3-2017

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ABSTRACT

Context: The role of the rotator cuff is to provide dynamic stability to the glenohumeral joint. Human and animal studies have identified sarcomereogenesis as an outcome of eccentric training indicated by more torque generation with the muscle in a lengthen position.

Objective: We hypothesize that a home-based eccentric exercise program can increases the shoulder external rotators eccentric strength at terminal internal rotation.

Design: Prospective case series.

Setting: Clinical laboratory and home exercising.

Participants: 10 healthy subjects (age=30 ±10 years)

Intervention: All participants performed two eccentric exercises targeting the posterior shoulder for 6 weeks using a home based intervention program using side-lying external rotation and horizontal abduction.

Main Outcome Measures: Dynamic eccentric shoulder strength measured at 60°/sec through a 100° arc divided into four equal 25º arcs (ER 50-25°, ER 25-0°, IR 0-25°, IR 25-50°) to measure angular impulse to represent the work performed. Additionally, isometric shoulder external rotation was measured at 5 points throughout the arc of motion (45° IR, 30° IR, 15° IR, 0°, and 15° ER). Comparison of isometric and dynamic strength from pre to post testing was evaluated with a repeated measure ANOVA using time and arc or positions as within factors.

Results: The isometric force measures revealed no significant differences between the five positions (P = 0.56, Table 1). The dynamic eccentric data analysis revealed a significant difference between arcs (P = 0.02). The arc of Internal Rotation 25-50° percent change score was found to be significantly greater than the arc of Internal Rotation 0-25° (P = 0.007).

Conclusion: Following eccentric training the only arc of motion that had a positive improvement in the capacity to absorb eccentric loads was the arc of motion that represented eccentric contractions at the longest muscle length.

INTRODUCTION

The innate function of skeletal muscle is determined by its cell structure (fiber morphology) and how these cells are arranged (muscle architecture). Fortunately, the plasticity of skeletal muscle permits modifications to morphology and architecture when the fibers are subjected to altered biochemical and mechanical stress during exercise-induced loss of homeostasis.[1] The subsequent architectural and structural adaptations attenuate these stresses, thereby modifying fiber and muscle function.[2, 3] For example, chronic training-induced fiber type transitions reduce the biochemical stresses produced by cell metabolism,[4] whereas fiber specific hypertrophy attenuates mechanical stresses.[5] Arguably, the most clinically recognizable exercise-induced adaptation in skeletal muscle is hypertrophy, or the cumulative effect of increased muscle fiber size. At the cellular level, muscle fibers can increase their size through mechanisms of myofibrillogenesis and / or sarcomerogenesis.

Myofibrillogenesis is muscle fiber hypertrophy in the axial direction and increases the cross sectional area of the fiber, because sarcomeres are added in parallel. Sarcomeres are force producing elements, and the forces produced by them are additive in parallel. Therefore, increases in muscle cross sectional area is a good predictor of peak isometric force[6] which is easily tested in the clinic and used as an objective criteria for return to play following injury.[7] Muscle fiber activation and the production of internal forces are essential stimuli to optimize exercise-induced myofibrillogenesis.[8-10] However, if a muscle fiber is also subjected to an external load that results in positive strain or stretch of the fiber, hypertrophy will also occur in the longitudinal direction, increasing fiber length due to sarcomerogenesis.[11, 12]

Sarcomereogenesis, or the addition of sarcomeres in series within a muscle fiber, has been studied extensively with *in-vitro*[13, 14], *in-situ*[15, 16] and *in-vivo* [12, 17-23] models. Although immobilizing a muscle in a lengthened position results in an increase in serial sarcomere number[21, 22, 24, 25] this addition is reversed if the stimulus is removed. Subsequently, the lack of tension sensing in the sarcomeres returns the serial sarcomere number to pre-stretch numbers within weeks, and demonstrates the plasticity of sarcomere number and its relationship to joint angle, and muscle tension.

