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The Effect of 8 Weeks Open and Closed Kinetic Chain Strength Training on the Torque of the External and Internal Shoulder Rotator Muscles in Elite Swimmers

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Abstract

Objectives: In accordance with the multiple causes of impingement syndrome being a major injury of the swimmers' shoulder, choosing an effective method in preventing shoulder injury is important. The purpose of this study was to compare the effect of eight weeks open and closed kinetic chain exercises on muscle torque of internal and external rotators of shoulder in elite swimmers.

Methods: In this study, 45 swimmers were selected based on the inclusion criteria and divided randomly and equally into three groups of open chain, closed chain exercises, and control. Both open and closed chain groups performed their own exercises three times a week for eight weeks, but no upper extremity exercises were given to the control group. Before the training, the pick torque of the external and internal rotators of shoulder were measured by the isokinetic HUMAC NORM machine at various speeds of 60, 120 and 180 degrees/s. After eight weeks of practice, the variables were re-measured. Shapiro-Wilk test was used for data normalization, one-way ANOVA and Tukey post hoc testes were used accordingly to compare the groups and to show the intra-group difference ($P < 0.05$).

Results: The results of this study showed that eight weeks of open and closed chain training improved the torque of internal and external shoulder rotator muscles at 60, 120 and 180 degrees per second ($P < 0.05$). There was a significant difference between open chain and closed chain exercises, and the effect of open chain was more than closed chain training ($P < 0.05$).

Conclusions: According to this study, it can be concluded that open and closed kinetic chain exercises improve the torque of the external and internal rotating muscles in swimmers. They also suggest that kinetic chain exercises are more effective than closed kinetic chain exercises in this regard so could be prescribed for swimmers.

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

1. Background

Swimming is one of the most popular sports in the world, which has various levels, including recreation - public to professional and championships which has overhead activities. Based on the nature of prolonged and high-level drills, the risk of shoulder overuse injury seems to be higher in swimming compared to the other sport disciplines (1-3). The method of treatment for this injury depends on the type of it, age of the athlete and level of activity. In a study conducted on swimmers in 2015, 20% had musculoskeletal injuries and the most common region of injury among them was shoulder with an incidence of 44% (4), which clearly highlights the priority of prevention vs. treatment. There are various treatments for shoulder injuries which range from exercise therapy and electrotherapy to plasma rich protein (PRP), arthroscopic surgery, and open surgery. Among them, exercise therapy is the one which could enhance both the mobility and stability of the shoulder (5-8).

The shoulder mobility is achieved through four glenohumeral, acromioclavicular, sternoclavicular and thoracoscapular joints (9). The shoulder is stabilized by muscles (dynamic stabilizers), as well as ligaments and joint capsules (static stabilizers). Muscles or dynamic stabilizers include muscles surrounding the shoulder joint (e.g. deltoid, serratus anterior, and trapezius) and rotator cuff muscles. The rotator cuff consists of four muscles (supraspinatus, infraspinatous, teres minor, and subscapularis) and play a key role in shoulder stability. Among these four muscles three of them are shoulder external rotators (10). Regarding the kinematics and biomechanics of swimming, it seems that factors such as decreasing articular stability which happens due to the repeated overhead activities will result in accumulation of micro traumas to the shoulder's stabilizer ligaments and also fatigue of muscles which provide dynamic stability (rotator cuffs). Fatigue and weakness of the rotator cuff muscles may also lead to dyskinesis of humerus in the glenoid, and finally the external impingement of the rotator cuff muscles in the upper anterior part of the coracoacromial space happens (11). Imbalanced muscle activation, rather than an overall weakening of muscles surrounding the shoulder joints, mainly causes structural changes (12).

In swimming hand drills, external rotation is increased at 90 degrees of abduction, as well as strength ratio of internal to external rotator muscles, so the scapula has winging and excessive protraction (13). Stretching, as well as endurance and strength training of serratus anterior, rhomboids, lower trapeziuses, and subscapularis along with core stability exercise are effective for injury prevention in swimmers (14). If exercises are limited in water for a long time, it can increase the strength of the internal rotators and reduce the ratio of internal to external rotator muscles, which increases the risk of swimmers' shoulder. Therefore, it is recommended to conduct dry-land strength training to prevent injury (15). Some studies show that dry-land exercises improve this ratio in swimmers and can dramatically strengthen the external rotators (16, 17).

