



Original Article

Comparing Shoulder Joint Functional Range of Motion in Overhead Athletes with and without Shoulder Impingement Syndrome: A Cross-Sectional Study

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ABSTRACT

Background: The shoulder complex is known as one of the most mobile joints of body whose frequently use for overhead movements causes changes in the shoulder joint range of motion. Sub-acromial impingement syndrome (SIS) is one of the most common causes of shoulder pain affecting shoulder joint range of motion. The purpose of this study was to compare shoulder joint functional range of motion in overhead athletes with and without Shoulder impingement syndrome.

Methods: The current research is a cross-sectional study, in which 63 male overhead athletes (30 subjects without impingement syndrome (age: 28.12 ± 6.13 y/o) and 33 subjects with impingement syndrome (age: 26.83 ± 4.81 y/o)) threw a handball ball three times, while seating on a chair. A 6-camera Vicon Motion Capture system recorded the markers placed on the upper limb and trunk during each of the throwing conditions. To evaluate the range of motion, a whole-body kinematic model was used in OpenSim software, with inverse kinematics used to obtain adequate joint angles (shoulder joint abduction as well as internal and external rotation).

Results: The results indicated that the external rotation and abduction range of motion were greater in the athletes with shoulder impingement syndrome in comparison to those without impingement syndrome ($P < 0/001$ and $p = 0.04$, respectively), while their internal rotation range of motion were more limited than that of athletes without impingement syndrome ($p < 0/001$).

Conclusion: Overhead athletes with impingement syndrome have greater glenohumeral external rotation and abduction and less internal rotation in the throwing shoulder in comparison to athletes without impingement syndrome. These findings can be used to screen and identify high-risk athletes and help the therapists to make more appropriate therapeutic plans in order to assist the injured athlete to return to sports as soon as possible.

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Introduction

The shoulder complex is known as one of the most

mobile joints of body whose structures are subject to minor injuries due to frequent use for overhead movements [1]. The shoulder is at a high risk of injury in overhead sports such as tennis or volleyball because it faces high loads and forces during serving and smashing [2]. In volleyball players, nearly 8 out of 20 injuries are

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associated with shoulder injuries. These problems arise from recurrent overhead movements [3].

Strong acceleration and eccentric energy absorption are necessary components for optimal throwing performance. Altered glenohumeral joint mobility and flexibility are observed in overhead athletes, and have been attributed to adaptive structural changes to the joint, resulting from the extreme demands of overhead activity [4, 5]. These adaptive changes have been defined as glenohumeral internal rotation deficit (GIRD), very often combined with external rotation gain [6]. It has been suggested that posterior shoulder stiffness results from repetitive microtrauma leading to the development of fibrotic scar tissue of the posterior capsule [7]. Currently, the exact cause and underlying mechanism of posterior glenohumeral joint stiffness has remained a matter of debate. Posterior capsule contracture as well as posterior cuff muscle inflexibility and osseous adaptations have been mentioned to explain the decreased internal rotation range of motion (ROM) [4, 8].

Posterior shoulder stiffness has been suggested to be a causative or perpetuating factor in shoulder impingement. Among all shoulder joint injuries, impingement syndrome is the most common cause of pain and limited mobility in the shoulder area. The syndrome is prevalent among people below 60, and normally develops by sports activities and those requiring repeated use of arms overhead [9]. The condition occurs due to various causes including changes in the acromial arch, posterior capsule tightness, scapular muscle weakness or functional disorder, cuff rotators wear and tear, changes in scapular kinematics, and postural changes [10-13]. The external and internal rotation ROM in the dominant arm have been shown to vary among uninjured and previously injured overhead athletes [14]. Although there are studies that have evaluated the passive or active ROM, to the best of our knowledge no study has assessed the shoulder joint functional ROM in athletes with shoulder impingement syndrome. Therefore, the aim of the current study was to compare of the joint functional ROM between overhead athletes with and without shoulder joint impingement syndrome. We hypothesized that there would be significant differences between overhead athletes with and without impingement syndrome with regards to their shoulder abduction as well as internal and external rotation ROM.

