Research Paper

The Role of Core Stability Exercises on Internal Rotator Cuff Muscles Strength and its Motor Function in Amateur Archers

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ABSTRACT

Purpose: Most studies have examined the effect of stretching and strengthening exercises on the glenohumeral joint (shoulder joint). However, due to the importance of the relationship between core stability and pectoral girdle, especially in archery athletes, this study aimed to investigate the effect of six weeks of core stability exercises on the internal rotator muscle strength of the glenohumeral joint and its motor function in male archers.

Methods: For this purpose, 30 athletes were randomly divided into 2 groups of 15: with core stability exercises (experimental group) and without core stability exercises (control group). The motor function was measured using the upper quarter Y-balance test (UQYBT), and the muscle strength of the lumbar muscles was measured using a hand-held dynamometer (HHD). Then, the experimental group underwent a selected exercise program for 6 weeks. Both groups were tested again (post-test). SPSS software version 21 was used to analyze the collected data; also, independent and dependent samples t-tests were used to compare the data. The significance level in the test was determined at 95%.

Results: Changes in posttest results on internal rotator muscle strength (P=0.001) and motor function (P=0.022) showed a significant difference between the two groups.

Conclusion: Therefore, due to the effect of core stability exercises on the above variables, it is recommended that archery athletes, in addition to specific exercises, do such exercises to improve the function of the glenohumeral joint.

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Highlights

- Injuries are an integral part of sports activities.
- Shoulder injury can cause an imbalance of strength and muscular endurance.
- Having sufficient endurance and strength in the muscles of the shoulder girdle is related to the ability of the spine muscles.
- The athletes should include core stability exercises in their training program.

Plain Language Summary

Today, injuries are an integral part of sports activities. Shoulder injury can cause an imbalance of strength and muscular endurance, decrease shoulder range of motion, lack of coordination between shoulder area and back area muscles. Numbness in the back of the hand and shoulder, also wrist drop has been reported after three hours of shooting during competition among men and women in archery. This type of injury is followed by fatigue and leads to a drop in the athlete's score. According to Janda's movement theory, a disturbance in one joint and other hand, strengthening the muscles of a joint can affect nearby joints as well. Therefore, we decided to measure the effect of core stability exercises (spine exercises) on improving the performance and rotational strength of the rotator cuff muscles as the most important muscle for archery athletes. 30 archery men who practiced three times a week for the past year participated in this research and were divided into two groups of 15 people. The experimental group performed six weeks of core stability exercises, and the control group did not perform these exercises during this period. First, pre-test was obtained from two groups in the muscle strength and motor function of the rotator cuff muscle. After six weeks, the same tests were taken again. Finally, by comparing the pre-test and post-test results of the two groups, the core stability exercises presented in this study improved both the strength and the motor function of the rotator cuff. Having sufficient endurance and strength in the muscles of the shoulder girdle is related to the ability of the spine muscles and this dependency is extremely important in the outcome of the archery athlete. It recommended that in addition to shoulder girdle muscle strengthening exercises, these athletes should include core stability exercises in their training program.

1. Introduction

Archery is an acquired skill developed with the help of physical and mental abilities, and in addition to proper technique, it requires proper physical strength and tactics to succeed in this field. Although archery, unlike many Olympic sports, does not have constant mobility, it is purely physical and requires a high level of physical strength and endurance in both men and women. In this sport, the glenohumeral joint is used more than other joints. The adaptations (retrogenes) of the humerus, which are caused by changes in the strength of the rotator muscles (mainly internal rotators) during puberty, can change the range of the mobility of the glenohumeral joint in athletes with overhead movements (especially archers) [1, 2]. In this case, the center of rotation of the arm changes direction in the upper posterior direction and reduces the point of contact of the head of the humerus in the lower anterior part of the joint capsule. This condition can be associated with changes in the range of motion of the glenohumeral joint on both sides of the body of these athletes, even throwers [3].

One of the physical disorders that may affect the motor function of athletes' shoulders and are considered a risk factor for shoulder injuries is a glenohumeral internal rotation deficit (GIRD) [4, 5]. Overhead throwing athletes apply significant repetitive eccentric forces to the shoulder, especially during the arm-acceleration phase, reducing muscular flexibility; this will likely reduce the athlete's internal rotation (IR) range of motion (ROM) [6].

The glenohumeral joint is one of the joints constantly under various pressures and stresses. In addition, it is always challenging to diagnose injuries and lesions due to the anatomical complexity of this joint. The glenohumeral joint sacrifices strength for movement [7-10]. To reduce the stress on the joints, it seems necessary to strengthen the constituent tissue, especially the surrounding muscles, which in addition to increasing muscle strength, can prevent the possible injuries caused by their long-term use [11-13].

