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The Impact of Eight Weeks Closed and Open Kinetic Chain Exercise on Ratio of the External to Internal Shoulder Rotator Muscles' Strength in Top Swimmers

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Abstract

Objectives: Based on previous studies, the strength ratio of internal to external rotator muscles of the shoulder in elite swimmers is a predisposing factor of impingement syndrome. So this study was done to compare the effect of open and closed kinetic chain exercises on this ratio.
Methods: Regarding the inclusion criteria, 45 swimmers were selected and distributed randomly to 3 groups of the open chain (15), closed chain (15), and control (15). Exercise prescribed for both open and closed chain groups three times per week, but the control group was deprived. Before starting the exercise and after eight weeks, the strength ratio of the internal to the external rotator shoulder muscles in both eccentric and concentric contraction was measured at various speeds of 60, 120, and 180 degrees/s. Subsequently, one-way ANOVA and Tukey post hoc tests were performed to compare the groups and show the intra-group difference ($P < 0.05$).
Results: Both types of exercises reduced the strength ratio of internal to external shoulder rotator muscles in both contractions. There was no significant difference between closed and open chain exercises, but the open chain reduced the ratio of internal to external rotator muscles' strength less than the closed chain in both types of contractions.
Conclusions: To reduce the ratio of internal to external rotator muscles' strength in swimmers and improve the muscle imbalance, open kinetic chain exercises are more effective than closed kinetic chain exercises and can be recommended for prevention and rehabilitation of swimmer's shoulder.

Keywords: Shoulder Internal Rotator Muscles, Shoulder External Rotator Muscles, Open Kinetic Chain, Closed Kinetic Chain, Shoulder Impingement Syndrome, Swimmer's Shoulder

1. Background

The shoulder joint of swimmers is constantly under some stresses and sacrifices the stability for mobility to achieve the highest range of motion and the degree of freedom compared to the other joints (1). Professional swimmers are prone to injury of the upper extremities, knees, and low back (2, 3). A professional swimmer may swim up to 110 kilometers per week (4) and will use her hands up to 2500 times in a training session (5); thus the rotator cuff muscles are more prone to injury, and it may cause shoulder instability and change the pattern of motion. The biomechanical changes in the shoulder can occur because of several causes, including fatigue, damage of proprioception, and power loss. The incidence of shoulder pain in swimmers was higher than the other sports. However, the improvement of shoulder's muscle strength has been recognized as one of the main aims of exercises and as one of the most effective techniques of shoulder rehabilitation as well as injury prevention (6).

Much of studies suggested that the balance between internal and external rotator muscles' strength is one of the most important factors in preventing injury and without this balance the possibility of shoulder pain increases (7). A macrocycle of swimming training limited to exercising in the water can rise the strength of shoulder internal rotators and makes an imbalance in the ratio of internal to external rotator muscles' strength, which increases the risk of a shoulder injury in swimmers.

Dryland training is one of the most important methods used in this field and could dramatically more strengthen the external rotator muscles compared to exercise alone in water (8, 9). Among the two types of exercises, the closed kinetic chain exercises have a greater effect on the function and position of the scapular and Glenoid-Humorous joint than open kinetic one and cause a natural simulation of the shoulder joint, proprioception, and muscle activation (10), but some researchers preferred open kinetic chain exercise for scapular stability and introduced these exercises for prevention of shoulder injuries (11). Considering the pros and cons of both practices, a mixture of open and closed kinetic chain exercises is recommended for shoulder muscles, but despite several studies, it is still a question that which method is more effective for injury prevention, treatment, and rehabilitation.

