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Contrast of Maximum Functional Torque in the Shoulder Joint in Overhead Athletes with and without Sub-acromion Impingement during Sitting Throw

Aboozar Saadatian[1]*, PhD; Mansour Sahebozamani[1], PhD; Mohammad Taghi Karimi[3], PhD

[1]Faculty of literature and human sciences, Department of physical education, University of Yasouj, Yasouj, Iran
[2]Department of Sport Injury and Corrective Exercises, Faculty of Sport Science, Shahid Bahonar University of Kerman, Kerman, Iran
[3]Orthotics and Prosthetics Department, School of Rehabilitation Sciences, Shiraz University of Medical Sciences, Shiraz, Iran

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ABSTRACT

Background: Throwing movements are repetitive motions in overhead athletes that cause soft tissue adaptations and ultimately lead to shoulder joint damage. The current study purposed to determine the torque of internal and external rotation of joint shoulder in overhead athletes with and without impingement syndrome in the ball throwing position.
Methods: This cross-sectional study was conducted on 63 male overhead athletes (33 with and 30 without shoulder impingement syndrome). Simulated maximum functional torque was evaluated while the athlete threw a ball into a net from a sitting position. A 6-camera Vicon Motion Capture system incorporated markers on the upper limb and trunk. A kinematic model of the upper limb was used in OpenSim software with inverse dynamics to obtain maximum torque.
Results: The internal and external rotation and elevation torques differed significantly in athletes with shoulder impingement syndrome compared to those without impingement syndrome (P<0.001, P=0.012, and P<0.001, respectively), while no significant difference was seen in shoulder depression (P=0.283) between the two groups.
Conclusion: The current findings suggest that there may be adaptations to shoulder strength and torque in response to throwing a ball that ultimately cause injury to the shoulder.

Introduction

Overhead throwing is considered a high-speed movement requiring neuromuscular control, muscle strength, coordination, and flexibility. Such movements create adaptations in proprioception [1-3], muscle strength balance [4, 5], and range of motion [3, 5] in the involved shoulder joint of the athletes. Although these adaptations may improve the performance of the athlete, they may also result in injuries, such as shoulder impingement syndrome [6, 7]. Arthroscopic findings showed that rotator muscle impingement of the anterior cuff in the posterior-superior margin of the glenoid frequently occurs in athletes performing overhead movements [8].

Shoulder impingement syndrome develops through increases in the dysfunction of the rotator cuff muscles, biceps, or sub-acromion bursa [8]. The eccentric activity of the shoulder joint rotator muscles is very important for controlling increases in joint load and maintaining dynamic stability [9]. The sensory-motor system includes sense, movement, and central integration and the processing components involved in maintaining functional stability of the shoulder [10]. Using a torque test to examine torque fluctuations, total sensory momentum

Corresponding author:* Aboozar Saadatian, Faculty of literature and human sciences, Department of physical education, University of Yasouj, Yasouj, Iran. **Tel: +98 9177302800
Email: aboozar.saadat67@gmail.com

can be maximally evaluated during contractions [11]. During a constant contraction, decreasing commands to the motion neurons are set in response to neuronal signals from the visual and proprioception systems [12].

Torque stability in people with impingement syndrome is usually affected by abduction [11-13] as well as internal and external rotation [14, 15] movements. An imbalance in the strength of internal and external rotator muscles is considered one of the factors associated with shoulder injury. Previous studies have shown that the balance in power between the internal and external rotator muscles differs between the dominant arm and the non-dominant arm of athletes [16, 17]. It has been proposed that the torque ratio of the scapula represents dynamic balance and risk of joint injury to the shoulder [16]. Concentric torque of the internal shoulder rotator muscles causes an increase in the acceleration of the arm while throwing, and eccentric torque of the external rotator muscles causes a decrease in the acceleration of the arm while throwing [18].

The torque production capacity of muscles has been found to be influenced by the speed of the movement. Physiological relationships well describe how maximum torque variations are influenced by the speed of movement during the activity of concentric contractions [19]. For eccentric contractions, however, the relationship between velocity and force does not follow a classical description. For example, previous studies have shown that female handball players have less muscular strength in concentric contractions of the internal and external rotator muscles when moving from fast to slow movements on the isokinetic machine; regarding eccentric contractions, however, athletes have shown less torque in slow movements than in quick movements [20].