To reduce the number of athletes with shoulder injuries and the resulting economic and social damage, it is necessary to investigate their cause and treatment in this group [14]. Therefore, matters following shoulder injuries, such as the cost of surgery and rehabilitation and psychological factors, have highlighted the need for injury prevention programs (strength training and nutrition) [15]. The muscular strength between the agonist and antagonist muscles around the scapula and shoulder provides the dynamic stability of the glenohumeral joint, which is essential for the optimal performance of exercises that use the glenohumeral joint [16].

By examining the short-term effect of a whole body vibration session on the isokinetic strength of rotator cuff muscles in young and healthy samples, Forouhideh et al., showed that these exercises improve strength and proprioception after a training session [6]. McCarrick et al. also reported no increase in concentric power in external rotation (ER) using three exercises of horizontal abduction with ER, scaption with IR, and ER, but the IR showed an increase in power [7].

On the other hand, the spine stability of the muscles is necessary to prevent the reduction of accuracy in shooting arrows, which lasts for 3 to 4 hours in the competition. In normal situations, only a tiny amount of coordinated muscle contraction, about 10% of the maximum contraction, is needed to stabilize the spinal sections. More muscle strength is needed in areas that have lost static stability due to ligamentous laxity or disk problems and prolonged standing. Given this amount of contraction, it is clear that muscle endurance is more crucial in the spine than muscle strength. Due to the long duration of archers and the resulting fatigue, it is necessary to strengthen the core stabilizing muscles in these athletes [11-20].

Many studies have been conducted to strengthen the muscles of the pectoral girdle, but less attention has been paid to strengthening the core muscles to optimally strengthen the function of that region [11, 17, 18, 20, 21]. Since a direct relationship exists between the function of the body joints according to the kinetic link principle, the role of the core muscles is vital in creating stability and optimal function, and given that strengthening these muscles requires the support and stability of the joint capsule [22-24], the present study aims to investigate the effect of six weeks of core stability exercises on internal rotator muscle strength and motor function of the glenohumeral joint of male archers.

2. Materials and Methods

According to the objectives and content of the research, the present study is developmental and quasi-experimental. The statistical population included active male archers who participated in 3 training sessions per week under the supervision of a coach during the past year. Based on the inclusion criteria, a group of 30 people was selected by a purposive convenience method. Then, they were randomly divided into 2 groups of 15 people with core stability exercises and a control group without exercises. Thus, the two-group research design with pretest and post-test was determined based on the application of the protocol of core stability exercises.

Inclusion Criteria

The inclusion criteria comprised not using joint injection drugs in the last trimester of pregnancy, being in the age range of 18-24 years, having perfect good health, lacking vision and hearing problems in the subjects, not having pain, and having a history of dislocation and partial dislocation in the shoulder, having consent to participate in the study, not having musculoskeletal abnormalities visible in the lower limbs such as genovarum, genovalgum, and ankle pronation, not using drugs affecting the central nervous system, such as sedatives on the day of the test, and lacking a history of back trauma, surgery on the lumbar region and related muscles, disc dislocation and ligament and meniscus damage.

Exclusion criteria

The exclusion criteria comprised not participating in both stages (the pretest and post-test), absence of more than 2 sessions in the training program, having a history of fractures and surgery on the shoulder and glenohumeral joints, or any situational deformities affecting the research process.

Research implementation process

Before measuring the variables, a summary of the research design was explained to the subjects in the form of a research introduction. Then, the initial screening of the subjects was performed based on the inclusion and exclusion criteria, and those willing to cooperate received a consent form. After identifying the eligible individuals, the subjects went to the relevant gym to perform the test according to the previously announced time. On the day of the test, after completing the subjects' consent form, their background information, including height, weight, age, and sports records, was entered into the data collec-