2. Methods

Healthy male swimmers were the population of this study who were training in the national team camp from June to August 2017 and aged 18 to 25 years old. Their swimming programs were various but not less than three times per week, containing at least 2 kilometers of crawl or backstroke. In accordance with the inclusion criteria, 45 subjects were selected and randomly distributed into three groups of the open and closed kinetic chain, and the control group, which their demographic characteristics are shown in Table 1. The athletes in both groups of the open and closed chain were trained their related dryland exercise for eight weeks three times a week, while no dryland exercise was specified to the control group. In accordance with the necessary physiological adaptations, the duration of training was considered 8 weeks (12). The content validity index (CVI) and content validity ratio (CVR) were used to evaluate the validity of the training protocol (13). While the CVI was 88% and the CVR was 85%, the protocol was valid. The strength exercises were arranged as 80% to 90% of 1RM and their repetition, sets, and recovery were as follows on Table 2 which were designed and performed progressively based on valid sports rehabilitation sources (14). For both open and closed chain groups, the warm-up and stretching were the same. The post-test was performed after eight weeks of training conducted on fully supervised athletes. The strength of internal and external shoulder rotator muscles in concentric and eccentric contractions, as pre-test and post-test were measured using the HUMAC NORM isokinetic device at 60°/s, 120°/s and 180°/s. For conducting the test, each subject seated on the device seat and was fastened by the straps to his chest to fix the trunk. By placing the shoulder on the plane of the scapula (elbow in 45° abduction, 30° flexion, 90° flexion and forearm in the pronation) and considering the horizontal position of the Dynamometers as a zero angle, the range of motion was compared to that of 90 degrees. To eliminate the gravity effect, the shoulder rotational movement was performed in the range of 90°, which included an about 90° internal and external rotation. First, the muscles were tested in concentric mode and then after 30 seconds an eccentric mode test was done. After a short description of how the device works for them, the athletes first performed five submaximal contractions as a warm-up. Then, they completed five maximal intensity repeats at each 60, 120, and 180°/s to measure the strength of internal and external shoulder rotator muscles at concentric and eccentric contractions and record the mean. To analyze the data, one-way ANOVA and post hoc Tukey test were done. The confidence level of the test was 95% and the significance level for all statistical methods was considered $P < 0.05$.

The procedure of pre-test, the exercises program as an intervention, and post-test have been described obviously for all participating athletes and written informed consent was obtained from the participants. The Committee of Research Ethics of Shahid Beheshti University approved this research and the ethical code is ir.sbu.icbs97/1020.

3. Results

In Table 3 descriptive statistics data on pre-test and post-test for the ratio of the internal to external shoulder rotator muscles' strength in concentric contraction are shown.

As can be seen, the mean was decreased by open and closed kinetic chain exercises, while the mean of the control group remained constant by the time. Also, the strength ratio of internal to external rotator muscles in concentric contraction was decreased with increasing the speed. To analyze the effect of open and closed kinetic chain exercises on the strength ratio of internal to external shoulder rotator muscles in concentric contraction, one-way analysis of variance (ANOVA) was used to compare the groups. The results showed a significant difference among groups in speeds of 60°/s ($P < 0.05$, $F = 9.4$), 120°/s ($P < 0.05$, $F = 15.5$) and 180°/s ($P < 0.05$, $F = 7.7$) for the ratio of internal to external rotator shoulder muscles' strength in a concentric contraction. Tukey test showed no significant difference between open and closed chain at speeds of 60°/s ($P > 0.05$), 120°/s ($P > 0.05$), and 180°/s ($P > 0.05$). A significant difference was shown between the open chain and control group results at 60°/s ($P < 0.05$), 120°/s ($P < 0.05$), and 180°/s ($P < 0.05$). Similarly, there was a significant difference between closed kinetic chain and control groups, at 60°/s ($P < 0.05$), 120°/s ($P < 0.05$), and 180°/s ($P < 0.05$). The impact of exercises significantly decreased the ratio of internal to external rotator muscles' strength in concentric contraction and although open kinetic chain exercise had

Table 1. The Mean and Standard Deviation of Age, Height, and Weight of the Participants

Group	Age (y)	Height (cm)	Weight (kg)	Number of Subjects
Closed kinetic chain	24.2 ± 4.2	178.9 ± 6.9	78.9 ± 9.8	15
Open kinetic chain	23.2 ± 3.3	179.3 ± 5.2	76.9 ± 10.6	15
Control	23.4 ± 3.8	181.5 ± 6.1	75.9 ± 10.4	15

