Posterior Rotator Cuff Strengthening Using Theraband® in a Functional Diagonal Pattern in Collegiate Baseball Pitchers

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Abstract: *The deceleration phase of the pitching mechanism requires forceful eccentric contraction of the posterior rotator cuff. Because traditional isotonic strengthening may not be specific to this eccentric pattern, a more effective and functional means of strengthening the posterior rotator cuff is needed. Twelve collegiate baseball pitchers performed a moderate intensity isotonic dumbbell strengthening routine for 6 weeks. Six of the 12 subjects were randomly assigned to an experimental group and placed on a Theraband® Elastic Band strengthening routine in a functional-diagonal pattern to emphasize the eccentric contraction of the posterior rotator cuff, in addition to the isotonic routine. The control group (n = 6) performed only the isotonic exercises. Both groups were evaluated on a KIN-COM® isokinetic dynamometer in a functional diagonal pattern. Pretest and posttest average eccentric force production of the posterior rotator cuff was compared at two speeds, 60 and 180°/s. Data were analyzed with an analysis of covariance at the .05 level with significance at 60°/s. Values at 180°/s, however, were not significant. Eccentric force production at 60°/s increased more during training in the experimental group (+19.8%) than in the control group (−1.6%). There was no difference in the two groups at 180°/s; both decreased (8 to 15%). Theraband was effective at 60°/s in functional eccentric strengthening of the posterior rotator cuff in the pitching shoulder.*

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Recent biomechanical and electromyographic (EMG) studies have determined that the muscles of the posterior rotator cuff (the external rotators; supraspinatus, infraspinatus, and teres minor) experience eccentric contractions during the deceleration and follow-through phases of baseball pitching.[3,5,12,17,23,24,28,31] Because the deceleration phase is strenuous to the shoulder in regards to torque during deceleration,[3,5,23,24] strong decelerators are vital in the posterior rotator cuff. Effective strengthening of eccentric muscles may be difficult to attain through traditional isotonic resistance exercises using light weights (approximately 5 lbs) in uniform movement patterns. Therefore, a more practical, functional, and effective means of eccentric strengthening of the posterior rotator cuff must be developed.

The purpose of this study was to determine if there was a significant increase in eccentric strength of the posterior rotator cuff through resistance exercise using Theraband Elastic Band (Hygienic Corporation, Akron, Ohio) in a functional-diagonal pattern as opposed to a traditional isotonic resistance exercise routine using light weights in uniform movement patterns during an in-season maintenance program for collegiate baseball pitchers.

Methods

For this study, two randomly assigned groups exercised for 6 weeks using a moderate-intensity isotonic maintenance program. One group exercised with Theraband (experimental group); the other did not (control group). Each group was pretested and posttested for average eccentric strength of the posterior rotator cuff.The independent variable was the mode of strengthening. The dependent variable was average eccentric strength, measured in pounds of force. Inferentially, analysis of covariance (ANCOVA) was used to determine any significant difference, with the pretest scores statistically controlled.

Subjects (n = 12) were volunteer members of the baseball team pitching staff participating in fall drills. By using preseason athletic participation physicals, we screened for any contraindications to exercise before the onset of the investigation. We randomly assigned six subjects to each of two groups.

Testing Procedures

Subjects were pretested and posttested on a KIN-COM 125E isokinetic dynamometer (Chattecx Corp, Hixson, Tenn). The dynamometer was calibrated according to the manufacturer's protocol before both testing sessions. Isokinetic testing has been found to be reliable in assessing strength.[15,20,37]

Testing was performed within the week before and the week after the 6-week strengthening trial. We tested individuals in each group over the course of 2 days; right-hand dominant first, then left-hand dominant. The same examiner administered the tests to insure adherence to the testing procedure through consistent positioning, instructions, and encouragement. Uniform instructions explaining the study, the procedures, and techniques of the test were read to the participants.

