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ISOLATED VS COMPLEX EXERCISE IN STRENGTHENING THE ROTATOR CUFF MUSCLE GROUP

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ABSTRACT. Giannakopoulos, K., A. Beneka, and P. Malliou. Isolated versus complex exercise in strengthening the rotator cuff muscle group. *J. Strength Cond. Res.* 18(2):144–148. 2004.—The purpose of this study was to compare 2 different training modes in improving shoulder cuff muscular performance. Thirty-nine participants were randomly assigned into 3 groups: the isolated group exercised using 2-kg dumbbells; the complex group used a protocol with complex exercises; and the control group had no training. All participants trained for 6 weeks (3 times per week) and were evaluated isokinetically before (pretest) and after the training period (posttest). Results showed that the complex group significantly improved their muscular performance, but the isolated group did not, indicating that isolated exercises are only effective when the training goal is to strengthen the weaker muscle group, but they must be replaced by more complex and closed-kinetic exercises in order to obtain considerable improvement of the rotator cuff strength. The authors propose that a strengthening program should start with isolated movements for better stimulation of the weaker muscles and continue with complex exercise for more impressive strengthening.

KEY WORDS. internal/external rotators, peak torque values

INTRODUCTION

The rotator cuff muscles are of particular importance to the motion of the shoulder complex, which is expected to move in almost unlimited movement patterns. These muscles act in accordance with the deltoid (19) to guide the head of the humerus during humeral elevation. Although the 2 rotator forces are exerted in opposite directions, they tend to move the humerus in the same direction (abduction) because they are applied on opposite sides of the joint axis of motion, forming a force couple. In contrast, the translator forces of the deltoid and the rotator cuff muscles cancel each other out, stabilizing the head of the humerus within the glenoid fossa. If the rotator cuff muscles are not adequately active (19), the translator force of the deltoid would presumably pull the humerus upward into the acromion of the scapula. In summary, although the deltoid is considered to be a prime mover for humeral abduction, it cannot work effectively in the absence of the rotator cuff muscles.

Considering that the shoulder is a very complex joint with a lot of different possible movement patterns, it would be very useful to know which way of strengthening the rotator cuff muscle group is more effective in order to improve the stabilization of the shoulder joint, especially of the glenohumeral joint. Regarding the training mode that could be more effective in strengthening those muscles, other studies (4) suggest using isolated exercise that better emphasizes recruitment of the muscles in question, and yet other studies refer to complex exercises (3, 16). More specific, Davies (9) determined open vs. closed ki-

netic chain as the following: in open kinetic chain exercise, an isolated joint movement occurs when 1 part of the extremity that forms the joint is stabilized and the other is mobile. The same author describes the closed kinetic chain as a pattern that occurs with multiple joint movements where both components of the extremity that form the joint are simultaneously moving. Thus, sports movements of the upper limbs often involve a combination of the shoulder, elbow, and wrist, thus indicating the need for applying more complex movement patterns. On the other hand, it is strongly recommended that after evaluating the muscular performance and detecting the possible imbalances in strength, an exercise program containing movements of an isolated joint that emphasize the weak muscles must be applied (4).

There are several studies referring to isolated movements or to more complex closed kinetic chain exercises. More specific, Beneka et al. (2) applied 2 different programs for strengthening the shoulder cuff, an isokinetic exercise program, and a multijoint dynamic resistance training program using the isokinetic testing mode. The results revealed that the multijoint dynamic resistance training can be a very simple and easy way to improve muscular performance of both internal and external rotators, and it can also be as effective as isokinetic exercise. However, the authors considered that further studies are needed to compare the 2 dynamic resistance training modes.

Also, Greenleaf et al. (12) compared an isokinetic protocol with the dynamic resistance training mode, indicating that the muscular performance improvement was not differentiated by the exercise training mode. The investigators compared the 2 training protocols in relation only to the leg muscular performance improvement and not the rotator cuff muscle group. According to Vandervoort et al. (21), the muscle groups of upper limbs seem to have different training adaptations than those of lower limbs due to differences in the familiarity with concurrent bilateral activation. This means that further study of the rotator cuff needs to be done.