Table 2. Training Protocol in Both Groups

Exercises	Sets	Repetition	Rest
Warm-up and stretching			
1. Jogging, running, or cycling			
2. Pendulum movements of the arm	2	10	30 s
3. Posterior deltoid stretching	1	4	30 s
4. Passive internal rotation	1	4	30 s
5. Passive external rotation	1	4	30 s
6. Sleeper stretch	3	4	30 s
7. Wall corner pectoral stretch	1	4	30 s
Closed kinetic chain			
1. Push Up	3	10	3 min
2. Scapular push up	3	8	3 min
3. Scapular dip	3	8	3 min
4. Crab walk	3	15	3 min
Open kinetic chain			
1. External rotation	3	8	3 min
2. Internal rotation	3	8	3 min
3. Dumbbell fly	3	6 (80% 1RM)	1 min
4. Reverse dumbbell fly	3	6 (80% 1RM)	1 min

more effect than a closed one, there was no significant difference between open and closed kinetic chain exercises. In Table 4, descriptive statistics on pre-test and post-test for the ratio of the internal to external shoulder rotator muscles' strength in eccentric contraction are presented.

As shown, by open and closed kinetic chain exercise the means have decreased and by the time the mean of the control group has been stayed constant. Also, with an increase in the speed, the ratio of internal to external rotator muscles' strength in eccentric contraction was decreased. The results showed a significant difference among the groups at speeds of 60°/s ($P < 0.05$, $F = 18.1$), 120°/s ($P < 0.05$, $F = 12.5$), and 180°/s ($P < 0.05$, $F = 27.7$) for the strength ratio of internal to external shoulder rotator shoulder muscles. Tukey test showed a significant difference between open and closed kinetic chain at speeds of 60°/s ($P < 0.05$), 120°/s ($P < 0.05$), and 180°/s ($P < 0.05$). Also, a significant difference was shown between open kinetic chain and control group at speeds of 60°/s ($P < 0.05$), 120°/s ($P < 0.05$), and 180°/s ($P < 0.05$). Similarly, between closed kinetic chain and control group, there was a significant difference at speeds of 60°/s ($P < 0.05$), 120°/s ($P < 0.05$), and 180°/s ($P < 0.05$). Tukey test results revealed that exercise decreases the strength ratio of internal to external shoulder rotator muscles in eccentric contraction. Moreover, there was a significant difference between the two kinds of exercises (open and closed chain), and open kinetic chain exercise caused more decrease.

4. Discussion

The weakness of rotator cuff muscles by displacing humerus upwards can be a cause of inflammation or rupture of these muscles and impingement syndrome (15-17). In this regard, humerus head stays in glenoid fossa center when there is a strength balance between internal and external rotator muscles. Leroux et al. described that the strength ratio of internal to external shoulder rotator muscles in impingement syndrome is decreased (18, 19). Wilk and Arrigo reported that the strength ratio of antagonist to agonist's muscles is important and the balance between agonist and antagonist muscles provides dynamic stability of the shoulder joint. In proper balance, the ratio of external to internal rotator muscles should be at least 65% (19). Hill et al. in a systematic review of 29 related articles found that impaired strength ratio of internal to external shoulder rotator muscles is an important risk factor for impingement syndrome (20). Subsequently, after the injury in tissues around the shoulder and onset of pain, the signals of the sensory-motor system are eliminated by pain and sensory input of mechanical looseness and ruptures of tissues inhibit muscles neurologically, which means a decrease in receiving signals from the sensory-motor system by these muscles (21-23). This disorder included delayed onset and shortening of time and an increase in the intensity of the movement (24, 25). Mihata et al. by studying the effect of the balance of shoulder rotator muscles on impingement syndrome showed that the balance between the strength of internal and external rotator muscles is an important factor in preventing shoulder pain and disrupting this balance increases shoulder pain (26). Also, McMaster et al. studied shoulder torque change in swimmers and

Table 3. Pre-Test and Post-Test Descriptive Statistics for the Ratio of the Internal to External Shoulder Rotator Muscles' Strength in Concentric Contraction