Each subject was positioned on the seat in a uniform fashion to adhere to the test position protocol (Fig 1). The KIN-COM dynamometer head was tilted at 30° and rotated as needed to allow the axis of rotation to pass through the axilla. The seat level and table-top length were positioned forward to accommodate this axis of rotation through the axilla. Spacers were placed between the subject's back and the table seat for stabilization of the back. A stool placed under the feet supported the legs. The sensor attachment pad was aligned in the middle of the forearm between the wrist and the elbow. The upper body was secured to the seat with a velcro-fastened strap across the chest, and the pelvis was stabilized with a seat belt. Mechanized stops were placed just beyond the computer stop and start angle to prevent any motion beyond the range of motion defined by the pattern tested.

Each test was performed as follows:

1. Subject stretched his/her dominant shoulder for 5 minutes.
2. Subject was positioned on the dynamometer and secured, as noted above.
3. Uniform instructions were read.
4. Subject was instructed to perform the following: one repetition at "50% perceived maximum"; one repetition at "75% perceived maximum"; three repetitions at "100% perceived maximum."

   Each repetition consisted of resisted lengthening of the posterior rotator cuff in a functional pattern of deceleration: D2-extension starting position, then abduction/flexion/external rotation, and ending with adduction/extension/internal rotation (Fig 2). As the subject performed the eccentric contraction of the posterior rotator cuff in the D2-extension pattern, the hand was kept open. For the return movement to the original starting position, the subject eccentrically contracted the anterior rotator cuff in the D2-flexion pattern in order to rest the posterior rotator cuff. In this movement, the hand was closed.
5. The test was given at two speeds, first at 60°/s and again at 180°/s in the same position after a 1-minute rest.
6. Verbal motivation was given only as needed to keep the athlete in proper motion during the testing.

Fig 1.— Isokinetic test protocol start (*a*) and isokinetic test protocol finish (*b*).

Strengthening Procedures

Both groups stretched the rotator cuff and performed isotonic exercises using a 5-lb dumbbell, as recommended for shoulder strength maintenance.[5,25,29,36] Each exercise was performed three times per week for one set of 10 repetitions each. This traditional isotonic routine (Fig 3) included the following exercises:

Circumduction
Abduction
Biceps Curls
Triceps Extensions
Standing supraspinatus "Empty-can"
Posterior Cuff External Rotation
Horizontal Abduction

The control group performed only the isotonic exercises in their daily routine. The experimental group performed these exercises in addition to eccentric and concentric strengthening, using the Theraband Elastic Band three times per week. The Theraband eccentric strengthening was preceded by the traditional isotonic maintenance routine.[11]

The Theraband routine consisted of exercise in the D2-diagonal pattern of proprioceptive neuromuscular facilitation (PNF) patterns.[27] Subjects attached the fixed end of the elastic band to the wall hooks even with the iliac crest (Fig 4). Standing with the opposite shoulder and side nearest the fixed origin, the subjects faced 90° in either direction to keep the opposite shoulder nearest the origin. The distance between the base of the wall hooks and the nearest foot was 3 ft. The dominant hand was placed on the opposite hip (nearest the origin), similar to the starting position for the D2-flexion pattern (Fig 2). The Theraband length was 3 ft from the origin to the hand, with no tension or slack in the elastic band.

Subjects performed the D2-flexion pattern concentrically to a position of full abduction, flexion, and external rotation by stretching the Theraband, paused 1 second, and performed the D2-extension pattern eccentrically by allowing the elastic band to pull the arm slowly back to the starting position of adduction/extension/internal rotation. We monitored subjects for correct posture during the exercise to ensure that all movement occurred only at the shoulder and that they maintained a smooth, slow, fluid motion. Care was taken to ensure that subjects did not "cheat" by engaging other muscles of the upper and lower body. Subjects performed the repetitions in about 10 seconds (3 seconds for the concentric phase, 2 seconds rest, and 5 seconds for the eccentric phase). They rested for 2 seconds between repetitions with the hand at the opposite hip (Fig 4) and for 1 minute between sets.