Dry-land trainings include of two different types of open kinetic chain, and closed kinetic chain training. Open kinetic chain exercises reduce resistance forces and increase the acceleration and also change mechanoreceptors of the joints and muscle which ultimately generate a higher shear force by creating higher torque. It is also possible to isolate muscle groups for the specific training in the open kinetic chain exercises. Closed kinetic chain exercises add more pressure to the joint and provide better joint stability, produce less shear force and enhance proprioceptive receptors. Due to the simultaneous contraction of the agonist and antagonist muscles in the closed kinetic chain exercises, the incidence of injury is less and these exercises are more functional (18). The closed chain exercises, compared to open chain exercises, significantly increase strength, mobility and function of shoulder muscles (19). Although closed chain exercises are effective in stabilizing the scapula, open kinetic chain workout is preferred to fix the scapula, and these exercises are more effective in preventing shoulder injuries (20). Lee and Kim in 2015 reported an increase in internal and external muscle peak torque in baseball players suffering from impingement after eight weeks of closed chain shoulder exercises and emphasized on the role of this type of workout in its prevention (21).

Due to the strengths and weaknesses of both types of exercises and because of the controversy among research results, a combination of open and closed kinetic chain exercises are suggested for shoulder muscles, but the choice of an effective method in preventing shoulder injury is still a matter of question.

2. Objectives

The purpose of the current research was to answer this question and find the best and the most effective exercise type for prevention, treatment and rehabilitation of swimmers' shoulder.

3. Methods

The population of this study was healthy male swimming students and swimmers who were currently in the national team camp from June to august 2017, aged between 18 to 25 years. Their swimming program was at least three times a week, and each time equal to or more than 2000 meters of crawl or backstroke. Out of them, 45 subjects were selected according to the inclusion criteria of the research and were randomly divided into three groups of open and closed kinetic chain, and also the control. Participants in each group of open and closed chain trained in their relevant program for eight weeks, three times a week and no dry land training was given to the control group. The duration of training were 8 weeks in accordance with the previous research (22). The strength exercises were prescribed as 80 to 90% of 1RM and repetition of 5 to 6 times in 3 sets with 2 to 5 minutes of recovery. The strength training was designed and performed progressively. The validity of training protocol was evaluated by content validity index (CVI) and content validity ratio (CVR) (23). The result showed that CVI was 88% and CVR 85% so the protocol was valid. These exercises were designed based on valid sources of sports rehab (24). The warm up and stretching program were the same for both open and closed chain groups and the workout program is shown in Table 1:

After eight weeks of training, which was conducted with full training of supervised athletes, a post-test was performed.

Measurement of the internal and external shoulder rotator muscles' torque:

In this study, each time as pre-test and post-test, the torque of internal and external shoulder rotator muscles

Table 1. Training Protocol in Both Groups

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

was measured using the HUMAC NORM isokinetic device at speeds of 60 degrees per second 120 degrees/s and 180 degrees/s. In order to conduct the test, each subject was seated on dynamometer seat. The straps were fastened to the individual's chest to fix the trunk. The shoulder was placed on plane of scapula (45 degrees abduction, 30 degrees flexion, 90 degrees flexion of the elbow and forearm in the pronation by strap). Horizontal position of the dynamometer's lever arm was considered as a zero angle and a range of motion compared to that of 90 degrees was determined. By eliminating the gravity, the shoulder rotational movement was carried out in the 90 degree range, which included a roughly 90 degree external and internal rotation. First, the muscles were tested in concentric mode and then an eccentric mode was performed after 30 seconds. After a brief explanation of how the machine works for subjects, they first performed five submaximal contractions as warm up. Then they completed five maximal intensity repeats each at 60, 120 and 180 degrees per second and the torque of internal and external shoulder rotator muscles was measured and recorded.

One-way ANOVA followed by post hoc Tukey test were used to analyze the data. For statistical analysis of raw data, SPSS software (version 22) was used. Meanwhile, the confidence level of the test was 95% and the significance level for all statistical methods was considered at $P < 0.05$.

4. Results

Demographic characteristics of samples are shown in Table 2. Using Shapiro-Wilk test, it was found that distribution of variables in all three groups had a normal distribution.