	Pre-Test			Post-Test		
	Mean and Standard Deviation	**Shapiro-Wilk Sig.**	**Lon**	**Mean and Standard Deviation**	**Shapiro-Wilk Sig.**	**Lon**
Speed of 60°/s			0.272			0.173
Open chain	1.7 ± 0.2	0.108		1.4 ± 0.2	0.126	
Closed chain	1.6 ± 0.2	0.374		1.4 ± 0.1	0.737	
Control	1.7 ± 0.3	0.159		1.7 ± 0.3	0.981	
Speed of 120°/s			0.074			0.394
Open chain	1.4 ± 0.1	0.224		1.3 ± 0.1	0.605	
Closed chain	1.4 ± 0.1	0.289		1.3 ± 0.1	0.131	
Control	1.4 ± 0.1	0.181		1.4 ± 0.1	0.188	
Speed of 180°/s			0.289			0.125
Open chain	1.3 ± 0.1	0.950		1.2 ± 0.1	0.838	
Closed chain	1.3 ± 0.1	0.499		0.2 ± 1.3	0.402	
Control	1.4 ± 0.2	0.717		1.5 ± 0.3	0.110	

Table 4. Pre-Test and Post-Test Descriptive Statistics for the Ratio of Internal to External Shoulder Rotator Muscles' Strength in Eccentric Contraction

	Pre-Test			Post-Test		
	Mean and Standard Deviation	**Shapiro-Wilk Sig.**	**Lon**	**Mean and Standard Deviation**	**Shapiro-Wilk Sig.**	**Lon**
Speed of 60°/s			0.319			0.274
Open chain	0.2 ± 1.8	0.205		0.2 ± 1.8	0.166	
Closed chain	0.2 ± 1.8	0.103		0.2 ± 1.6	0.942	
Control	0.3 ± 1.8	0.931		0.2 ± 1.9	0.419	
Speed of 120°/s			0.088			0.055
Open chain	0.1 ± 1.6	0.470		0.2 ± 1.3	0.379	
Closed chain	0.1 ± 1.6	0.271		0.2 ± 1.6	0.284	
Control	0.1 ± 1.7	0.628		0.2 ± 1.7	0.148	
Speed of 180°/s			0.316			0.370
Open chain	0.1 ± 1.5	0.883		0.1 ± 1.2	0.446	
Closed chain	0.1 ± 1.5	0.369		0.1 ± 1.4	0.106	
Control	0.11 ± 1.51	0.084		0.2 ± 1.6	0.568	

concluded that the torque of adductor to abductor's muscles in swimmers increases, and the torque ratio of external to internal rotator muscles decreases and it is due to repetitive movements of front crawl swimming, which focus on adduction and internal rotation (27). It has been also concluded that measuring the strength ratio of concentric and eccentric contraction in internal and external rotator muscles has been more important and in this measurement, the possible deficiency could be determined and a proper exercise could be designed (28, 29). Hence Baker and Matalino studied internal and external rotator muscles' strength for concentric contraction in baseball players and reported that more internal rotator muscle strength is necessary for throwing speed (29). In 2012, Kilber et al. concluded that closed kinetic chain exercises are more effective for function and posture of the scapula as well as glenohumeral joint and simulate the natural position of the shoulder joint, while enhances proprioception and muscle activation. Lee and Kim showed that in people with shoulder impingement syndrome, peak torque of internal rotator muscles in 60°/s is more than the peak torque of external rotator muscles and in 120°/s it is also about twice more than the peak torque of external rotator muscles (20). Heron et al. in their study on comparing three rehabilitation exercises for shoulder impingement syndrome reported that all three methods of the closed and open kinetic chain, and the range of motion exercises, improve this syndrome and there was no significant difference between those three kinds of exercises (30). Open and closed chain exercises increase the strength of both internal and external rotator muscles, but more focus was on external rotator muscles. Also, open kinetic chain exercises usually activate one joint and during movement of two joints, one joint is remaining static while the other one is performing dynamically, which means one provides stability and the other one runs mobility in a kinetic chain accordingly, so it activates muscles more purposefully. Therefore, by open kinetic chain exercises, we could focus more on the increase of external rotator muscles' strength and finally, decrease the ratio of internal to external rotator muscles for achieving proper muscle balance.

Supplementary Material

Supplementary material(s) is available here [To read supplementary materials, please refer to the journal website and open PDF/HTML].

Footnotes

Conflict of Interests: The authors declare that they have no conflicts or competing interests.

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