Table 1. Type of training and protocol of core stability training

Exercise	Week 1 Set×Time Hold	Week 2 Set×Time Hold	Week 3 Set×Time Hold	Week 4 Set×Time Hold	Week 5 Set×Time Hold	Week 6 Set×Time Hold
 Side plank	5×10 s On the elbow, of the upper arm around the body	5×12 s Increase the duration	5×12 s On the elbow, the upper arm suspended in space	5×12 s On the hand of the upper arm around the body	5×14 s Increase the duration	5×14 s On the hand of the upper arm around the body
 Full plank	5×10 s On the elbows and knees	5×12 s Increase the duration	5×12 s On the elbows and toes	5×14 s Increase the duration	5×12 s On the hands and toes	5×17 s Increase the duration
 Bird dag	5×12 s Lift one leg	5×14 s Increase the duration	5×14 s opposite arm and leg lift	5×15 s Increase the duration	5×17 s Increase the duration	5×20 s Increase the duration
 Diagonal crunch	5×8 s Hands on knees	5×10 s Increase the duration	5×10 s Hands on chest	5×12 s Increase the duration	5×12 s Hands around the head	5×14 s Increase the duration
 Abdominal bridge	5×12 s Hands around the body, lift hip off the floor	5×14 s Increase the duration	5×14 s Hands around the body, lift one leg	5×14 s Hands around the body, heels of both feet on the step	5×17 s Increase the duration	5×17 s Arms up, separating one foot from the step
 Hand-heel	5×10 s	5×12 s Increase the duration	5×15 s Increase the duration	5×10 s Lift one leg	5×12 s Increase the duration	5×14 s Increase the duration

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tion form. In an overall process, on the day of the test, after measuring the height, weight, and leg length of the subjects in both groups (control and experimental) in the pretest, the motor function was evaluated using the upper quarter Y-balance test (UQYBT), and the strength of the pectoral girdle muscles was evaluated using a dynamometer, respectively (Adapted from 17 and 19).

Then, the experimental group practiced for 6 weeks, 3 sessions per week for one hour under the direct supervision of the examiner. The training method was as follows: first, the subjects warmed up for 10 minutes and then performed core stability exercises (Table 1) according to the following training protocol (adapted from 25). At this time, the control group had no exercise program. At the end of 6 weeks, as in the pretest, the research variables (motor function and strength of pectoral girdle muscles) were measured once again, and the records of all subjects (experimental and control groups) were noted.

Table 2. Effect of 6 weeks of core stability training on internal rotator cuff muscles strength of the glenohumeral joint

Groups	Mean Difference	t	df	Sig.
Experimental	-2.56	-8.28	14	0.001
Control	0.25	0.72	14	0.483

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Table 3. Results of independent t-test, corresponding to the scores values of internal rotator cuff muscles strength in pretest and post-test

Variable Statistics	t	Levene's Test, F, P	Mean Difference	df	Sig.
Pre-test	-1.149	0.048 0.828	-0.393	28	0.260
Post-test	6.535	0.031 0.861	2.425	28	0.001

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Statistical analysis

SPSS software v. 21 was used to analyze the collected data. The Kolmogorov-Smirnov test was used to evaluate the normality of the variables' distributions, and the independent and dependent t-tests were used to compare the data. To compare the means within the group, the dependent t-test method was used at a significant level of less than 0.05. To examine the differences between groups, first, the pretest values of the two groups in the dependent variable were compared to the independent t-test. If no significant difference was observed between the pretest values in the two groups, the post-test scores of the two groups were also compared to an independent t-test. To evaluate the effect of six weeks of core stability exercise on the strength of the internal rotator muscles of the glenohumeral joint in male amateur archers, a paired t-test with a coefficient of $\alpha \geq 0.05$ was used.

3. Results

Tables 2 and 3 present the results. According to Table 4, a significant difference is observed between pretest and post-test values in the experimental group ($P \leq 0.05$), but no significant difference was observed in the control group ($P \geq 0.05$).

According to Table 3, and due to the lack of significant differences in the strength of the internal rotator muscles in the pretest of the two groups, an independent t-test was used to compare the strength of the internal rotator muscles scores in the post-test. According to Table 3 and Figure 1, the null hypothesis that the means of the two groups are equal is rejected ($P \geq 0.05$). Therefore, a significant difference is observed between the results of the two groups in the post-test values.

To evaluate the effect of six weeks of core stability exercise on glenohumeral joint motor function in male amateur archers, a paired t-test with a coefficient of $\alpha \geq 0.05$ was used. Tables 5 and 6 present the results. According to Tables 5, a significant difference is observed between pretest and post-test values in the experimental group ($P \leq 0.05$), but no significant difference is observed in the control group ($P \geq 0.05$).

