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ORIGINAL ARTICLE

A Comparative Study on Shoulder Rotational Strength, Range of Motion and Proprioception between the Throwing Athletes and Non-athletic Persons

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Abstract

Purpose: **The repetitive micro traumatic stresses placed on the athletes shoulder joint complex during the throwing motion challenge the surrounding tissues. The purpose of this study was to compare shoulder rotational strength, range of motion and proprioception between the throwing athletes and non-athletic persons.**

***Methods*:** **Fifteen throwing athletes and 15 non-athletes participated in a nonrandom case – control study. Strength of shoulder rotational movements was tested with a hand held dynamometer. The ranges of internal and external rotation of shoulder were measured by a standard goniometer. The ability of subjects to replicate the target position and kinesthetic sense was examined on the subjects' right shoulder by using a continuous passive motion device. Independent and paired t tests were used to statistically analyze between and within group differences.**

***Results*:** **No significant difference was detected on the range of internal rotation between throwing athletes and non-athletic candidates (P=0.3). The range of external rotation was significantly more in athletic subjects (P=0.03). The results also showed that throwing athletes demonstrated a significantly higher isometric strength of shoulder external and internal rotation than the non-athletic group (P<0.05). However, the comparison of the internal and external rotation strength of dominant side in each group showed that throwing athletes showed a significant lower isometric strength of shoulder external rotation than internal rotation (P<0.001). It was also demonstrated higher joint position acuity in the throwing athletes than non athlete subjects (P=0.01).**

***Conclusion*:** **The repetitive nature of overhead throwing and the high forces that it causes result in adaptive changes of the dominant extremity. Throwing can lead to mobility, strength and neural adaptation.**

Key Words: Throwing Athletes; Muscle Weakness; Mobility Impairment; Proprioception

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INTRODUCTION

Shoulder injuries in overhead athletes are common. Previous studies have demonstrated the repetitive microtraumatic stresses during the throwing motion can lead to chronic soft tissue adaptations in the glenohumeral joints. The repetition of high velocity overhead throwing can change the shoulder stability – mobility relationship and ultimately lead to injury [1-3].

Overhead athletes often exhibit numerous adaptive changes. Mobility impairment, changes in shoulder muscle strength and proprioceptive deficit have been found in overhead athletes [2,4]. Decreased shoulder internal rotation and increased external rotation range on the dominant side have been reported in throwing athletes [2,4-7]. Reinold et al [5] reported a decrease in internal rotation and no change in dominant shoulder external rotation, therefore total arc is decreased, reflecting the loss of internal rotation. Dwelly et al [6] observed that the thrower's dominant shoulder would lose internal rotation and gain external rotation, leaving the total arc unchanged. Among the findings reported in throwing populations are an increase in external rotation and a decrease in shoulder internal rotation in the dominant arm. However, Barnes et al [8] demonstrated that even the dominant side of a young age group (0-10 years) displayed significantly greater external rotation than non-dominant arms.

Shoulder rotational strength has been examined in the throwing athletes with varying results. Some investigators have shown that the external rotation strength of the dominant side of the throwing athlete is weaker and their internal rotation strength is stronger than the non throwing shoulder [2,9,10]. However, Wilkin et al [11] reported no significant differences in isokinetic internal or external concentric peak torque of the shoulder of baseball pitchers throughout the season. The large–magnitude forces that create and transfer through the upper limb in throwing athletes must be controlled efficiently to avoid injury. The responsibility of maintaining dynamic stability falls on proprioception system [12].

Several studies have examined joint position sense and kinesthesia (proprioception) in the overhead throwing athlete. Some investigators believe that repetitive movements of throwing athletes can lead to improved proprioceptive abilities, while conversely the other researchers believe that in throwing athletes the presence of significant capsular laxity and excessive range of motion may lead to diminished proprioception [13-15, 2].

Several studies have examined shoulder range of motion, strength and proprioception in athletic populations such as baseball, volleyball and tennis players. Researchers have theorized that throwers experience some adaptive changes over time; however, these authors reported comparisons between throwing and non-throwing shoulders or between throwers and non-throwing athletes. Clinical observations suggest that hand dominance leads to some differences between the dominant and non-dominant shoulder, so bilateral comparisons may be misleading.

Therefore, our purpose was to compare shoulder rotational strength, range of motion and proprioception between the dominant arms of throwing athletes and non-athletic persons.