Methods

Participants

In this cross-sectional study, 66 semi-professional overhead male athletes (volleyball and swimming players) participated including 30 overhead athletes without impingement syndrome (age: 28.12 ± 6.13 y/o) and 33 overhead athletes with impingement syndrome (age: 26.83 ± 4.81 y/o). The participants of the two groups were matched for the age factor. However, three of the athletes without impingement syndrome refused to continue the study. The athletes without impingement syndrome did not report any history of surgery or pain

over the last year in the shoulder girdle. The athletes with impingement syndrome had been suffering from this condition in their dominant arm at least for three months including pain associated with resisted flexion and abduction, positive result for Neer's test, Hawkins test, and Supraspinatus Empty Can test, as well as palpation of the supraspinatus tendon tenderness when palpating the greater tuberosity of the humerus which has been described as being indicative of supraspinatus tendon pathology (15). All of these were performed and verified by a physical therapist.

Testing Conditions

The subjects completed the consent form before testing. The subjects were asked to sit on a chair and throw handball balls towards a net. Throwing the ball when sitting on a chair made the throwing position isolated at the upper limb and decreased the variability of the throwing action of athletes from different sports (Figure 1). A 5-min warm-up was performed, after which the subjects gradually increased their throwing velocity to maximum (16). Before athletes performing the test, a static trial was made while the athlete was sitting on the chair with dominant hand hanging on the side of the body. They were asked to throw three times at their maximum power, the mean of which formed the basis for statistics [14].

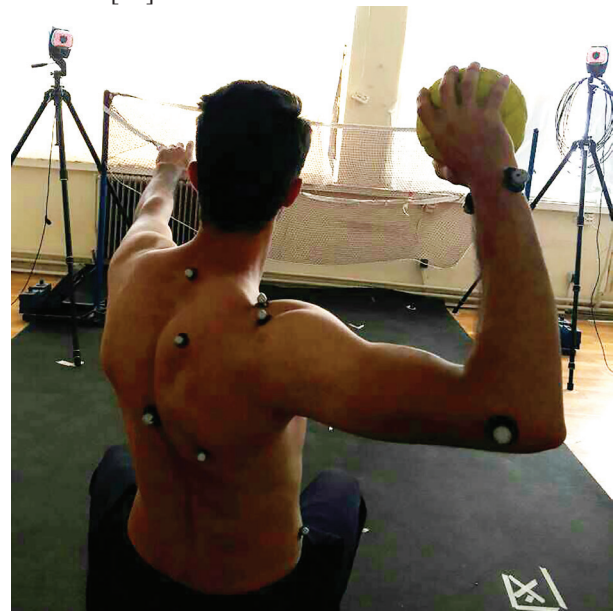


Figure 1: Experimental set up, with the subject seating and throwing the ball into the net

Data Collection

The 3D motion analysis system with 6 Optoelectronic Cameras (Rapture H Motion Analysis System, Santa Rosa, CA, USA) were used to evaluate the data. Passive reflective markers were installed on the upper limbs, which were fixed on subjects' bodies using a double-sided adhesive. The markers were placed on the anterior and posterior superior iliac spines of the pelvis, sternum, seventh cervical spinous process, acromion process of the extremity throwing the ball, anterior-superior section

of the shoulder approximately 2 cm below the acromion process, medial and lateral epicondyles of the humerus, as well as ulnar and radial processes.

These markers were used to analyze the arm motion at the throwing point. A static calibration was performed in the sitting position before the throwing trials. The whole-body kinematic model presented in this study was developed using OpenSim platform version 3.3 (National Central for Simulation in Rehabilitation Research NCSRR, Stanford, CA, USA). A whole-body kinematic model was implemented using static calibration. ROM was evaluated in the OpenSim software using inverse kinematics to use the shoulder ROM with three degrees of freedom. The maximum range of external rotation was measured one frame after full cock with initiation of the elbow velocity. Similarly, the maximum range of internal rotation was assessed at the zero speed of elbow when the ball was dropped (Figure 2). Zero speed of the elbow was the frame on which the ball was dropped, with the elbow movement in the sagittal plane reaching

zero (17). The maximum abduction was measured in the frontal plane.

Statistical Analysis

Kolmogorov-Smirnov (K-S) test was used to determine whether the data was normally distributed. To compare the ROM abduction as well as internal and external rotation of the shoulder joint, independent t-test was used. An alpha of $P < 0.05$ was used to determine significance. For all comparisons, the exact p-value has been reported.