The rationale for the present study is that many sports contain complex closed kinetic exercises of the shoulder, but at the same time there is always a need for executing isolated open kinetic exercises in order to obtain better muscular recruitment. Considering the important role of the rotator cuff muscle group in stabilizing the glenohumeral joint, it is necessary to identify those muscles that are weak and long and then apply a strengthening program to restore these imbalances. These goals are very crucial since muscular imbalances might be an important injury risk factor (11, 15, 20, 23). That is why the authors chose to compare 2 different dynamic resistance training modes for their effectiveness to

TABLE 1. Strengthening program of the experimental groups during the training period.

Exercise	Week 1 set (rep)	Week 2 set (rep)	Week 3 set (rep)	Week 4 set (rep)	Week 5 set (rep)	Week 6 set (rep)
Isolated group						
Internal rotate right	2 (8–15)	3 (8–15)	4 (8–15)	5 (8–15)	6 (8–15)	7 (8–15)
Internal rotate left	2 (8–15)	3 (8–15)	4 (8–15)	5 (8–15)	6 (8–15)	7 (8–15)
External rotate right	2 (8–15)	3 (8–15)	4 (8–15)	5 (8–15)	6 (8–15)	7 (8–15)
External rotate left	2 (8–15)	3 (8–15)	4 (8–15)	5 (8–15)	6 (8–15)	7 (8–15)
Complex group						
Pull-up	2 (8–15)	3 (8–15)	4 (8–15)	5 (8–15)	6 (8–15)	7 (8–15)
Overhead press	2 (8–15)	3 (8–15)	4 (8–15)	5 (8–15)	6 (8–15)	7 (8–15)
Reverse pull-up	2 (8–15)	3 (8–15)	4 (8–15)	5 (8–15)	6 (8–15)	7 (8–15)
Push-ups	2 (8–15)	3 (8–15)	4 (8–15)	5 (8–15)	6 (8–15)	7 (8–15)

strengthen the rotator cuff muscles: an open kinetic chain protocol containing isolated movement patterns (“isolated”) training, and a closed kinetic chain protocol with complex movements (“complex”) training.

The testing mode that was selected to evaluate the 2 groups was the isokinetic way because of the fact that this is the most common and standard clinical evaluation method to assess both muscle groups at the same time and draw conclusions about the existence of muscular imbalances that can be comparable and objective. Also, regarding the functional implication of the isokinetic testing results, many significant correlations have been proven between several functional tests and isokinetic muscular performance (26).

METHODS

Experimental Approach to the Problem

Considering that there is always a need for strengthening the rotator cuff muscles, this study examines 2 different dynamic resistance training protocols for their effectiveness: (a) a protocol with isolated movements that has the characteristics of an open kinetic chain exercise, and (b) another protocol with more complex and closed kinetic chain exercises. The main question is, which one will be more effective in improving the muscular performance: the one that seems to better recruit the muscles in question, or the one that better reflects the sporting activities?

Thirty-nine active men volunteered to participate in this study. The subjects had a mean age of 20.7 ± 1.7 years, a mean weight 69.5 ± 6.1 years, and a mean height of 173.1 ± 5.6 cm. None of the subjects were participating in throwing sports. They also were free from injury in their shoulders in the past 2 years (according to self-report) and had full range of motion at the testing position, no biomechanical abnormality (after clinical diagnosis), and had no other resistance training activity prior to and during the entire research period.

Prior to undergoing the testing procedure, each subject performed a 5-minute warm-up on an upper body ergometer (Cybex, Inc., Ronkonkoma, NY) at an intensity of $600 \text{ kgm}\cdot\text{min}^{-1}$ using the 90 rpm setting. This was followed by passive range of motion of both shoulders in flexion, abduction, $90^\circ\cdot\text{s}^{-1}$ of abduction with external rotation, and $90^\circ\cdot\text{s}^{-1}$ of abduction with internal rotation. A random determination of starting extremity was followed to minimize the effects of learning bias. Three submaximal and 1 maximal trial repetition at each speed were performed before each bout to prepare the subject for the testing procedure. A 30-second rest was allowed between

testing speeds for all subjects. Standardized verbal instructions and encouragement were given, with the subjects unable to receive visual feedback during the testing procedure (1).

All isokinetic testing was completed using the Cybex 6000 isokinetic dynamometer. The reliability of the testing procedure was calculated at 0.98. The mechanical and physiological reliability of the Cybex Dynamometer system and of the 90° abducted testing position has been previously established (8).