Serial sarcomere number within individual fibers demonstrates a high correlation to joint angle[26], and signifies a mechanical advantage produced through the gain of sarcomeres in series. Increased serial sarcomere number would be of benefit in a static contraction, improving the muscle function by shifting the force-length relationship to the right, producing peak isometric force at a longer muscle length, or greater torque at a greater joint angle. During a dynamic contraction, this would reduce sarcomere strain for a given joint angle during eccentric contractions [3, 12]. Further adaptations to function would be manifested as increases in contractile velocity[27], muscle power[28], and extensibility[11]. Clinically, this functional adaptation in serial sarcomere number may also prevent injury when the muscle consistently works eccentrically at longer lengths[11, 22, 29]. These dynamic adaptations have been demonstrated in animal models using freely walking rats [20, 23, 30] and controlled eccentric exercise protocols in rabbits [12, 15, 31].

The adaptation of sarcomere addition in series following chronic eccentric exercise supports a previously proposed mechanism whereby sarcomere length is optimized for the muscle length at which force exerted on the tendon is the greatest[32]. Therefore this adaptation in serial sarcomere number has clinical implications as a potential injury preventing mechanism, due to the shift of the force-length (torque-joint angle) relationship to produce greater force (torque) at longer muscle lengths [11]. Although sarcomere numbers have not been counted in human subjects following eccentric exercise training, recent studies have demonstrated indirect evidence of sarcomerogenesis in human subjects, including adaptations in muscle function [33, 34] and morphology [35, 36] focused primarily on thigh [35-39] and brachial [34, 35] muscles. To date, there are no data available as to the effectiveness of an eccentrically biased training protocol on the function of the external rotators of the glenohumeral joint. Because these muscles are integral to the deceleration of the humerus during throwing [40], training protocols that produce a rightward shift of the torque – joint angle relationship may prove beneficial. Therefore, the purpose of this study was examine the effectiveness of a six week home-based eccentric exercise program to enhance isometric and eccentric external rotation strength in lengthened positions.

METHODS

Setting and Participants

Ten participants volunteered for this study from a sample of convenience at a university setting. (Age: 30±10years, Height: 164±10cm, Mass: 79±18kg). Subjects were excluded from participation if they reported a history of shoulder or neck pathology, previous shoulder or neck surgery, or shoulder or neck pain within the last 6 months. All healthy subjects not excluded and willing to participate read and signed a University of Kentucky Institutional Institutional Review Board approved informed consent prior to participation in the study.

Subjects filled out the Penn Shoulder Score before testing to evaluate level of shoulder function prior to participating. The Penn shoulder score ranges from 0-100 with 100 representing highest level of function. The score has been found to be a reliable and valid measure of shoulder function[41]. The Penn shoulder score averaged 97 with a range (85 – 100) indicating that current participants demonstrated near normal function at the onset of the study. All testing was completed at the Musculoskeletal Laboratory at the University of Kentucky with a single unblinded investigator performing all testing.

Study Design

This prospective case series investigation was designed to investigate the effectiveness of home-based eccentric exercises for the posterior shoulder to improve external rotation strength and improve ability of the posterior shoulder to absorb dynamic internal rotation forces. Three days of familiarization with 1 week of rest between testing episodes was used to establish baseline values and evaluate reliability of testing procedures. A six-week exercise intervention incorporating 2 exercises was carried out by all participants. The same testing procedures were repeated after the program to evaluate changes from the intervention. Participants were asked to not start a new exercise program during the study however they could continue to perform their normal exercise and activities of daily living during the study. The independent variable is time identified as pre-exercise and post-exercise tests. There are 2 dependent variables (isometric torque at 5 angles and dynamic eccentric shoulder external rotation angular impulse) that were measured at every time point.

Isometric and Isokinetic Testing Procedures

Prior to shoulder testing all participants completed 3 shoulder stretches (cross body, sleeper stretch, corner wall shoulder stretch) for 2 sets of 30 seconds each. Participants then warmed up with two active range of motion exercises with no load consisting of side-lying external rotation and side-lying horizontal shoulder abduction and adduction. Each exercise was performed for approximately one minute. The same warm-up occurred prior to each day of testing.