Subjects performed three sets of repetitions per day. They began with 10 repetitions per set during the first sets of a new resistance. Each session added five more repetitions, as tolerated by the subject, up to 25 repetitions. The resistance of the Theraband is color-coded in progressive strengths. The resistance began with light (yellow band) and increased progressively in strength (yellow, red, green, and blue) based on the ability of the subject to properly complete the prescribed sets and repetitions without soreness or perceived excess fatigue. After three sets of 25 were accomplished, the resistance was

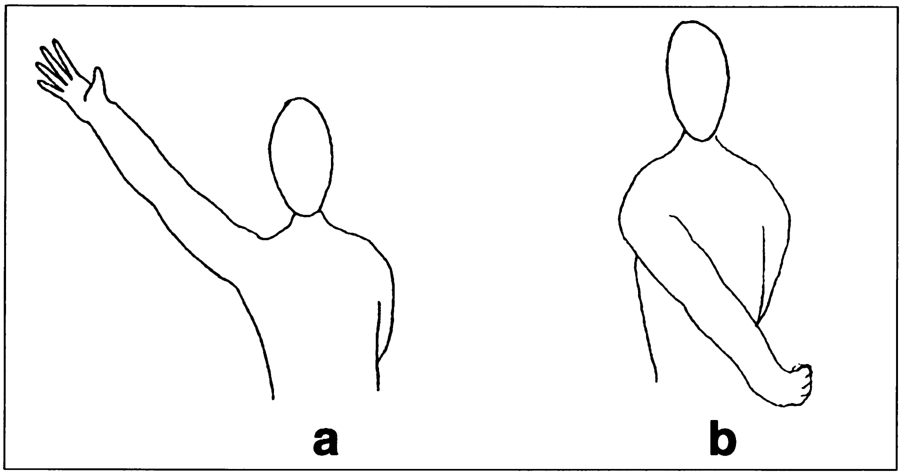

Fig 2.—PNF D2-extension pattern start (*a*) and stop (*b*); PNF D2-flexion pattern start (*b*) and stop (*a*).

increased and the repetitions decreased to three sets of 10, again progressively increasing. The goal of three sets of 25 repetitions was established to ensure that the subjects were working at a light weight with high repetitions, thus improving endurance and aerobic capabilities, while providing for strength gains. These exercises were performed 3 days per week after the isotonic routine in the experimental group. We instructed subjects to stretch their shoulders on their own for 5 minutes before and after exercise.

We performed two one-way analyses of covariance on the data to determine if the posttest scores of the two groups were significantly different, with pretest scores as the covariate.

Results

At 60°/s, the experimental group increased 19.8 ± 7.1% in eccentric posterior rotator cuff strength while the control group decreased (−1.6 ± 14.8%; (Table 1). Both groups decreased in strength at 180°/s (−14.8 ± 25.3% and −8.1 ± 25.6%, respectively). The experimental group was significantly stronger following train-