The isokinetic testing mode was performed with the glenohumeral joint in 90° of abduction in the coronal plane, with a range of motion of 0° – 90° of external rotation and 0° – 65° of internal rotation. Range of motion stops were used according to the manufacturer’s recommendations to ensure that identical ranges of motion were tested bilaterally (8).

Each subject was positioned supine on the UBXT (upper body testing table, Cybex) with stabilization straps secured at the pelvis and midthoracic levels. An offset handle was provided for the nontesting extremity to grip during the testing procedure. Gravity correction was not utilized for the testing position, consistent with the manufacturer’s recommendation (8). The effect of gravity is almost zero because of the fact that in each half of both movements, its value is the same but with opposite effect. The dynamometer input shaft was aligned with the axis of rotation of the glenohumeral joint. The isokinetic test was initiated with the arm in 90° of external rotation, consistent with the manufacturer’s recommendation (8).

Testing was performed at 60° , 120° , and $180^\circ\cdot\text{s}^{-1}$. The same sequence was followed for all of the subjects to enhance reliability (22) of the data acquisition. Data used in this study were recorded during 3 maximal repetitions of internal and external rotation at each speed (24).

The testing procedure was followed by a training period of 6 weeks (3 times per week), and then the participants repeated the same testing procedure. The 39 participants were randomly assigned in 3 groups, 2 experimental groups undergoing the strengthening program (Table 1) and 1 control group.

The first experimental (isolated) group followed a muscular strengthening program with 2-kg dumbbells. Each subject was positioned as described in the isokinetic mode holding a dumbbell, but this time the exercised extremity was positioned on a table with stabilization straps secured at the humeral level, obtaining the same axis of rotation as in the isokinetic testing mode. In order to train the internal rotation movement, the exercise was

TABLE 2. Means and standard deviations (Mean \pm SD) for external isokinetic concentric peak torque values for the strong side.

	Complex group		Isolated group		Control group	
	Pre (Nm)	Post (Nm)	Pre (Nm)	Post (Nm)	Pre (Nm)	Post (Nm)
60°·s ⁻¹	25.2 \pm 7.7	27.2 \pm 7.6	26.1 \pm 7.3	27.2 \pm 7.7	24.1 \pm 7.0	23.6 \pm 8.6
120°·s ⁻¹	22.3 \pm 7.0	24.2 \pm 8.4	23.0 \pm 6.5	24.0 \pm 6.7	21.3 \pm 7.5	20.1 \pm 7.5
180°·s ⁻¹	20.8 \pm 7.3	21.9 \pm 6.6	20.2 \pm 6.6	20.9 \pm 6.1	20.4 \pm 7.6	17.4 \pm 6.8
<i>F</i>	9.95**		2.96		6.02*	

* $p < 0.05$.** $p < 0.01$.*** $p < 0.001$.**TABLE 3.** Means and standard deviations (Mean \pm SD) for external isokinetic concentric peak torque values for the weak side.

	Complex group		Isolated group		Control group	
	Pre (Nm)	Post (Nm)	Pre (Nm)	Post (Nm)	Pre (Nm)	Post (Nm)
60°·s ⁻¹	22.7 \pm 7.9	26.2 \pm 8.7	23.3 \pm 7.4	26.0 \pm 8.0	22.0 \pm 6.4	22.5 \pm 6.8
120°·s ⁻¹	20.3 \pm 7.4	24.0 \pm 8.3	20.9 \pm 6.2	23.6 \pm 6.7	19.0 \pm 6.0	19.6 \pm 5.8
180°·s ⁻¹	18.4 \pm 6.5	22.3 \pm 9.2	18.1 \pm 6.0	20.4 \pm 6.1	17.3 \pm 5.5	16.7 \pm 5.7
<i>F</i>	29.67***		13.37**		0.04	

* $p < 0.05$.** $p < 0.01$.*** $p < 0.001$.**TABLE 4.** Means and standard deviations (Mean \pm SD) for internal isokinetic concentric peak torque values for the strong side.