Table 2. Mean and Standard Deviation of Age, Height and Weight of 3 Groups

Group	Age	Height	Weight
Closed kinetic chain	24.2 ± 4.2	178.9 ± 6.9	78.9 ± 9.8
Open kinetic chain	23.2 ± 3.3	179.3 ± 5.2	76.9 ± 10.6
Control	23.4 ± 3.8	181.5 ± 6.1	75.9 ± 10.4

As the groups did not have a significant difference in the pre-test, the groups were compared in the post-test. One-way ANOVA was used to compare the groups in the pre-test as follows: The torque of the shoulder external rotator muscles at 60 degrees/s was ($F = 0.292$, sig = 0.748) at 120 degrees/s was ($F = 0.2.200$, sig = 0.820), and at 180 degrees/s was ($F = 0.152$, sig = 0.820). Table 3 shows data on the torque of external shoulder muscles in different groups before and after 8 weeks of training.

The results of one-way ANOVA in post-test showed a significant difference between the groups at 60 degrees/s ($F = 16.5$, $P < 0.05$), at 120 degrees/s ($F = 17.3$ and $P < 05.05$) and 180 degrees/s ($F = 21.1$, $P < 0.05$) for the torque of the external shoulder rotators muscles.

In order to demonstrate the inter-group differences, Tukey post hoc test was used. Tukey test showed a significant difference between the open and closed chains at a speed of 60 degrees/s ($P < 0.05$), 120 degrees/s ($P < 0.05$) and 180 degrees/s ($P < 0.05$). In addition, a significant difference between open and control chains is shown at 60 degrees/s ($P < 0.05$), 120 degrees/s ($P < 0.05$) and 180 degrees/s ($P < 0.05$). There was a significant difference between the closed and control chains at 60 degrees/s ($P < 0.05$), 120 degrees/s ($P < 0.05$) and 180 degrees/s ($P < 0.05$) and the highest effect was due to the open kinetic chain exercises.

The data of shoulder internal rotator muscles' torque of the subjects is presented in Table 4.

The results of one-way ANOVA on the torque of internal rotator muscles of shoulder showed a significant difference between the groups at a velocity of 60 degrees/s ($F = 16.0$ and $P < 0.05$), 120 degrees/s ($F = 14.6$ and $P < 0.05$) and 180 degrees/s ($F = 14.7$ and $P < 0.05$) for the torque of the internal shoulder rotator muscles.

Tukey post hoc test was used to show the intra-group difference. Tukey test showed a significant difference between the open and closed kinetic chain exercises at the speed of 60 degrees/s ($P < 0.05$), 120 degrees/s ($P < 0.05$)

Table 3. External Rotator Muscles of Shoulder's Torque (degrees/second)

Torque of External Shoulder Rotator Muscles	60, degrees/second		120, degrees/second		180, degrees/second	
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Open kinetic chain	18.4 ± 4.5	27.3 ± 5.8	16.5 ± 5.9	25.9 ± 5.6	12.4 ± 4.1	22.2 ± 5.3
Closed kinetic chain	18.1 ± 4.0	21.8 ± 4.5	15.5 ± 3.7	21.1 ± 4.5	12.1 ± 3.3	17.7 ± 5.3
Control	17.1 ± 5.6	16.7 ± 4.7	15.5 ± 5.2	15.2 ± 4.7	11.6 ± 4.5	10.8 ± 3.7

Table 4. Internal Rotator Muscles of Shoulder's Torque

Torque of Internal Shoulder Rotator Muscles	60, degrees/second		120, degrees/second		180, degrees/second	
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Open kinetic chain	24.4 ± 5.5	34.3 ± 7.2	22.7 ± 7.0	32.3 ± 6.3	20.2 ± 5.3	29.8 ± 7.2
Closed kinetic chain	24.3 ± 4.8	28.4 ± 4.2	21.8 ± 4.5	26.4 ± 5.2	19.2 ± 4.8	24.1 ± 5.0
Control	23.8 ± 6.6	22.3 ± 5.6	21.5 ± 6.7	21.1 ± 5.5	18.9 ± 6.0	17.9 ± 5.7

and 180 degrees/s ($P < 0.05$). In addition, a significant difference between the open and control chains was shown at 60 degrees/s ($P < 0.05$), 120 degrees/s ($P < 0.05$) and 180 degrees/s ($P < 0.05$). There was a significant difference between closed chain and control at 60 degrees/s ($P < 0.05$), 120 degrees/s ($P < 0.05$) and 180 degrees/s ($P < 0.05$).

Therefore, it could be concluded that the effect of training was significant in improving the torque of internal shoulder rotator muscles, and the highest effect was due to the open kinetic chain exercises.