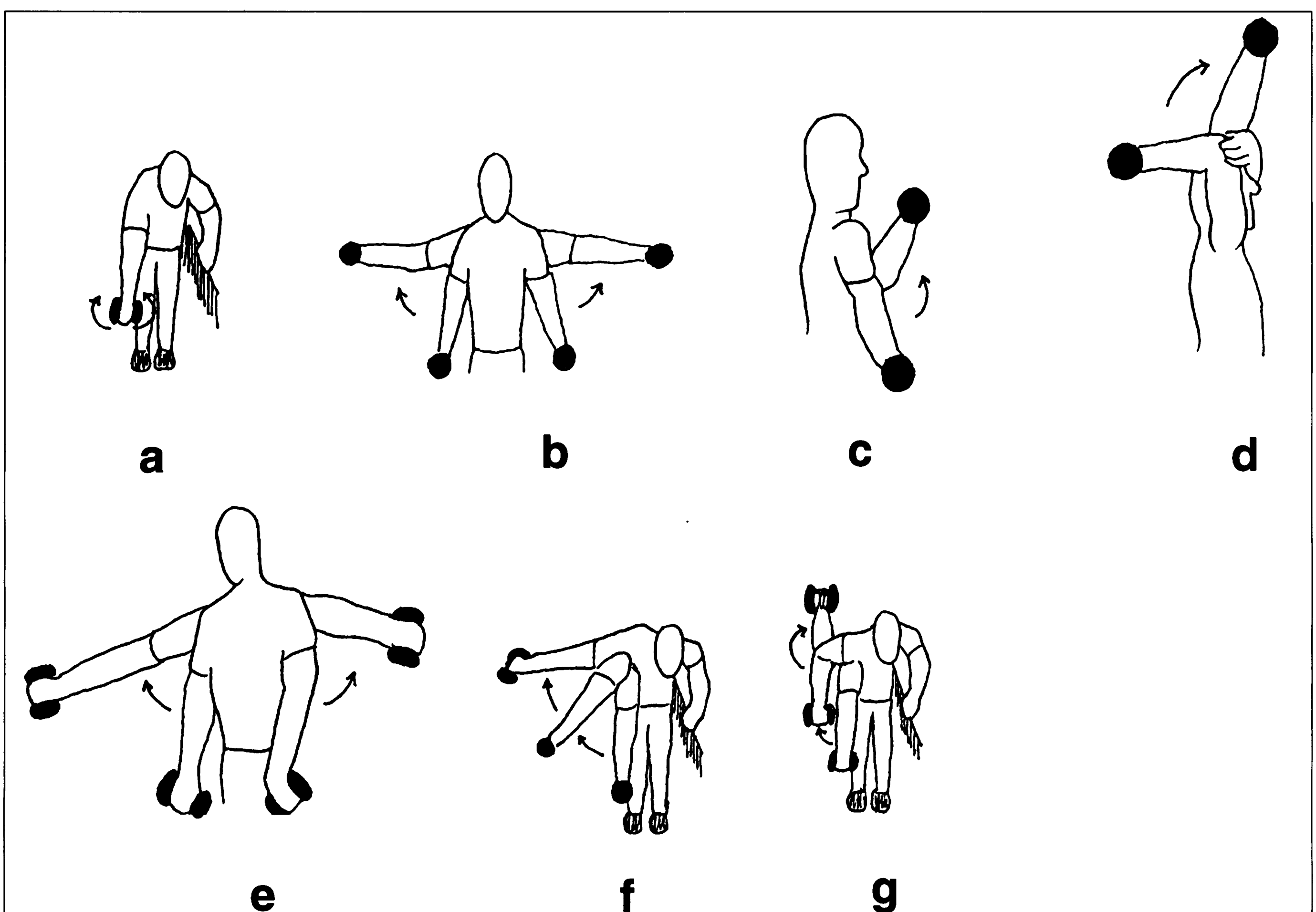

Fig 3.—Isotonic exercises: (*a*) circumduction; (*b*) abduction; (*c*) biceps curls; (*d*) triceps extensions; (*e*) standing supraspinatus; (*f*) posterior cuff external rotation; (*g*) horizontal abduction.

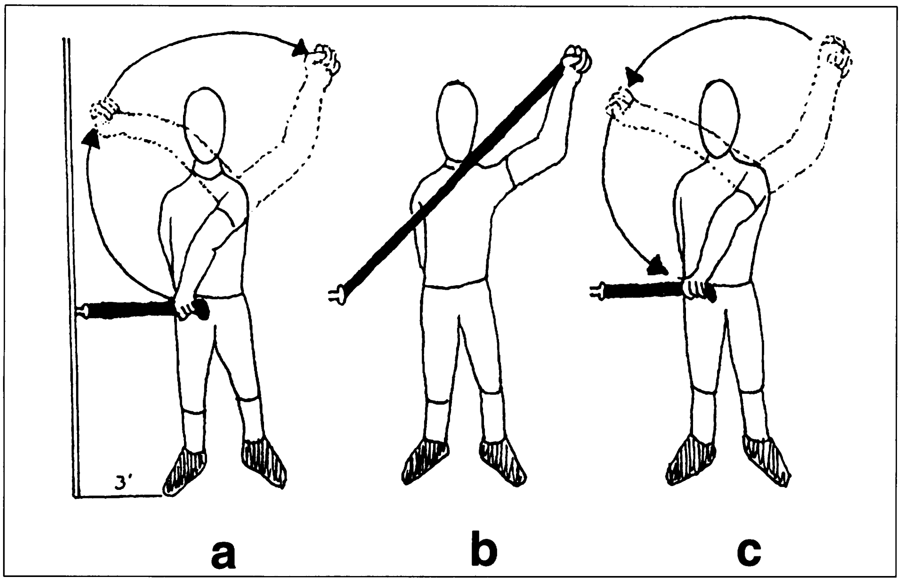

Fig 4.—Theraband routine start (*a*), middle (*b*), and finish (*c*).

ing than the control group at 60°/s ($F(1,9) = 11.75$, $p = .008$), but there was no significant difference between groups at 180°/s ($F(1,9) = .20$, $p = .66$).