Although much research has been done on the isokinetic torque of the rotator muscles of the shoulder joint [18-21], no study was found to have evaluated functional torque in real throw positions. Therefore, the current study hypothesized that torque changes are equivalent in athletes with or without impingement syndrome. The present study aimed to evaluate the torque of internal and external rotations of the shoulder joint in overhead athletes with and without impingement syndrome in the ball throwing position.

Methods

Design

This study was cross-sectional.

Participants

A total of 63 male volunteers took part in this study. Participants were classified into two groups of athletes and asked to perform overhead movements in their sports fields (swimming, volleyball, badminton) for evaluation. One group comprised athletes with impingement symptoms (n=33) and included 15 volleyball players, 12 swimmers, and 6 badminton players. The second group comprised athletes without impingement symptoms (n=30) and included 15 volleyball players, 9 swimmers, and 6 badminton players. All participants were right-handed.

Inclusion criteria for the selection of athletes with impingement syndrome were having complaints of posterior-upper shoulder pain during throwing [14], cross body abduction [22], positive test results for a diagnosis of impingement syndrome, such as Neer's test, Hawkins test, and job test [23], external rotation, abduction, and flexion resistance tests [24], and regular attendance in sports exercises (average of three days a week) for both study groups. Inclusion criteria for the selection of athletes without impingement syndrome were negative results for all of the above-mentioned criteria.

Exclusion criteria included total joint instability measured by Beighton and Horn scores [5], systemic and neurological diseases [22], history of joint dislocation [5, 24], or a history of surgery or neck and shoulder physiotherapy during the 12 months prior to the study [9]. All diagnostic tests were performed equally by a physiotherapist specialist. This study was approved by the Ethics Committee of Kerman University of Medical Sciences (IR.KMU.REC.1396.16). All participants in this research provided written informed consent.

Procedures

Athletes were asked to sit on a chair and throw a ball to a net. The use of a sitting position made it possible to isolate the throwing in the upper limb and reduce the variables related to the throwing activity of athletes in different sports fields [24]. Before throwing, the athletes held the ball in front of their chests with both hands; then, they threw the ball toward the net with their dominant arm. Athletes were given a 30-second rest between each throw. Before the main test, participants were asked to perform 5 minutes of warm-up by throwing the ball at different speeds. The athletes were asked to complete three maximum throws. The average of three throws was considered for statistical analysis of the data (Figure 1).

Six cameras were used for motion analysis (Rapture H Motion Analysis System, Santa Rosa, CA, USA) and captured operations with 120 Hz markers located on the upper limb and body retro-reflective markers attached to the landmarks advised by the International Society of Biomechanics for upper extremities [24]. Anatomical markers were placed on the anterior-superior iliac spine, iliac crest, spinous process of C7, T8 process, xiphoid process, inferior angle of the scapula, acromion process, medial and lateral humerus epicondyles, radius bone head, and ulna bone head of the throwing hand. A static calibration was performed before throwing, which included markers in the internal and external epithelial parts of the arm, the radius and ulna bones, the acromion appendage, and the anterior superior part of the scheduler joint approximately two centimeters below the acromion appendage. The three-dimensional musculoskeletal model of the upper limb (Wu shoulder model) was determined by the static collaboration of joint centers [25]. Reverse dynamics were used to estimate the torque of the shoulder using the OpenSim software platform version 3.3 (National Central for Simulation in Rehabilitation Research [NCSRR], Stanford, CA, USA).