Next, shoulder strength testing was performed using an isokinetic dynamometer (Cybex Norm, Ronkonkoma, NY) as previously reported.[42] Participants were seated with their dominant shoulder in 60 degrees of abduction and 30 degrees of horizontal adduction. This was defined as the scapular plane in the Cybex Norm user's manual. Both positions were confirmed using a hand held goniometer on all subjects. Isometric testing was always performed first, isometric shoulder external rotation strength was determined from the average of two trials taken at five test positions (45° IR, 30° IR, 15° IR, 0°, and 15° ER). The order of the test position was randomly assigned using a random number generator with Microsoft Excel on each testing day in order to minimize length change biases related to the length-dependent and time-dependent properties of muscle.[43, 44]

In each test position, subjects performed one sub-maximal practice repetition for 3 seconds, rested for 20 seconds and then performed two maximal repetitions for 3-seconds with a 60 second rest between each effort as previously established.[33] Standardized verbal encouragement was given during isometric strength testing for maximal repetitions to attempt to maximize the subject's effort and strength potential.[45] Peak torque was recorded for both isometric contractions at every angle and averaged to represent angle specific torque. The excellent reliability of these testing procedures between days (ICC ≥ 0.85) has been previously reported.[42]

Following the collection of isometric torque data, dynamic eccentric shoulder external rotation torque data were collected, while maintaining the shoulder in the same test position and through a 100° arc of motion from 50° of external rotation to 50° of internal rotation. The continuous passive motion (CPM) mode was used with the Humac software (Computer Sports Medicine Inc, Stoughton, MA) on the Cybex Norm with an internal rotation velocity set at 60°/second. From the start position of 50º external rotation, the subject was instructed to maximally contract into external rotation to initiate internal rotation. The subject was instructed to maximally resist internal rotation through the entire range of motion in order to evaluate dynamic eccentric external rotation torque production. The subject was asked to relax his/her arm as the isokinetic dynamometer passively returned the arm into external rotation starting position at 15°/second. This process removed all concentric activity during testing. Participants were given three minutes to rest following the familiarization phase and then performed six maximal efforts in a row, with 7 seconds of recovery during the passive return to 50º of external rotation between trials. Standardized verbal encouragement was given during eccentric testing. The middle four trials were averaged together to determine angular impulse later used for data reduction and statistical analyses. A total of 3 baseline-testing sessions, one week apart, were collected before initiating the home exercise eccentric program to reduce the effect of motor learning during a novel task.[46, 47] Post-intervention testing occurred at 6 weeks after the start of the home exercise program, and consisted of the same procedures described above. The reliability of the dynamic eccentric shoulder external rotation strength as determined by angular impulse is excellent (ICC ≥ 0.97) as previously reported.[42]

Exercise Procedures

The home-based exercise program consisted of 2 eccentrically-biased exercises consisting of side-lying horizontal adduction and side-lying external rotation. This exercise protocol is modified from Blackburn et al., shown to be an excellent position to activate the posterior shoulder musculature[48]. Participants were all given the same exercise instructions for performing two sets of each exercise with 15 repetitions per set, 4 times a week. In order to focus on the eccentric component of the exercise and minimize the concentric portion, specific instructions were provided and initially performed with investigator supervision. To bias the exercises for eccentric contractions, subjects removed the weight from their own hand at the end of the eccentric contraction phase, and rotated to a supine position to allow gravity to externally rotate the humerus back to the starting position to minimize concentric activity. They then placed the weight back in the hand of the experimental side, and rotated back to side laying for the next repetition. All participants had to demonstrate proper form with both eccentric exercise maneuvers. Form was deemed proper when subjects could effectively eliminate concentric contractions from both exercises regimens, and perform eccentric contractions through the full range of motion at the correct speed as per the instructions (Appendix). To support the clinical instruction, detailed written methods and pictures were given to participants to take home (Appendix). All eccentric exercises were performed at a slow pace of eight seconds for lowering the weight to emphasize the eccentric load to the posterior rotator cuff. Participants returned weekly to progress their resistance loads and assure proper exercise form.

Starting resistance for the eccentric exercise was determined from the highest dynamic eccentric shoulder external rotation average peak torque generated on one of the 3 baseline testing days. Average peak torque (Nm) was divided by the length of the subject's forearm (m) to estimate the force (N), which was then converted to pounds and multiplied by 0.2 to determine the weight used for the first week of training. Subjects were progressed on a weekly basis using a linear progression of increasing loads while repetitions were held constant. After the first week, the initial load was increased 20% and then subsequently increased by 25% weekly for the next 5 training weeks. Subjects were given a log to track their weight, sets, and repetitions that was returned at the end of the study. Additionally, a modified Borg perceived exertion scale was used to record level of difficulty when performing exercise. The scale ranged from 0-10 with 10 representing maximal effort during an exercise. This allowed the researchers to monitor exercise progress so that resistance loads could match perceived exertion during exercise.