	Complex group		Isolated group		Control group	
	Pre (Nm)	Post (Nm)	Pre (Nm)	Post (Nm)	Pre (Nm)	Post (Nm)
60°·s ⁻¹	30.2 \pm 11.3	34.0 \pm 10.8	31.9 \pm 12.0	33.5 \pm 12.9	28.2 \pm 7.9	29.0 \pm 10.9
120°·s ⁻¹	27.2 \pm 11.1	30.8 \pm 10.3	26.3 \pm 9.8	29.5 \pm 10.9	24.3 \pm 7.2	25.8 \pm 10.1
180°·s ⁻¹	24.0 \pm 10.2	27.8 \pm 10.2	24.7 \pm 9.1	27.2 \pm 9.9	21.8 \pm 8.3	22.8 \pm 9.8
<i>F</i>	8.60**		3.36		0.49	

* $p < 0.05$.** $p < 0.01$.*** $p < 0.001$.

initiated with the arm in 90° of external rotation. Respectively, when the external rotation had to be trained, the exercise was initiated with the arm in 90° of internal rotation.

The second experimental (complex) group used the complex training mode for strengthening the internal and external rotators. Their strengthening program consisted of 4 closed kinetic chain exercises: (a) pull-ups or lat pull-downs, (b) overhead press, (c) reverse pull-ups, and (d) push-ups. The training protocol for both groups was preceded by a 10-min warm-up period on an upper-body ergometer and consisted of 3–7 sets of 8–15 repetitions. The rest between sets ranged from 2–4 minutes. The equations of Brzycki (5) and Mayhew et al. (14) were chosen to determine the maximal muscular performance and the number of sets, repetitions, and the weight that changed according to the training adaptations during the whole training period in order to obtain submaximal exercise intensity.

The control group had no strengthening training.

Dependent variables were the performance in the initial pre- and posttests of the internal and external rotators for both limbs. After the completion of the pretests, the best peak torque values defined the performance of the strong side, and the lower values specified the weak side for both movements (internal and external rotation movement). The independent variable was set as the

group that corresponds to the 3 groups (complex, isolated, and control group).

Statistical Analyses

The peak torque values were collected in Newton meters (Nm) from the isokinetic computer system. Means and standard deviations were calculated. Multivariate analysis of variance (MANOVA) repeated measures (2 \times 3, tests by different training method) was performed on peak torque data to detect differences in each group for each movement (external and internal rotation) and each side (strong and weak). The independent variable was the group, and repeated factors were the test (pre- and post-test) and the angular velocity (3 angular velocities). Statistical significance was accepted at $p \leq 0.05$.

RESULTS

The results revealed that the experimental groups showed a performance improvement in all angular velocities, but the control group did not, meaning that both training modes were effective in improving muscular strength. Tables 2–5 illustrate the means and standard deviations for external and internal isokinetic concentric peak torque values for both sides. Comparing the 2 groups, the results showed that there was a more significant improvement for the group that trained with complex exercises. More specific, the first experimental group

TABLE 5. Means and standard deviations (Mean \pm SD) for internal isokinetic concentric peak torque values for the weak side.

	Complex group		Isolated group		Control group	
	Pre (Nm)	Post (Nm)	Pre (Nm)	Post (Nm)	Pre (Nm)	Post (Nm)
60°·s ⁻¹	26.7 \pm 11.3	32.0 \pm 10.6	25.7 \pm 8.2	30.6 \pm 9.5	25.1 \pm 8.5	27.5 \pm 10.2
120°·s ⁻¹	22.9 \pm 1.1	28.0 \pm 10.0	20.3 \pm 7.6	25.9 \pm 9.0	21.4 \pm 7.6	21.7 \pm 9.2
180°·s ⁻¹	20.8 \pm 10.4	25.8 \pm 9.5	18.3 \pm 7.0	21.7 \pm 8.2	18.4 \pm 6.9	19.3 \pm 7.8
<i>F</i>	17.47***		13.34**		0.64	

* *p* < 0.05.
 ** *p* < 0.01.
 *** *p* < 0.001.

(complex) showed statistically significant performance improvement of the strong side in external rotation (*p* < 0.01) and internal rotation movement (*p* < 0.01). Very impressive was also the improvement of the weak side in external (*p* < 0.001) and internal movement (*p* < 0.001). The second experimental group (isolated) also improved its muscular performance, but this improvement was significant only for the weak side in both movements (internal and external). More specific, this group improved its performance in external and internal rotation movements for the strong side, but these improvements were not significant (*p* > 0.05). However, the improvement was significant for the weak side in external (*p* < 0.01) and internal (*p* < 0.01) rotation movement.