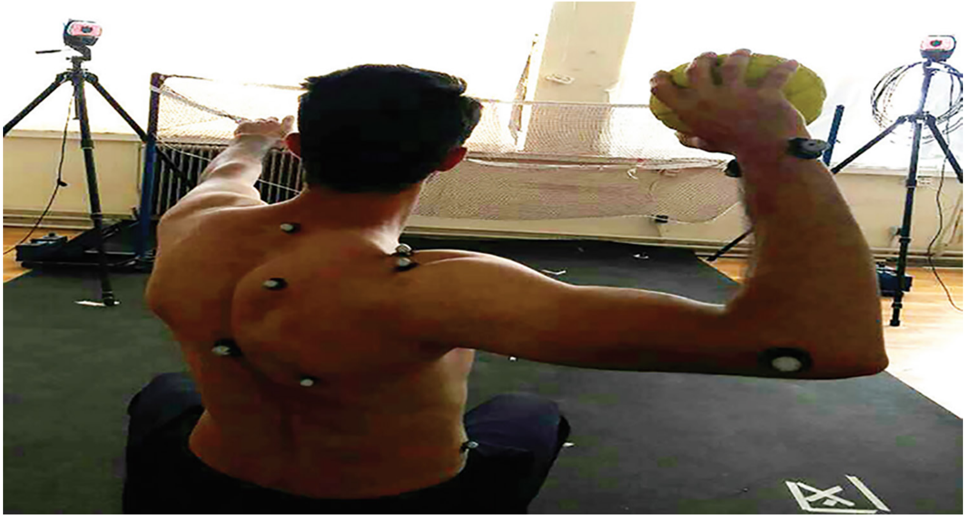

Figure 1: Experimental set up, with the subject seating and throwing the ball into the net

Table 1: Demographic data of the overhead athletes (Mean and Standard Deviation)

Variable	Group	Numbers	Mean ±Standard Deviation	P value
Age(y)	With impingement syndrome	33	28.12±6.13	0.361
	Without impingement syndrome	30	26.83±4.81	
Height(cm)	With impingement syndrome	33	184.57±8.14	0.675
	Without impingement syndrome	30	180.33±5.82	
Weight(kg)	With impingement syndrome	33	77.78±9.83	0.218
	Without impingement syndrome	30	80.36±5.94	
BMI(kg/m^2)	With impingement syndrome	33	22.81±0.40	0.256
	Without impingement syndrome	30	23.42±0.32	
Sports experience(y)	With impingement syndrome	33	8.39±2.68	0.337
	Without impingement syndrome	30	9.03±2.55	

BMI: body mass index

Table 2: Independent sample t test result for internal and external rotation, depression and elevation shoulder torque between groups

Variable	Group	Mean±SD [a]	Δ (95%CI)		t	P value
			Lower	Upper		
Internal rotation (N/m)	With impingement syndrome	0.34±0.030	-0.050	-0.015	-3.740	<0.001*
	Without impingement syndrome	0. 30±0.038				
External rotation (N/m)	With impingement syndrome	0.20±0.029	0.019	0.056	4.135	0.001*
	Without impingement syndrome	0.24±0.042				
Depression (N/m)	With impingement syndrome	0.16±0.031	-0.0067	-0.022	1.083	0.283
	Without impingement syndrome	0.17±0.026				
Elevation (N/m)	With impingement syndrome	0.40±0.39	0.016	0.092	9.811	<0.001*
	Without impingement syndrome	0.32±0.21				

*P<0.001; [a]Data normalize with body mass each person

Statistical Analysis

SPSS software version 24 was used to analyze the data. Mean and standard deviation was presented to describe the data and descriptive statistics. Kolmogorov-Smirnov (K-S) test was used to determine the normal distribution of data. The independent samples t-test was used to evaluate differences between the two groups. A P value of 0.05% was considered statistically significant. Maximum torque was normalized with respect to the bodyweight of the participant [1].

Table 1 shows the demographic data of the athletes with and without impingement syndrome such as age, weight, height, and body mass index. Athletes in both study groups were matched in terms of the variables of sports field and age. The independent sample t-test results indicated no significant difference between the two groups in terms of weight, age, height, or sports experience.

Results

The results showed that there is a significant difference between the internal rotational torque (<0.001), external rotational torque (0.001), and elevation (<0.001) of the dominant arm in athletes of both study groups (Table 2). Higher internal rotation and elevation torque were observed in athletes with impingement syndrome than in athletes without impingement syndrome. External rotation torque, however, was lower in athletes with impingement syndrome than in athletes without impingement syndrome (Figure 2). No significant difference was observed between the two study groups in shoulder depression (0.283).