Data Reduction and Statistical Analysis

The two isometric trials for each day of testing were averaged together to represent external rotation torque at each shoulder angle. The post-exercise test data were subtracted from the pre-exercise test data for each subject to determine the change score. Shapiro-Wilk test for normality revealed that the isometric data were not normally distributed. Non-Parametric analysis was carried out using Friedman test to determine if change scores differed across the five positions (IR 45°, IR 30°, IR 15°, Neutral, ER 15°) for isometric data with alpha level set at $P \leq 0.05$. Wilcoxon Signed Rank Test was used to compare individual differences between positions if appropriate, with alpha level corrected for ten comparisons ($P \leq 0.005$).

Raw data from each dynamic eccentric testing day for each subject were extracted from the Cybex. The raw data provided time, speed, angle and torque at a rate of 100Hz. These data were imported into an excel (Microsoft, Redwood CA) template to calculate angular impulse. Angular impulse was calculated using the trapezoidal equation for area {Σ(1/2 [θ at point A + torque at point B]*.01)} for entire trial. The four middle efforts of the 6 trials were averaged together. The average total angular impulse was further divided into 4 equal 25° arcs of motion to clearly represent work production through the range of motion. The post-exercise test data were subtracted from the pre-exercise test data for each subject to determine the change score. Shapiro-Wilk test for normality revealed that the dynamic eccentric data were not normally distributed. Non-Parametric analysis was carried out using Friedman test to determine if change scores differed across the four arcs (ER 50-25°, ER 25-0°, IR 0-25°, IR 25-50°) for dynamic eccentric data with alpha level set at $P \leq 0.05$. Wilcoxon Signed Rank Test was used to compare individual differences between arcs if appropriate, with alpha level corrected for six comparisons ($P \leq 0.0083$).

RESULTS

The isometric data analysis is presented using median values and inter-quartile ranges as non-parametric analysis was performed which revealed no significant differences between the five positions (P = 0.56, Table 1). The dynamic eccentric data analysis revealed a significant difference between arcs (P = 0.02, Figure 1). Correcting for multiple comparisons between the four arcs, there was only one pairwise comparison to reach significant difference. The arc of Internal Rotation 25-50° percent change score was found to be significantly greater than the arc of Internal Rotation 0-25° (P = 0.007, Table 2). Following eccentric training the only arc of motion that had a positive improvement in the capacity to absorb eccentric loads was the arc of motion that represented eccentric contractions at the longest muscle length.

DISCUSSION

Although Fridén was the first to propose sarcomerogenesis as a beneficial, functional adaptation to eccentric exercise in 1984,[49] direct mechanistic evidence of increased serial sarcomere number following chronic training with eccentrically biased contractions has only been demonstrated in animal models to date. By training rats to walk on a treadmill, Lynn and Morgan were the first to show an exercise-specific adaptation in serial sarcomere number in the vastus intermedius muscle.[30] Although fiber strains were not directly measured, it was reasonably assumed that the quadriceps operated eccentrically during daily bouts of downhill walking, and eccentric training was associated with a significant increase in fiber length and serial sarcomere number, and therefore greater force at longer lengths.[20, 30] By directly measuring fiber dynamics, Butterfield et al. associated positive active fiber strains to subsequent serial sarcomere number increases of ~10% in the vastus intermedius after 10 days of eccentrically-biased exercise.[23] Subsequently it was shown that higher positive fiber strains during eccentric exercise resulted in greater serial sarcomere number adaptations, and this could be accomplished by exercising the muscle through excursions involving long muscle lengths near or at terminal ranges of motion.[50] [12]