METHODS AND SUBJECTS

Subjects:

Fifteen healthy athletes that trained or played for the Iranian national women's volleyball team were recruited for this study. Subjects reported a mean of 5.53 years experience and a range of 4-12 years of experience in their sport. Each participant completed a health history and sport participation questionnaire about demographics, years of athletic participation and history of shoulder and neck disorders and pain. All subjects had no history of trauma, musculoskeletal and neurologic disorders, previous shoulder surgery and any upper extremity or spine abnormality [2]. The control group was age, height, weight and sex matched, with the same inclusion and exclusion criteria but no history of sport. Before participating in the study, all subjects signed an informed consent form approved by the human subjects committee of the University of Social Welfare & Rehabilitation Sciences.

Test procedures:

The passive rotational range of motion for the glenohumeral joint was assessed by a standard goniometer. The participant lay supine on a treatment table with the legs straight and the dominant arm in 90º abduction in the coronal plane and 90º of elbow flexion with the elbow slightly off the table's edge. Maximal external and internal rotation were measured with the goniometer's axis in line with the shaft of the humerus, the stable arm perpendicular to the floor and the movable arm in line with the ulnar styloid. When measuring internal rotation, we allowed motion to occur until the spine of the scapula began to lift off the table. This defined the maximal value for internal rotation. One researcher measured all participants to eliminate inter-observer error [8].

Isometric peak forces of the shoulder internal and external rotations were measured in prone position with the participant arm positioned in 90º of abduction and 0º of rotation with the elbow flexed to 90º. The humerus was stabilized distally against the examination table. A handheld dynamometer (Nicholas Manual muscle test, Co, Lafayette IN) was placed just proximal to the ulnar styloid process on the posterior surface of the forearm to assess external rotation strength and on the anterior surface of the forearm to evaluate the strength of shoulder internal rotation [9]. All participants undertook a familiarization session. After a brief explanation of the testing procedures, participants were asked to execute three sub maximal trials to familiarize themselves with the tests procedures .The mean of three repetitions of maximal isometric contraction was measured in kilogram (Kg).

Proprioception tests were performed during passive repositioning and kinesthesia using a continuous passive motion (CPM) apparatus. In the passive repositioning test, participants were tested while laying supine on a treatment table. To eliminate visual and auditory clues to arm position all subjects were blindfolded and wore earphones. Prior to beginning each proprioception test, the participants were given two practice trials to become familiar with the testing procedure The dominant shoulder was tested at 90º of abduction with the elbow flexed to 90º and forearm was pronated and fastened by a padded strap. The reference angle was midrange of external rotation. The CPM rotated the shoulder at 1 deg/s into external rotation position through the axis of the joint. When the subject felt his shoulder was positioned at the reference angle, she stopped positioning via a hand-held switch. The test procedure was repeated three times and the mean error was recorded as absolute matching error [14,15].

Kinesthetic sense of the shoulder was evaluated by measuring of threshold to detection of passive movement for dominant shoulder. This test was used to examine the threshold to the sensation of movement. The subjects were placed in the apparatus with their dominant shoulder positioned in lateral rotation. The speed of CPM was set at 1 deg/s rotation. Participants were instructed to push a hand-held switch when movement was detected. Threshold to detection of passive motion was measured by recording angular rotation between the starting position and the position where movement was detected. The test was repeated three times and the mean threshold to detection of passive movement was recorded (Fig. 1) [13]. The order of test procedures was randomized to minimize the effects of fatigue.

Fig. 1: Measuring the joint position and kinesthetic sense

Test-retest reliability of the measuring devices was determined in a pilot study prior to data Collection by testing a single shoulder twice, conducted on one day, according to the methodology described above. Ten healthy subjects that were not included in this study were tested for reliability testing.

Statistical analysis:

The data was analyzed using the SPSS (version 17). Means and standard deviation were calculated. The intra-class correlation coefficient (ICC), two way mixed effect model, and standard error of measurement (SEM values) were used to assess intra-tester reliability of the measurement. We calculated the ICC (3,1) as described by Shrout and Fleiss [16], because only one judge evaluated the same population of subjects.

Independent t tests were performed to compare shoulder rotational strength, range of motion and proprioception between the throwing athletes and non-athletic persons. Paired t tests were used to compare the internal and external rotation strength of dominant side in each group. The significance level of 0.05 was chosen.