Discussion

While this study indicated that Theraband strengthening may increase eccentric strength in the diagonal pattern, it raises further issues and questions for discussion. Little research exists regarding Theraband, eccentric functional shoulder testing, or strengthening studies involving pitchers. There have been no previous studies regarding the effectiveness of Theraband strengthening, and there are very few regarding elastic-band exercise. Most literature provides only suggested exercises.[4,5,25,29,36,38] Many use elastic tubing exercise as a strengthening device; however, most do not know the extent or actual value of its resistance. Elastic resistance exercise has not been labeled as being specific to a mode of contraction (ie, isotonic or isokinetic) because of its elastic properties. There is some question as to sets, repetitions, and resistance. It may be assumed to be isodynamic or accommodating resistance, because the resistance can be effectively changed by varying the band length or lever arm. No norms or recommendations have been established. Research is needed to substantiate claims by practitioners regarding both. Therefore, this study provides a basis for much needed further research in this area.

Speed and Mode of Contraction

The posterior rotator cuff (decelerator) muscles must contract eccentrically during the deceleration pattern; therefore, we evaluated the extent of eccentric strengthening of these muscles, specific to speed and mode of contraction. Both speed and mode were influenced. The strength gain by our subjects was only significant at the slower testing speed, 60°/s, which is still much slower than the actual angular velocity of the pitching arm (6180°/s).[31] Isokinetic technology does not allow for such high velocity functional testing; therefore, speed protocols had to be established for the hypotheses of this study.

The two testing speeds, 60 and 180°/s, were chosen because they are commonly used in isokinetic testing of the shoulder.[14,19] Different speeds may be used, but these two speeds seemed to be the limits of accurate testing. Below 60°/s, the speed was very slow, thus increasing muscle fatigue due to the prolonged eccentric contraction; above 180°/s, the speeds were much faster than the subject would have been comfortable with, due to the diagonal pattern.

The reasons for the difference in significance between speeds is uncertain. Duncan and associates[13] report that eccentric training at higher speeds increased the tension-generating capacity of connective tissue. Hageman et al,[19] however, report inconsistent increases in eccentric torque production at higher speeds. The increase in eccentric strength of the experimental group at the slower isokinetic testing speed could indicate that the 60°/s may have been more specific to the strengthening speed, since the strengthening repetitions were slow and controlled to emphasize the eccentric contraction. Conversely, the specificity of training principle of speed may then lead one to assume that a faster strengthening speed would have produced a significant gain at 180°/s, contrary to the slow and controlled motion in this study.

The difference may also be attributed to the order of testing of speeds during evaluation. Because 60°/s was evaluated first, it may have fatigued the decelerator muscles to the point of not providing a significant contraction

Table 1.—Average Eccentric Force of Posterior Rotator Cuff (ft-lb)

	Experimental	Control
60°/s		
Pretest	22.7 ± 7.4	23.3 ± 5.7
Posttest	28.2 ± 8.1	22.7 ± 4.5
% difference	19.8 ± 7.1	−1.6 ± 14.8
180°/s		
Pretest	31.5 ± 8.1	27.5 ± 6.9
Posttest	27.3 ± 5.9	24.5 ± 5.5
% difference	−14.8 ± 25.3	−8.1 ± 25.6

at the higher speed for the second test. Future eccentric testing might first evaluate the faster speeds, followed by slower speeds, or randomize the order of testing speeds.

The concentric phase of the strengthening pattern may have also contributed to an increase in eccentric strength. In order to facilitate the eccentric contraction using Theraband in the diagonal pattern, the subjects had to concentrically contract the posterior rotator cuff to the starting position (Fig 4). Some authors suggest that concentric contractions may be sufficient to provide gains in eccentric-strength.[34,35] This strength gain, however, may not be specific to the functional mode of contraction.