Serial sarcomere number measurements, and therefore direct measurements of sarcomerogenesis, are impractical, if not impossible in human subjects. Therefore, architectural and functional measures previously associated with sarcomerogenesis in animal models are used as indirect measures of a beneficial adaptation to eccentric exercise in humans, including a rightward shift in the muscle's torque-joint angle relationship,[34, 37] adaptations in muscle architecture such as longer muscle fibers,[35, 36, 51] and/or increased fiber pennation angles.[52]

In this study, by training the posterior shoulder muscles eccentrically, we were interested to see if changes in both isometric and dynamic eccentric strength of the shoulder external rotators would increase the ability of the posterior shoulder musculature to absorb eccentric loads at the end range of the eccentric motion. We found that our eccentrically biased training program for the posterior shoulder muscles did not have an effect on their isometric torque-joint angle relationship. Although a rightward shift following repeated bouts of eccentric exercise training has been associated with serial sarcomerogenesis in human muscle,[37] there is evidence that sarcomere number adaptations can also occur without a significant shift in this relationship. Chen et al., found a direct association between training load and torque-angle shift following eccentric exercise training in human subjects.[34] In their study, only subjects that performed eccentric exercises at 100% of maximal voluntary contraction exhibited a rightward shift of the torque-angle curve on the biceps brachii, despite additional groups that trained submaximally exhibiting other beneficial training adaptations such as the repeated bout effect, or resistance to subsequent eccentric exercise-induced injury.[34]

It is therefore possible that our training program was not long enough or the resistive load may not have been adequate to facilitate a measureable muscular adaption in isometric torque. This is supported, in part, by the aforementioned eccentric training studies in rabbits, whereby higher evoked forces during eight weeks of eccentric training resulted in greater rightward shift of the torque-angle curves. [12, 50] In addition, the lack of a shift in the isometric torque-angle relationship may be associated with the methodology in calculating the angle of isometric peak torque production.[53] By necessity, the isometric torque measures in our study herein are discreet data points, measured at every 15^{o} of glenohumeral rotation. Therefore, it is possible that changes in isometric peak torque may have occurred between two discreet measurements. Lastly, the torque-angle relationship is a measurement that is sensitive to several factors, and easily altered by factors such as reduced effort, fatigue, alterations in series compliance, and/or changes in muscle / tendon stiffness.[53]

Therefore, we also measured the dynamic eccentric torque-angle relationship as a more robust indicator of the muscle’s capacity for energy absorption.[54, 55] The mechanism of force production during an eccentric contraction differs significantly from the traditional mechanism of cross-bridge produced force during isometric and concentric contractions.[56-60] Therefore, forces produced eccentrically are independent of fiber type[61] and although fiber transitions can modify the muscle’s contractile velocity, power, and rate of force development during concentric contractions, their influence on force is essentially eliminated during isometric contractions, when the velocity is zero.[62] However, exercise-induced alterations in the elastic elements of the muscle and/or tendon can modify force production.[63, 64] Elastic energy storage is an essential component of the shoulder musculature for throwing activities[65] and stiffening of the parallel elastic component of the muscle by itself or in conjunction with sarcomerogenesis could explain our results. The increase in angular impulse at the longest muscle length is a significant adaptation to eccentrically biased exercise. It can be produced by increasing the length of the muscle fibers[20], is indicative of serial sarcomere number increases[11, 12], and it increases the amount of energy that the external rotators can absorb while actively lengthening, [3, 66] and reduces the potential for eccentric exercise-induced strain damage and injury.[11, 20, 29, 33, 34, 36, 37, 39, 51, 52, 54]

It is well documented that the posterior shoulder needs to act eccentrically to decelerate the arm during the termination of a baseball pitch, tennis serve or similar movement.[67-70] We believe the ability to effectively activate the posterior shoulder musculature eccentrically through the full range of motion is critical for avoiding injuries in the shoulder, specifically for overhead throwing athletes. Although our subjects performed the testing and exercise procedures with the shoulder in a different position compared to that of a throwing motion, we propose that the functional adaptations measured in this study are translatable. The posterior shoulder musculature must decelerate the shoulder during both the deceleration phase and the follow-through phase of pitching, as the loads are dissipated. Fleisig et al., calculated a significant internal rotation torque at the shoulder that was still evident at terminal internal rotation.[69] At the time of ball release, Werner et al., calculated high distraction forces that were dissipated over course of the following 200ms[71, 72], as the shoulder continues to internally rotate to approximately 0° of glenohumeral rotation.[73]

Limitations

We used two different positions for exercising and testing the muscles of the posterior shoulder. It is reasonable to expect that exercise-induced adaptations in skeletal muscle to be specific function; i.e. contraction type and muscle length.

