Despite the recognized benefit of using rubber-tubing resistance exercises to assist with warm-up before throwing, few researchers have described such programs. Our purpose was to describe the activation levels of upper extremity muscles during 12 rubber-tubing resistance exercises commonly used by throwers for warm-up. Our objective was to specifically describe which muscles are being activated and which exercises are most effective in facilitating activation of the shoulder muscles believed to be important for the throwing motion.

From our results, we have provided recommendations to assist clinicians, coaches, and players in deciding which exercises may be better suited for their prethrowing warm-up programs. Recommendations are based on several factors, including the presence of at least moderate activation (defined as >20% of the MVIC[23–25]) in each muscle tested, inclusion of all muscle groups important for pitching, amount of resistance provided, and practicality of performing the exercises (ie, appropriate number of exercises and ease of implementation in the field setting).

None of the 12 exercises tested resulted in moderate activation of all muscles. Four of the 12 exercises—shoulder extension, shoulder flexion, throwing acceleration, and throwing deceleration—resulted in at least moderate activation of 12 of the 13 muscles tested. With shoulder extension, only the biceps brachii was <20% MVIC (Figure 2). Additionally, all muscles except for the pectoralis major demonstrated moderate to marked activation during the shoulder-flexion exercise (Figure 3). Moderate to marked (>50% of MVIC) activation was present in all muscles except the biceps brachii for both the throwing acceleration (Figure 4) and the throwing deceleration (Figure 5) exercises. Four of the 12 exercises—external rotation at 90° of abduction, scapular punches, high scapular rows, and low scapular rows—resulted in at least moderate activity in 11 of the 13 muscles measured (Figures 6 through 9). On the basis of the EMG results, we found that performing a regimen of 7 exercises—shoulder extension, shoulder flexion, throwing acceleration, throwing deceleration, external rotation at 90° of abduction, scapular punches, and either high or low scapular rows—resulted in at least moderate activation (>20% of MVIC) in all muscles tested. Of the 2 scapular row exercises (high and low) that resulted in moderate activity in 11 of the 13 muscles, we recommend the low scapular row exercise be performed with the other 6 exercises, because the muscles that were not moderately activated (ie, pectoralis major and anterior deltoid) are at least moderately activated during the 6 other exercises. With these 7 exercises, all shoulder muscles important for the throwing motions (ie, rotator cuff, scapular stabilizers, and humeral movers) are represented. Interestingly, many of the 7 exercises that resulted in moderate activation in the most muscles also resulted in the most force exertion, based on the load cell data collected (see Table 2). According to these findings, performing these 7 exercises would result in moderate to marked activation (>20% MVIC) in each muscle of the rotator cuff, primarily the humeral movers and scapular stabilizer muscle groups.

Figure 2
Muscle activation during the shoulder extension exercise

Figure 3
Muscle activation during the shoulder flexion exercise

Figure 4
Muscle activation during the throwing acceleration exercise

Figure 5
Muscle activation during the throwing deceleration exercise

Figure 6
Muscle activation during the external rotation at 90° of abduction exercise

An additional consideration for choosing appropriate exercises for throwers is whether the program is convenient to perform in the field setting. The 7 exercises described as most effective in eliciting moderate activation in the muscles important for throwing can be grouped according to where the tubing would be positioned in the field setting. For example, an athlete could perform throwing acceleration and shoulder extension exercises by securing the tubing onto an immovable base (eg, fence or pole) at a position equal to the height of his or her fingertips with the arm fully flexed in a standing position (high fixation position). Then external humeral rotation at 90° of abduction, throwing deceleration, shoulder flexion, low scapular rows, and scapular punch exercises can be performed with the tubing secured at a position equal to the height of the athlete's fingertips from the ground in anatomical position (low fixation position). Thus, all 7 exercises can be conveniently performed with very little change in the position of attachment of the tubing. Additionally, these 7 exercises can be performed in less than 10 minutes if 30 repetitions (2 seconds per repetition) are completed for each exercise, making them a simple warm-up option.

Although we are the first researchers to describe the rubber-tubing resistance exercises that should be included in prethrowing warm-up routines for throwers, others have described muscle activation during various tubing exercises and have validated their use. As we did, Decker et al[26] demonstrated that the scapular punch is an effective exercise for eliciting serratus anterior activity, yielding approximately 80% and 50% MVIC in both studies during the increasing and decreasing phases, respectively. In a separate study, Decker et al[27] described which exercises were most effective in facilitating contraction of the subscapularis. Common exercises in that study and ours included internal rotation at 90° of abduction, internal rotation at 0° of abduction, scapular punch, and a diagonal movement pattern similar to the throwing acceleration exercise, resulting in similar levels of muscle activation ranging from 20% to 80% MVIC, depending on muscle and exercise. McCann et al,[23] Townsend et al,[28] Blackburn et al,[29] and Moseley et al[30] performed EMG analyses of several exercises targeting the glenohumeral and scapular stabilizer muscles. Specifically, Townsend et al[28] ranked 17 dumbbell resistance exercises and identified 4 that were consistently the most challenging for every muscle. They suggested that the rehabilitation of the glenohumeral muscles for throwers should include (1) standing humeral elevation in the scapular plane with the thumb down, (2) standing shoulder flexion, (3) prone horizontal abduction in a position of shoulder external rotation, and (4) press-up.[28] This work set the stage for many of the “thrower's 10” exercises described by Wilk et al,[12] which have become the staple of rehabilitation for throwers after injury.