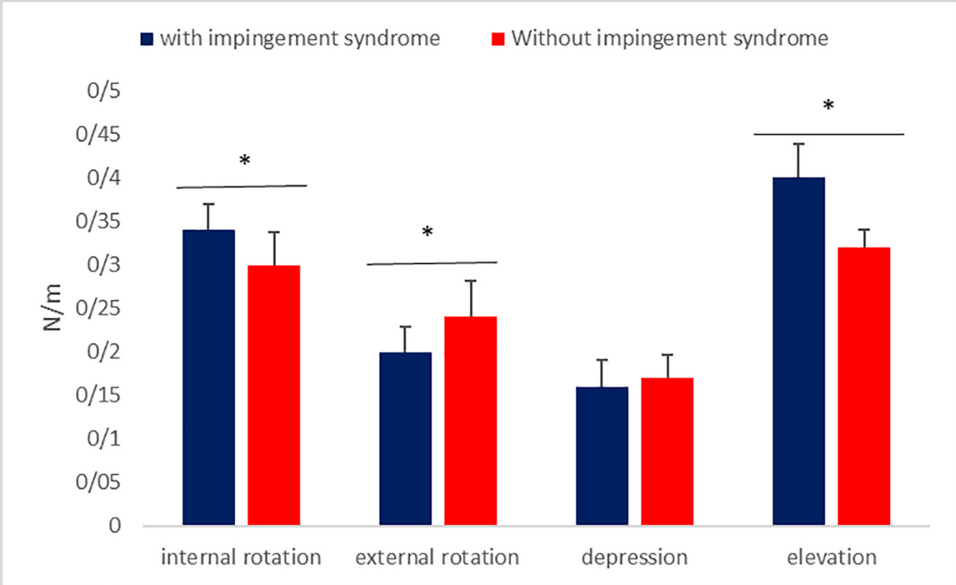

Figure 2: Shoulder torque in internal & external rotation, depression and elevation. The unit of measurement was Newton meter.

Discussion

The main outcomes of this study revealed less external rotational torque, more internal rotational torque, and more elevation torque in the dominant arm of overhead athletes with impingement syndrome compared to healthy athletes. The results of this study were confirmed by some previous studies [6, 8, 26, 27], but disagreed with those of other studies [14-16]. Differences between the current study and previous studies include variations in test position and studied groups.

Muscle imbalance between the internal and external rotator muscles of the shoulder can lead to impingement syndrome and dysfunction in movement patterns [8]. Adaptive power changes may occur in athletes performing overhead movements, including reductions in the eccentric power of external rotator muscles and increases in the concentric power of internal rotator muscles in the athlete's superior hand. These adaptive changes are considered as risk factors for joint shoulder injury [6].

Studies have shown that the range of muscle torque ratios depends on the state of the test, the speed, the study participants, and the type of muscle contraction. It is believed that the eccentric power of external rotator muscles should be similar to that of internal rotator muscles, so that the shoulder joint dynamic stability control can be optimized in the throw acceleration phase [17, 27]. In the cocking phase, an imbalance in torque between internal and external rotations causes an increase in the displacement of the joint. In addition, limitations in the power of the internal rotator muscles activated as an eccentric power in the cocking phase may lead to increases in the range of motion in external rotations. This condition is considered one of the most common conditions increasing the risk of supraspinatus muscle impingement syndrome as well as instability in the shoulder joint.

Magnusum reported that the torque ratio of the internal rotation to the external rotation was different in the injured shoulder of swimmers compared to healthy swimmers. In addition, he found that the injured participants showed an increase in maximum internal rotation torque compared to the healthy group, while the maximum eccentric torque of internal rotations in injured participants was approximately equal to that of the healthy participants [17].

The combination of the eccentric action of the internal rotation and the concentric external rotation in service and throw movements were found to be another possible mechanism related to torque and damage variations when the arm is abducted to 90 degrees and flexed to 90 degrees at the maximum external rotation of the shoulder joint [28]. In the absence of adequate muscle power, the exposure of the arm in this condition causes pressure on the suprascapular nerve and, ultimately, atrophy in the infraspinatus and supraspinatus muscles. Low neuromuscular performance in athletes with a history of injury suggests that the shoulder should have more elevation with a greater displacement of the shoulder in the upper hand. It has also been suggested that athletes with shoulder injuries have atrophy in the infraspinatus muscles as well as traction in the trapezius muscles, the rhomboid, and the posterior muscles of the shoulder. These changes consequently influence the production of power [29]. The results of the present study showed that elevation torque is greater in athletes with impingement syndrome than those without impingement syndrome. Changes in elevation torque may be due to increased muscle strength of the levator scapulae and upper trapezius and muscle weakness in the lower and middle trapezius, serratus anterior, infraspinatus that has been identified as an upper cross syndrome in people with impingement syndrome [30, 31].

One of the limitations of the present study was the use of different sports fields. Although athletes in overhead sports perform almost the same pattern, the execution method is different; for example, in volleyball, hitting and in handball, throwing movements are used, which may have different effects on the shoulder.

Conclusion

Shoulder impingement syndrome causes changes in external and internal rotation torque and in the elevation of the shoulder joint, which may occur because of changes in the balance of power in the shoulder muscles.

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Conflict of Interest: None declared.

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