5. Discussion

Our current study was compatible with Jobe et al. (25), Bandy et al. (26), Kryger and Andersen (27), Lee and Kim (21), and Šmite et al. (28), but was incompatible with Prokopy et al. (29), Augustsson et al. (30), Blackburn and Morrissey (31), and Rogol et al. (32). Possible reasons for the incompatibility were the differences between the subjects and the types of given exercises.

Regarding the multifactorial nature of impingement syndrome as the main swimmers' injury, the choice of an effective method for prevention of shoulder injury has been questioned and the present study has considered one of these factors, which means changes in the strength ratio of the internal to external shoulder rotator muscles and the role of exercise types on them. The results of the present study showed a significant difference between the groups (open kinetic chain exercises, closed kinetic chain exercises and control group) in the torque of the external shoulder rotator muscles at 60, 120 and 180 degrees/second. Inter-group comparison also showed a significant difference between the open kinetic chain group and the control group in the torque of the external shoulder rotator muscles at 60, 120, and 180 degrees/second. Also, there was a significant difference between the closed kinetic chain group and the control group in the torque of the external shoulder rotator muscles at 60, 120 and 180 degrees/s. Therefore, open chain and closed chain exercises both increased the torque of the external shoulder rotator muscles at 60, 120 and 180 degrees per second. Comparison of open chain and closed chain training groups showed a significant difference between them for increasing torque of the external shoulder rotator muscle at 60, 120 and 180 degrees per second, and the effect of open kinetic chain exercises at all those speeds was more than closed kinetic chain exercises. Closed kinetic chain exercises by creating a compressive force improve posture stability and dynamism, leading to increased joint coordination and retrain proprioceptive receptors which leads to enhancement of neuromuscular junctions. Closed kinetic chain exercises are also safer and produce lesser exhaustion and injuries. Therefore, they are more applicable in the first stages of rehabilitation. The open kinetic chain exercises, more than closed kinetic chain exercises, enhance the torque of the external shoulder rotator muscles, by increasing muscle pressure and on the basis of overloading principle (18).

The shoulder impingement syndrome affects the torque of the shoulder muscles, and reduces the torque of external shoulder rotator muscles by 17% (33). The researchers concluded that rehabilitation exercises should include muscular balance, muscular endurance, muscle strength, dynamic stability and neuromuscular control (34-37), in which open and closed kinetic chain exercises increase external shoulder rotator muscle torque. Resistance and motor control exercises improve shoulder performance (38). Closed kinetic chain exercises enhance the proprioception by coordinating the mechanical receptors (39) as well as the strength of the external shoulder rotator muscles, reduce the pain and improve the shoulder.

The effect of open chain kinetic chain was more than closed kinetic chain exercise on the external shoulder rotator muscles. As mentioned above, closed kinetic chain exercises could be used in the first steps of rehabilitation but could not be as effective as open chain exercises for enhancement of shoulder muscle torque. Open kinetic chain exercises usually involve muscles of a single joint and while one joint is moving, the other one could be stable, so targeting a joint for strengthening is easier. On the other hand, in open kinetic chain trainings, the pressure is rotationally on one motion plane forced on the joint. Therefore the joint could be trained more easily and the progression of exercises could be done by overloading principles to increase muscle torque. This increased strength could be related to the enhanced cardiovascular condition, as well as rehabilitation of injured shoulder. Consequently, after closed and open kinetic chain exercises some adaptations happen which include increasing the total contracting protein, enhancing the quantity and strength of connective tissues, and increasing of capillaries in muscles that finally results in stability of ligaments. Open and closed kinetic chain stretching also increase muscle coordination between agonists and antagonists (40). In current study the results showed that by increasing the velocity, the torque decreases which is compatible with previous studies (25, 26, 41, 42).

Patten et al. have studied on the effect of combined functional task training on upper extremities and found that this kind of training promotes recovery of upper extremity motor function (43). Prokopy et al. compared the open and closed kinetic chain exercises and demonstrated that closed kinetic chain exercises have more significant impact on increasing the torque and power of shoulder muscles than the open kinetic chain exercises (29).

We had limitations in using electromyography on these muscles and in future studies it is better to evaluate these variables with electromyography. The maximum voluntary contraction (MVC) and muscle activity onset detection had a lot of useful information regarding this issue.

Footnotes

Authors' Contribution: Farhad Moradi Shahpar: Data collections and writing the manuscript, Nader Rahnama: Reading and correcting the proof and supervision the study, Shahin Salehi: Statistical analysis.

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