In the thrower's 10 program, several resistance tubing exercises are incorporated for strengthening, including both D2 flexion and extension patterns (similar to the throwing acceleration and throwing deceleration exercises in the current study) and internal and external rotation at 0° and 90° of abduction. Applying the current results to the thrower's 10 rubber-tubing resistance exercises, the exercises involving throwing acceleration, throwing deceleration, external humeral rotation at 90° of abduction, and internal humeral rotation at 90° of abduction elicited at least moderate activation of all muscles tested except for the biceps and triceps muscles. External humeral rotation at 0° of abduction and internal humeral rotation at 0° of abduction resulted in moderate to marked activity of the humeral rotator cuff muscles that these exercises are designed to target (the teres minors and infraspinatus and the subscapularis, respectively). Treiber et al[31] examined the effectiveness of combining internal-external humeral rotation rubber-tubing resistance and lightweight dumbbell training on shoulder rotation strength and tennis-serve performance. Resistance training that used a combination of rubber tubing (similar to ours) and lightweight dumbbell exercises resulted in increased internal and external humeral rotation and increased serve velocity. Page et al[32] evaluated the effectiveness of D2 diagonal flexion-extension rubber-tubing resistance exercises in training the posterior rotator cuff and found that the eccentric strength (as measured isokinetically in a D2 extension-flexion pattern) can be increased. Researchers in our laboratory have demonstrated the effectiveness of a rubber-tubing plyometric training program for enhancing proprioception and muscle performance characteristics. Swanik et al[33] used a 6-week shoulder plyometric training program that combined rubber-tubing resistance and pitchback Plyoball (JUMPUSA.com, Sunnyvale, CA) exercises for collegiate swimmers. The training resulted in significant improvements in proprioception as measured with active reproduction of passive position and threshold to detection of passive motion. Additionally, during isokinetic testing, significant decreases were noted in the time to peak torque (at 60°/s and 240°/s), and significant improvement was seen in isokinetic endurance (at 240°/s). As a follow-up to their first study, Swanik et al[34] demonstrated that a resistance training program including rubber-tubing resistance training resulted in a lower incidence of shoulder pain in collegiate swimmers.

Although our focus was to determine which exercises were most effective in facilitating activation of the shoulder muscles believed to be important for the throwing motion, we must state that the results have direct application to nonthrowing overhead athletes as well. The overhead tasks associated with throwing, swimming, tennis, volleyball, and golf all rely on similar muscle-activation patterns of the rotator cuff, humeral movers, and scapular stabilizers.[25,35–42] The findings of Treiber et al[31] and Swanik et al[33,34] suggest that rubber-tubing resistance exercises will benefit all overhead athletes, not just throwers, by improving strength, proprioception, muscle performance characteristics, athletic performance, and injury prevention.

We recognize several limitations of our study. This study design was descriptive, and except for the descriptive statistics reported for each variable, we performed no statistical calculations (ie, comparisons among exercises). Our goal was not to determine which exercise was best for a particular muscle but rather to describe which muscles important for the throwing motion are active during each exercise. Clinicians, coaches, and athletes can look at the descriptions of each exercise and make decisions concerning which exercises to include. The descriptive design of the current study met that goal.

A second limitation is the use of the load cell for assessing the force present during each exercise. Although we made every effort to standardize how much tension was present within the cord at the beginning of each exercise, the amount of tension present throughout the exercise changed depending on the subject's limb length. For example, a taller subject with a longer arm placed more tension on the rubber tubing-load cell apparatus as he moved away from the starting position. This resulted in more variability within the force data. Our primary purpose for using the load cell was to delineate the increasing and decreasing force phases of each exercise. The force data in Table 2 provide readers with a description of which exercises typically resulted in more tension within the rubber tubing-load cell apparatus, but this was not our primary objective.

A final limitation is that the 15 subjects in this study were all physically active but were not all throwers. Although we are not aware of any research that demonstrates a difference between throwers and nonthrowers when performing exercises, this limitation must be acknowledged.

Our results provide a foundation for future research. The 7 exercises described in the current study will be used to develop a validated injury-prevention program specifically designed for overhead athletes. Such a program must be validated by demonstrating adaptive strength and muscle endurance improvement in the desired muscles, significant carryover to more efficient muscle activation during overhead activity, and decreased injury rates in the upper extremity.

CONCLUSIONS

We are the first researchers to describe and rank the effectiveness of 12 rubber-tubing resistance exercises commonly used by throwers in the bullpen, in the dugout, or on the sidelines to activate the shoulder muscles important for throwing. According to the EMG analyses, performing 7 exercises—external humeral rotation at 90° of abduction, throwing deceleration, shoulder flexion, shoulder extension, low scapular rows, throwing acceleration, and scapular punches—resulted in the most activation of all muscles tested. With these 7 exercises, moderate activation (>20% MVIC) was present in each muscle of the rotator cuff and primary humeral mover and scapular stabilizer muscle groups. The results of this descriptive study will assist clinicians, coaches, and athletes in deciding which exercises may be better suited to include in their rubber-resistance tubing warm-up programs before throwing.