DISCUSSION

The results of this study showed that both training programs were effective in improving the muscular performance in external and internal rotation movement, providing the same results with recent studies regarding to the effectiveness of these protocols. The complex training was studied by Beneka et al. (2) and concluded that this protocol can be as effective as the isokinetic exercise for the shoulder cuff. Also, Blievernicht (4) stated that the muscle groups that fire in an uncoordinated way can primarily be restored using isolated movements. During isolated exercise, the muscles that are strong and short are lengthened using active range of motion that will lengthen and inhibit these muscles. Typically, actively shortening a passive muscle will lengthen and inhibit its dominant antagonist. Thus, a single exercise according to Blievernicht (4) can be used to stretch 1 muscle and strengthen another.

When the 2 groups were compared in terms of better strength improvement, it was found that the group that used the isolated movements to exercise the internal and external rotators improved its performance significantly only to the weak side. These conclusions are also in agreement with Blievernicht (4) who stated that as muscle balance improves, the isolated exercises should be replaced by more complex movements.

This last statement seems to be in agreement with the results of this study concerning the significant improvement that was found for both sides of the group that exercised with closed kinetic chain exercise. It might be considered that although an improvement of the muscle balance applying the isolated exercise program was found, further strengthening modes need to be applied in order to obtain more impressive results in performance. Blievernicht (4) proposed that after strengthening the weak side, isolated exercises had to be replaced with more complex movements in order to obtain more complete perfor-

mance, providing the same conclusion as the present study. It is not argued that with practicing with complex movements, the upper extremity is familiarized with executing more mass movement patterns, which can be sport-specific. The unlimited number of movement patterns that a shoulder is performing emphasizes the need for using exercise in many possible combinations of the elbow as well as the wrist. However, isolating a joint is rarely specific to sport performance (7). These exercises have also received increased attention within the rehabilitation community because they simulate and replicate many functional movements. Since studies have shown that the major changes as a result of strength training are task-specific (16–18), it may be necessary to incorporate the rehabilitation into task-related practice. As such, specificity of training becomes a significant factor (16, 18).

Also, clinical research studies examining the strength of the rotator cuff and scapular stabilizers in addition to joint position concluded that a training routine containing closed kinetic chain exercises may also enhance proprioception, kinesthesia, and neuromuscular control (10). Kibler (13) found that closed chain techniques can increase the effectiveness of rehabilitation protocols because they allow more normal physiological activation and biomechanical motions, especially in the early rehabilitation phase. They have been shown to be effective in knee/leg rehabilitation, but are also useful in shoulder/scapula rehabilitation. These conclusions are proving the importance of the present study, which indicates the need for evaluating the rotator cuff's performance and restore the imbalances.

Our results confirm the findings of Campbell and Glenn (6) who report a significant increase in quadriceps and hamstring muscle strength as a result of a 7-week open kinetic chain rehabilitation program. Also, Witvrouw et al. (25) found significant strength increases of the quadricep and hamstring muscles in both rehabilitation groups (which exercised with open and closed kinetic chain exercise) suffering from patellofemoral pain.

Concerning the more important improvement of the strong side for the complex group, it is not surprising since these exercises contain more eccentric muscle work, and thereby develop more tension in the muscle and a greater training effect (3).

PRACTICAL APPLICATIONS

Apparently, in this study the increase in strength of the weak side was independent of the type of exercise used (open-isolated vs. complex-closed). We therefore do not advocate replacing the traditional open kinetic chain exercises by closed kinetic chain exercises, but rather suggest a combined use of them. The few significant differ-

ences between the training groups concerning the strong side supports the premise that complex-closed kinetic chain exercises are more effective in strengthening the rotator cuff muscle group when the imbalance is partially restored by the isolated-open movements.

It is suggested that after identifying those muscles that are weak, a strengthening program to restore the imbalances must be applied. Regarding the training protocol that would be more effective, the isolated-open exercise is recommended because it emphasizes recruitment of the muscles in question. The results of this study also suggest that after having enhanced the muscular performance of the weak muscles, the isolated exercises must be replaced with more complex-closed kinetic exercises in order to obtain better improvement in strength.

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