Therefore, it is possible that the exact magnitude of the adaptations were not measured due to the different position of testing. However, we did find an improved eccentric impulse at long muscle lengths for the posterior shoulder musculature in a shoulder position (and muscle position), which indicates the robustness of the adaptation at the tissue level. Future studies will utilize a laboratory setting to test and measure in identical positions.

It is possible that adaptations in motor unit recruitment occurred in our subjects over the course of the study. However, the lack of a significant training effect in the isometric torque data in conjunction with the systematic improvement in eccentric torque production in only the terminal arc of motion makes this less likely. In addition, muscle morphological and functional adaptations to eccentric loading are evident earlier compared to adaptations from isometric and concentric training, which supports fiber adaptation following a short, eccentrically-biased, four week training program.[74] In future studies measuring eccentric exercise-induced adaptations in our laboratory, we will include longer exercise durations and higher intensities, incorporate methods to assess muscle activation such as EMG, and measure rate of torque development and muscle stiffness to further separate viable mechanisms underlying the functional adaptations in skeletal muscle.

Conclusion

In this pilot study, we have shown for the first time that an eccentrically-biased home exercise program can improve the energy absorption capacity of the posterior shoulder muscles by increasing the eccentric torque production at terminal internal rotation. The exercises performed in this study can be translated easily for clinical use by overhead athletes. While these exercises do not approach the velocity seen in overhead sports, they could be good options for training program for overhead athletes or during rehabilitation to facilitate eccentric strengthening of the posterior shoulder musculature. The two posterior shoulder eccentric exercises used during this six week intervention appear to support the concept of specific adaptation to imposed demand principle and increases the ability to absorb forces with the muscle in a lengthened position.

Table 1. Isometric Change scores

	Median Change Score	Interquartile Range
External Rotation 15°	4.79	(-5.6 – 11.4%)
Neutral 0°	1.18	(-5.1 – 21.6%)
Internal Rotation 15°	7.75	(-10.4 – 26.5%)
Internal Rotation 30°	-1.91	(-2.9 – 17.8%)
Internal Rotation 45°	1.64	(-1.2 – 17.4%)

(-) indicates that the isometric strength decreased from baseline value

Table 2. Dynamic Eccentric Percent Change Scores compared to the longest position of Internal Rotation arc 25-50°

	Short External Rotation 50-25°	External Rotation 25-0°	Internal Rotation 0-25°	Long Internal Rotation 25-50°
Median Change Scores	-3.4	-3.0	+0.4	+9.5
Interquartile Range	(-21.8 – 12.7)	(-14.1 – 7.9)	(-8.9 – 12.9)	(2.2 – 31.0)
Significance Compared to Long IR 25-50°	P = 0.059	P =0 .017	P = 0.007*****	

* Indicates that change scores is significantly different from Internal Rotation 25-50°