Testing Protocol and Deceleration Patterns

The testing and strengthening pattern in this study was an important issue; however, there was some question as to the reliability of this testing position. This specific eccentric testing position has never been used in research involving the pitching shoulder. Diagonal patterns testing the concentric strength of the pitching shoulder are used on other dynamometers, however.[8,10] By combining the literature on the biomechanics of the deceleration pattern and studies using the diagonal testing pattern, we developed the subject positioning for testing (Fig 1).

Jobe et al[23] used EMG analysis to determine the contraction of muscles during the deceleration phase. Electromyographic analysis of the muscles of the posterior rotator cuff during this deceleration pattern strengthening and testing may be needed to establish the validity of the testing position. Through EMG studies, the decelerator muscles can be evaluated for their function as well as their contraction pattern during strengthening or testing.[5] This may lead to a better understanding of eccentric exercises used to train the decelerator muscles.

Because no studies were available on this specific eccentric testing pattern, no posterior rotator cuff norms have been established. This pattern must be evaluated to establish norms on baseball pitchers or other throwing athletes to determine adequate levels of conditioning for competition, or to establish goals for strength training. This may also lead to the establishment of normal ratios for vital agonist/antagonist balance[2,8,16,18,21,25,38] of the anterior and posterior rotator cuff using eccentric and concentric contractions. Cook et al[8] report muscle asymmetry between rotator cuff muscle groups in baseball players. Norms are reported in regards to internal rotation/external rotation in concentric testing.[2,9,10,22] This, however, is not functional to both the movement pattern or muscular contraction type during deceleration.

Other studies evaluate isokinetic strength in pitchers at different arm positions[2,6,8] and compare strength to pitching velocity.[32,33] Most studies report a 3:2 concentric internal rotation-to-external rotation ratio.[2,10,22] The functional-diagonal pattern we used may be used to evaluate anterior rotator cuff concentric strength specific to acceleration. It can then be used to correlate the strength with other variables specific to pitching or throwing, or to shoulder injuries.

Injury Prevention Through Conditioning

The deceleration pattern used in this study has numerous implications regarding shoulder injuries, including preventive strengthening and evaluation. The strengthening pattern may be used to specifically train the decelerators and thereby prevent injury to the posterior rotator cuff. The biomechanics of the deceleration pattern as well as the agonist/antagonist balance are important in injury prevention. McLeod[28] stated that deceleration forces are twice as great as acceleration forces and act for a much shorter time, with peak torque reaching 300 ft-lb. Biomechanically, the shoulder joint is "thrown" toward the target in pitching, and has a natural tendency to follow the ball after release. This can cause the humeral head to separate from the glenoid fossa, due to distraction forces. Only the rotator cuff muscles, joint capsule, and glenohumeral ligaments provide stabilization for the shoulder. Unlike the decelerator muscles, capsular and ligamentous tissue cannot be strengthened or tightened with resistive exercise. The distraction of the humeral head and glenoid fossa may lead to microtrauma of the rotator cuff, glenoid labrum, capsule, or ligaments.[3,28] Therefore, strong posterior rotator cuff muscles must eccentrically contract to decrease the joint distraction during follow-through and subsequent injury.[12,21,23]

Pitchers may experience posterior shoulder soreness following extensive throwing. There are many theories regarding the cause of this soreness. Eccentric contractions of the decelerators may cause delayed-onset muscle soreness.[1,7,30] Specific eccentric training may enhance muscular recovery following pitching, thus reducing soreness. This soreness may also be attributed to microtrauma of the shoulder, secondary to muscular weakness or imbalance.[3,28]

Conclusion

This study has provided evidence that Theraband exercise of the posterior rotator cuff in the deceleration pattern is effective in increasing eccentric strength at slow speeds, but not at fast speeds. These findings can be used to substantiate some claims of strength gains using elastic-band exercise, but much further research is necessary. An ideal design would include two larger experimental groups—one group using isotonic strengthening alone and one using Theraband strengthening alone, and a larger control group using no strengthening. This would easily be accomplished using an untrained subject sample or performing the study during the off-season of athletes. However, we were interested in evaluating an in-season maintenance program of collegiate baseball players. Elastic rubber tubing should also be compared with a more aggressive isotonic program.[26] Research from different areas could be tied together and could benefit throwing athletes in prevention, maintenance, and rehabilitation of the shoulder.

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