Table 4. Presents the demographic information of the study participants

Variables	Mean±SD	
	Experimental	Control
Age (y)	22.35±6.75	23.08±3.98
BMI (kg/m^2)	66.06±12.75	69.12±8.55
Height (cm)	178.35±25.75	174.85±01.25

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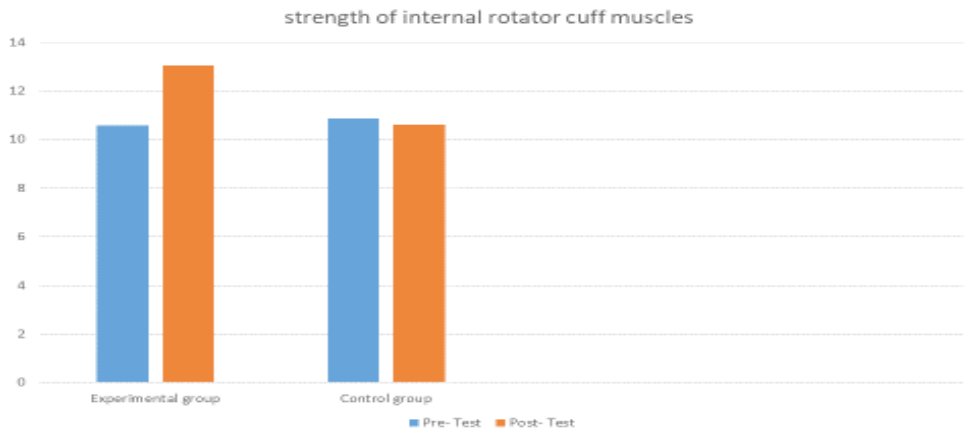

Figure 1. Pretest and post-test values of strength of internal rotator cuff muscles (kg)

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According to Tables 5, and due to the lack of significant differences in motor function scores in the pretest of the two groups, an independent t-test was used to compare motor function scores in the posttest. According to Table 6 and Figure 2, the null hypothesis that the means of the two groups are equal is not accepted (P≥0.05). Therefore, a significant difference is observed between the results of the two groups in the posttest values.

4. Discussion

Internal rotator muscle strength

The results showed that after six weeks of training, a significant difference was observed in the strength of the internal rotating muscles of the glenohumeral joint. Although the exercises on the muscles of the glenohumeral joint, and in particular in some movements, involved the rotator cuff muscles, they positively affect the strength of the internal rotator muscles of the glenohumeral joint. The results of the present study are consistent with the studies of Mohammadi et al. [26], Town Sand et al. [27], and Seyf et al. [28]. Previous studies that investigated the effect of key glenohumeral joint exercises on isometric torque of glenohumeral joint movements in healthy young women [26] showed that these key and specific exercises for the glenohumeral joint increase the movement torque of this joint. In the study, an increase in torque of all movements was observed in the experimental group, so the movement of the body away from the scapula plate at an angle of 90° showed the highest increase in torque. Since this condition shows a high activity of the supraspinatus muscle, it has caused better activation of this muscle to some extent. Job et al. considered Shoulder Internal Rotation (SIR) exercises, that is, raising the arm on the scapula plate with internal rotational movements, appropriate for this muscle [29]. In the present study, this exercise was also used, and an increase in arm torque was observed. In another study, a 10% improvement in supraspinatus muscle activity was observed in SIR exercise [27]. Another researcher also considered horizontal abduction with ER suitable for the activity of this muscle [30]. In the Town Sand study, all supraspinatus muscle exercises in the arm-raising position showed an increase in torque peak; therefore, the torque of this movement should be observed. Also, because bringing the hands forward into a fist-resistant position is an effective exercise for supraspinatus muscle

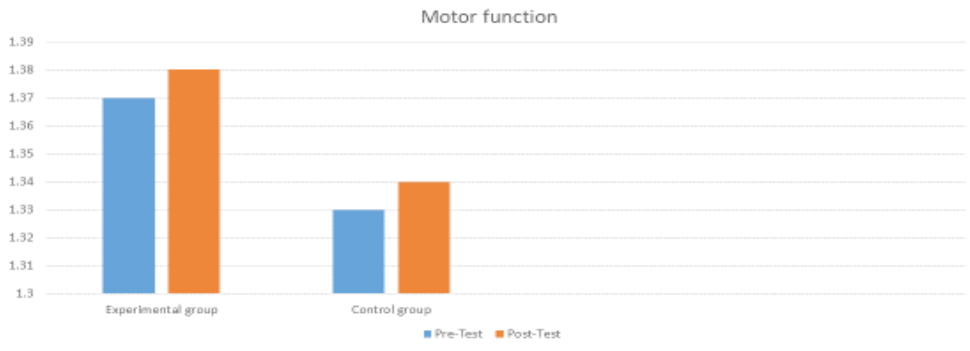

Figure 2. Pretest and posttest values of motor function scores (cm)

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Table 5. Effect of 6 weeks of core stability training on motor function of the glenohumeral joint

Groups	Mean Difference	t	df	Sig.
Experimental group	-0.01	-4.37	14	0.001
Control group	-0,01	-2.34	14	0,054

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activity [31], some movements involved the supraspinatus muscle: hence, increasing the strength seems logical.