(-) indicates that the angular impulse decreased from baseline value

Figure 1

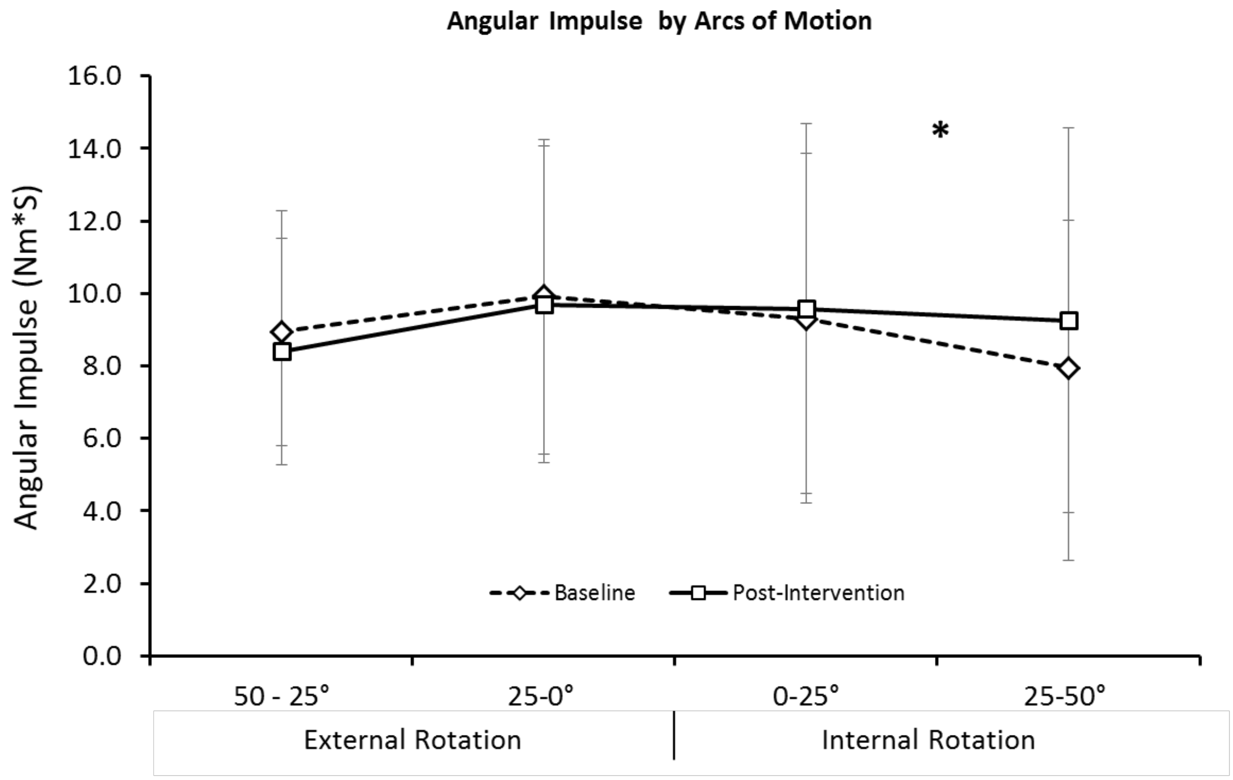
Angular Impulse by Arcs of Motion
Angular Impulse (Nm*S)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
*
Baseline
Post-Intervention
50 - 25°
25-0°
0-25°
25-50°
External Rotation
Internal Rotation

Figure captions

Figure 1. Mean eccentric angular impulse for the posterior shoulder muscles on day 1 (open triangles) and following and eccentrically biased training program (open squares) for four arcs of motion. Eccentric contractions began with the posterior shoulder muscles at their shortest length (50^{o} of external rotation) and the muscles were lengthened during contraction to their longest lengths (50^{o} internal rotation). Following eccentrically biased training, the area under the eccentric torque-angle curve (angular impulse) was significantly greater (*) for the arc of motion that represented the longest muscle lengths ($25\text{-}50^{o}$ internal rotation).

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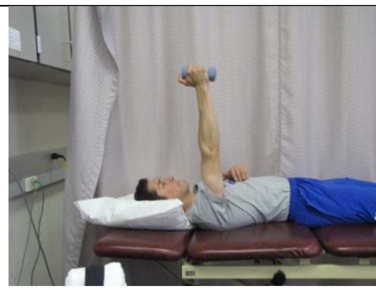
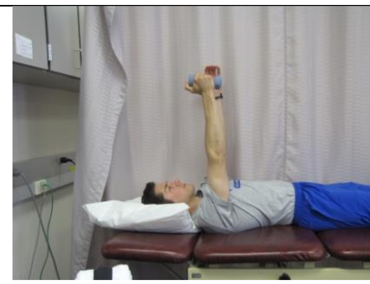
Appendix