Table1: Results of independent t test comparison of shoulder rotational strength, range of motion and proprioception of dominant side between the throwing athletes and non-athletic persons

Variable	Athlete Mean (SD)	Non-athlete Mean (SD)	*P*. value
Age (years)	24.26 (1.70)	24.80 (2.27)	0.2
Weight (kg)	61.13 (5.97)	59.40 (5.16)	0.4
Height (cm)	161.96 (5.97)	161.29 (5.64)	0.6
Internal rotation range (degree)	40.80 (6.73)	38.26 (7.42)	0.3
External rotation range (degree)	94.66 (10.76)	86.26 (9.79)	0.03
Internal rotation strength (degree)	12.09 (0.66)	8.63 (0.81)	<0.001
External rotation strength (degree)	9.39 (0.62)	7.90 (1.35)	<0.001
Joint position sense (matching error) (degree)	3.00 (2.67)	6.00 (3.77)	0.01
Kinesthesia (threshold to the sensation of movement) (degree)	0.33 (0.48)	0.53 (0.74)	0.4

SD: Standard Deviation

RESULTS

Demographic data of subjects in both groups has been shown in Table 1. There was no statistically significant difference in subjects' age, weight and height between the two groups.

The ICC (3,1) values for the measurements of external/internal rotation ranges (ICC=0.83, 0.89 and SEM=0.88, 0.52), internal/external strengths (ICC= 0.91, 0.93 and SEM=1.42,1.23), joint position sense (ICC=0.90 and SEM=0.29) and kinesthesia (ICC=0.92 and SEM=0.25) were greater than 0.80.

Descriptive statistics for the measurement scores in two groups are presented in Table 1. The result of independent t test showed that the mean of dominant external of rotation range was statistically higher in the athletic group than non-athletic subjects (P=0.03). However, no significant difference was found between shoulder internal rotation range scores between two groups (P=0.3) (Table 1).

The result of independent t test also showed that throwing athletes demonstrated a significantly higher strength of isometric shoulder external and internal rotation movements than the non-athletic group (P<0.05) (Table 1).

The result of paired t test to compare the internal and external rotation strength of dominant side in each group showed that throwing athletes demonstrated a significantly lower strength of isometric shoulder external rotation movements than internal rotation (P<0.001). However, no significant difference was found between internal and external rotation strength of dominant side in non-athletic group (P=0.1) (Table 2).

Throwing athletes also demonstrated higher joint position test acuity than non-athlete subjects (P=0.01). However, no significant difference was found between threshold to detection of passive movement scores between two groups (P=0.4) (Table 1).

Table 2: Results of paired t test comparing of shoulder internal and external rotation strengths, of dominant side in throwing athletes and non-athletic persons

Group	Variable	Mean (SD)	Standard error mean	T	*P*. value
Athlete	Internal rotation strength	12.09 (0.66)	0.21	10.21	<0.001
	External rotation strength	9.39 (0.62)	0.19		
Non-athletic	Internal rotation strength	8.63 (0.81)	0.25	1.76	0.1
	External rotation strength	7.90 (1.35)	0.42		

SD: Standard Deviation

DISCUSSION

The result of this study supports this hypothesis that the shoulder rotation range of motion of the dominant arm in overhead athlete is shifted toward a relatively more external rotation. However, no significant difference was found between shoulder internal rotation range scores between two groups.

Some previous studies have shown that baseball athletes experience an increase in glenohumeral external rotation range and a corresponding loss of internal rotation range at 90º of abduction when the dominant and non-dominant limbs are compared [2,6]. This shift in motion (i.e. external rotation gain and internal rotation loss) has been attributed to repetitive microtraumatic stresses (leading to tightness of the posterior shoulder capsule), physiological adaptation to training or progression of pre-existing inherent glenohumeral laxity [1].

Our finding revealed different changes in shoulder rotational range compared with the findings of these other investigators. The reason of such inconsistencies is that we compared the dominant sides of athletic and non-athletic subjects, but the other investigators compare side–to side differences. We believe that the increase of external rotation range is secondary to the demands of throwing that may not necessarily lead to decrease of internal rotation. It has been mentioned that internal rotation deficit is as consequence of tightness of the posterior soft tissue structures [1,2]. Levine et al [17] investigated range of motion differences among athletes in 3 age groups and reported that adaptive changes in the throwing shoulder initiated with increased external rotation, and followed by the development of posterior capsule contracture and decreased internal rotation. Dwelly et al [6] observed that the throwers gain much external rotation over the course of 1 athletic season but their internal rotation doesn't change. Barnes at al [6] also showed that dominant arms of non-athletic subjects displayed significantly greater external rotation than the non-dominant arm. Therefore, when assessing the overhead athlete's shoulder, a simple dominant to non-dominant comparison is not adequate for determining whether these athletes have normal shoulder motion. Athletes showing large range of motion changes over the course of athletic seasons may have abnormal acute adaptations that need further clinical investigation.