In the study of Jobe et al., the internal rotational torque is increased [29]. In the Town Sand study, the exercises that highly showed activity in the subscapularis muscle were those that initially involved raising arms. The internal rotation movement, commonly used in rehabilitation for glenohumeral joint instability, was not used in subscapularis muscle activation exercises [27]. In the present study, better subscapularis muscle activation was observed with lateral plank and full plank exercises. Another study also showed that the activity of the upper subscapularis muscle in IR increased with arm movement away from the body and with arm support [32]. Thus, the increase in activity in the IR is observed by moving the arm away from the body, and this may be why Town Sand et al.'s study did not show an increase in activity in IR [27]. McCarrick showed an increase in strength in IR by doing key exercises, namely horizontal abduction with ER, scaption with IR, and ER [7]. In Town Sind's study, swimming press exercises were performed in different modes of training with high peak activity for the muscle, and since the movement of the closer arm shows a high activity of the pectoralis major muscle; therefore, it is appropriate to do essential exercises to increase the torque of this muscle.

A point to consider when developing muscle strength is that muscle balance, defined as the relative equality of length and strength of the agonist and antagonist muscle, is essential for normal movement and function. Muscle balance may refer to the equal strength of bilateral muscle groups (right versus left). Muscle balance is essential in normal human movements because it requires the coordination of different muscle groups. Muscle imbalance occurs when the length or strength of the agonist and antagonist muscle prevents normal function. Muscle imbalance may occur in response to adaptation to movement patterns, which includes imbalances in strength or flexibility of the antagonist muscle group [16].

Motor function

The motor function of the glenohumeral joint of male archers was measured using the UQ-YBT-test. The present study's findings showed that in both groups, the highest achievement scores were in the middle, lower-lateral, and upper-lateral directions, in this order. Previous research has yielded similar results [33, 34]. Given the position of the access hand relative to the three directions of the test, it is obvious that the person obtains a higher score in the middle direction on the access hand side, but in the upper-lateral direction, which is farther away from the access hand and the person cannot compensate for this distance, like the lower-lateral direction by rotating the body, gets the lowest score. Also, the statistical results showed that the changes in motor function within the group after six weeks of training were significant in the experimental group (P=0.001), but no change was observed in the control group (P=0.054). Also, intergroup changes showed differences between the two groups (P=0.022). According to the results of the present study, based on the difference in the results of training groups, it seems that increasing muscle strength in the experimental group can increase functional stability, and as a result, higher UQYBT results are observed in the shoulder.

Poor strength and efficiency of the sensorimotor system and proprioception of the shoulder are other factors that can cause the functional instability of the shoulder and thus reduce the achievement in different directions of the UQYBT-test [33, 35, 36]. Hazar et al. (2014) ex-

Table 6. Results of independent t-test, corresponding to the scores values of motor function in pretest and posttest

Variable Statistics	t	Levene's Test, F, P	Mean Difference	df	Sig.
Pre-test	1.376	1.367; 0.252	0.031	28	0.123
Post-test	1.710	2,018; 0.166	0.022	28	0.022

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amined the results of the UQYBT-test in two groups of 15 people with and without shoulder impingement syndrome [35] and achieved the same result as the results of the present study in two directions. Of course, the participants in the study of Hazar et al. were non-athletes with shoulder impingement syndrome [35]. Damage to the muscles that drive the cuff may also impair the feedback of the spindle receptors. With the spread of this disorder in the function of the articular afferents, the movement patterns that should act based on the precise feedback of the sensory receptors cannot manage the coordinated pattern of muscle contraction, and as a result, the joint becomes functionally unstable.

5. Conclusion

According to the results of the present study and previous research, a direct relationship is observed between strengthening the body's core muscles and the stabilizing muscles in the spine, scapula, and pectoral girdle because stability is vital factor in starting the movement and sports performances. Therefore, archery athletes can improve the motor function and strength of the rotator muscles of this joint by performing stability exercises. It is recommended that archery athletes, in addition to specialized training in their physical fitness exercises, use core stability exercises.

The same research is suggested on female archers and compares the results with this study. On the other hand, core stability training could be applied to athletes and non-athletes with various shoulder girdle instabilities, and its results can also be helpful in that type of injury and the recovery period. The review of various studies showed no significant contrast with the present study. However, we have limitations such as a lack of control over nutrition, sleep, and daily activities outside of the exercise program, as well as a lack of measurement of different levels of motivation to participate in research. However, improving the physical ability of athletes, which had a direct effect on improving their performance, was crucial in the present study.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article. The participants were informed of the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished, and if desired, the research results would be available to them. A written consent has been obtained from the subjects.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest

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