Side-lying Eccentric Horizontal Adduction

1) Lie on your back near the edge of a firm surface; preferably the floor or a firm mattress. (Figure 1)
2) Extend the non-exercising arm straight up in the air while holding the weight. (Figure 2)
3) Extend your exercising arm straight up in the air, transfer the weight to the opposite (exercising) hand and drop your non-exercising hand to your side. (Figures 3-5)
4) Roll on to your non-exercising side keeping the weight still extended straight up in the air. (Figure 6)
5) Now, using an 8 count, slowly lower the weight, keeping your thumb pointing towards the ceiling, your arm straight, and your arm in-line with your mouth. (Figures 7-8)
6) Let the weight lower as far as the surface will permit, hanging off if possible (Figure 8)
7) Once the weight has been fully lowered, roll on to your back (Figure 9) and assume the starting position. (Figure 1) Repeat the steps for 2 sets of 15 repetitions.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		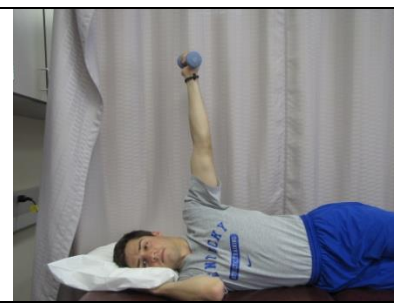
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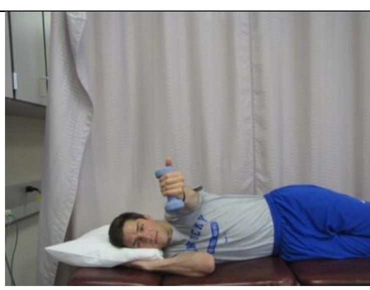


Figure 7	Figure 8	Figure 9

Side-Lying Eccentric External Rotation

1) Lie on your side on a firm surface, with a rolled up towel or bolster placed under your arm, with the weight held by your non-exercising arm as shown. (Figure 1)
2) Roll onto your back and bring the weight up to your exercising arm, making sure to keep the towel under your arm. (Figure 2)
3) Roll back on to your side, your arm should rotate up towards the ceiling. (Figure 3)
4) Slowly lower the weight towards the surface, keeping the elbow bent at a right angle. (Figures 4-6)
5) Once you have gone through your available range of motion, drop the weight to the surface. (Figure 7)
6) With the non-exercising arm, pick up the weight. (Figure 8) and position your arm back in the starting position to repeat the exercise for the given number of repetitions. (Figures 9, 1)

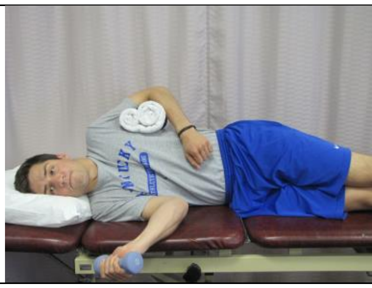


Figure 1

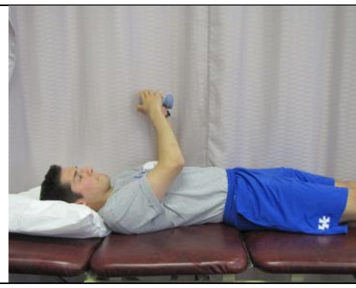
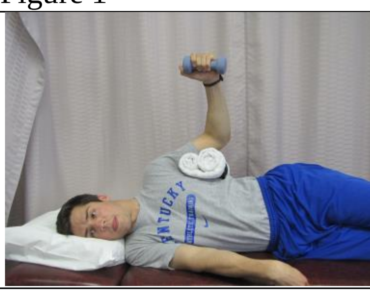


Figure 2

Figure 3



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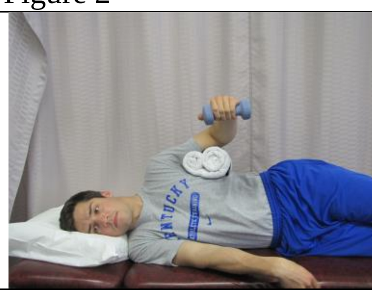

Figure 5

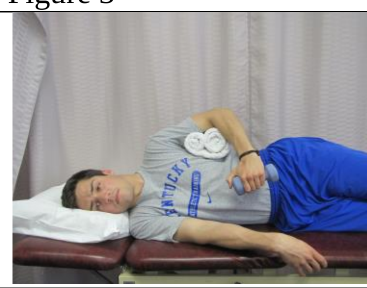

Figure 6

Figure 7

Figure 8

Figure 9