Another finding of this study was that, in throwing athletes the shoulder rotator muscles were significantly stronger compared to non-athletic subjects.

The athletes in this study have participated regularly in upper limb strengthening exercises. The control group had no history of resistive training. Wilkin et al [11] observed that those baseball pitchers who perform regular stretching and strengthening exercises don't lose internal and external rotational strength throughout a 4 month season.

Our result also showed that the external rotator muscles were significantly weaker on the throwing side compared with the internal rotation strength. However no significant difference was found between internal and external rotation strength of dominant side in non-athletic group.

Throwing is one of the fastest human movements. In acceleration phase of throwing humeral internal rotation velocities will reach over 6000 deg/sec, which must be controlled by shoulder external rotators and scapular retractors [18]. It has been shown that high eccentric load that is placed on the external rotators during the deceleration phase of throwing can lead to intramuscular connective tissue tearing, chronic inflammation and at last muscle weakness [17, 18]. In contrast, during throwing, the internal rotator muscles undergo a plyometric type of training (eccentric and concentric contractions). This type of training has been found to greatly enhance muscular power and proprioception [19,20].

The glenohumeral stability is provided mostly by contraction of the rotator cuff and long head of biceps, especially in the midrange of motion where the ligaments are lax [21]. The shoulder rotator muscles (internal and external rotators) play a critical role in providing stability and mobility to the glenohumeral joint especially in throwing athletes. A proper balance between agonist and antagonist muscle group is essential for normal shoulder function [2,21].

The increased strength of internal rotator muscles without comparable increase in external rotator muscles has been found in many previous studies [8-10]. The result of Wang's study [4] showed that the average eccentric external rotator strength was weaker in the dominant arm, compared the concentric internal rotator strength. Wilk et al [9] believed that to provide proper dynamic stabilization, the external to internal rotator muscle strength ratio should be 66% to 75%. The development of unbalanced strength gain between internal and external rotator muscles could predispose throwing athletes to injury [2,9]. The shoulder rotator imbalance exhibited in the throwing shoulder draws attention to the need for special exercises to prevent and correct this imbalance [22,23].

In agreement with the previous studies, our results showed that strength in internal rotators increases as an adaptation to the serving motion, but the external rotators don't increase proportionally in strength. However the external to internal rotator muscle strength ratio in our study was found to be within the optimal range as defined by Wilk (i.e. 66% to 75 %).

Our results also indicated that the volleyball players are more accurate in reproducing the target angle, as has been noted in some studies. The mean values for threshold to detection of passive motion in the dominant side of throwing and non-throwing groups were respectively 0.33 and 0.53. The data exhibited the non-throwing subjects had a greater difficulty detecting motion compared with the throwing group. However, no significant difference was found between two groups. The athletes in this study were all highly trained with a mean of 5.53 years of participation in sport. This finding suggests that peripheral and central neural adaptations were induced by training, resulting in improved joint position sense [12]. The overhead throwing motions are composed of plyometric activities. It is believed that, these tasks may evoke peripheral and central adaptations that are essential for functional stability [20]. It has been suggested that in response to long term training, golgi tendon organs may desensitize and muscle spindle sensitivity is increased. Additionally the peripheral adaptations may have occurred from the repetitive stimulation of the articular mechanoreceptors near the end range of motion in the shoulder during throwing motions. Thus, by modifying the sensitivity of the muscle spindle and articular mechanoreceptors, proprioception can be enhanced [12,20].

This finding is in contrast to that of Allegrucci [13] and Dover [24] studies who find overhead throwers (mostly baseball players) to have proprioception deficit compared with controls. The difference between the findings may be related to the nature of sports and periods of participations in overhead throwing. It is possible, with longer years of experience in unilateral overhead sports; throwing athletes create greater laxity and exhibit a trend toward further diminishing of proprioception acuity.

In the present study only maximal isometric force of shoulder rotational strength was measured. Further research is needed, however, to evaluate shoulder rotational strength isotonically.

CONCLUSION

This study suggests that overhead throwing imposes some adaptive changes in the dominant arm. The internal rotators' strength increases, but the external rotators don't increase proportionally in strength and shoulder rotation. The range of motion of the dominant arm in overhead athletes is shifted toward relatively more external rotation. Our data also showed that overhead throwing may facilitate neural adaptations that enhance proprioception. The shoulder rotational range of motion and strength characteristic measured in this study can assist clinicians in evaluation and management of overhead throwing athletes.

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Conflict of interests: None

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