Results

The demographic data of the subjects are presented in Table 1. The results of independent sample t-test did not show any significant differences in the variables of age, height, weight, and BMI between the groups. The results K-S test revealed that the data distribution was normal for both groups as well as for the arm abduction and its internal and external rotation.



Figure 2: Sagittal view of full-cock (A), ball-release (B), and zero elbow velocity (C) events used to define the release (A to B) and breaking (B to C) phases of an overhead seated thro.

Table 1: Demographic data of the overhead athletes

Variable	Group	Numbers	Mean \pm Standard Deviation	P value
Age(y)	With impingement syndrome	33	28.12 \pm 6.13	0.36
	Without impingement syndrome	30	26.83 \pm 4.81	
Height(cm)	With impingement syndrome	33	184.57 \pm 8.14	0.67
	Without impingement syndrome	30	180.33 \pm 5.82	
Weight(kg)	With impingement syndrome	33	77.78 \pm 9.83	0.21
	Without impingement syndrome	30	80.36 \pm 5.94	
BMI(kg/m ²)	With impingement syndrome	33	22.81 \pm 0.40	0.25
	Without impingement syndrome	30	23.42 \pm 0.32	

Table 2: The comparison of shoulder joint abduction as well as internal and external rotation ROM between the two groups

Variable	Group	Mean \pm Standard Deviation (deg)	Mean Difference	95% Confidence Interval		T	P value
				Lower	upper		
External rotation(deg)	With impingement syndrome	150.42 \pm 10.18	8.46	4.15	12.76	3.93	<0/001
	Without impingement syndrome	133.53 \pm 7.59					
Internal rotation(deg)	With impingement syndrome	49.96 \pm 6.93	-16.89	-21.45	-12.32	-7.40	<0/001
	Without impingement syndrome	58.43 \pm 10.0					
Arm abduction (deg)	With impingement syndrome	106.24 \pm 7.52	-4.17	-8.16	-0.18	-2.09	0.04
	Without impingement syndrome	102.06 \pm 8.31					

The results obtained from the independent samples t-test (Table 2) indicated that the overhead athlete with impingement syndrome had a more limited internal rotation ROM (9° , $T_{(61)} = -7.40$, $P < 0.001$), greater external rotation ROM (17° , $T_{(61)} = 3.93$, $P < 0.001$), and greater arm abduction (4° , $T_{(61)} = -2.09$, $P < 0.04$) on the dominant arm versus the overhead athletes without impingement syndrome.

Discussion

The purpose of this study was to compare the shoulder joint functional ROM in overhead athletes with and without shoulder impingement syndrome. The results indicated that there is a significant difference of the functional ROM of internal and external rotation as well as abduction between athletes with impingement syndrome and those without impingement syndrome. This change involves decreased internal rotation and increased external rotation and abduction. Mayer et al found that passive glenohumeral internal rotation deficits and posterior shoulder tightness are common characteristics found in the throwing arm of all throwers [18]. Almeida et al observed that handball players with a history of pain in the shoulder joint had a greater active glenohumeral internal rotation deficit (GIRD) and external rotation in the throwing arm and more limited internal rotation in the throwing arm in comparison to the athletes without pain [19]. Similarly, McConnell et al observed a significant difference in the shoulder joint functional ROM of healthy athletes compared to the affected athletes [17]. Various studies have suggested that a decline occurs in the internal rotation ROM of overhead athletes [20-22]. However, Scher et al found no difference in rotation ROM among baseball pitchers with and without a history of shoulder injury, where the difference in the dynamic range between the uninjured and previously injured athletes was considerable, suggesting that the previously injured subjects may have inadequate eccentric internal and external rotator muscle control for the throwing activity [23]. The forceful and repetitive nature of overhead throwing activities and poor scapular muscle control (scapular dyskinesia) are hypothesized to cause an anterior shift of the humeral head, altering the rotational arc of the shoulder, increasing the external rotation, and decreasing the internal rotation [24]. Repeated throwing and cumulative pressure through the deceleration phase in overhead activities leads to the occurrence of micro-traumatic stress and the formation of scar tissue in the shoulder joint posterior capsule. This tightness in the posterior joint capsule is associated with a reduction of internal rotation which are linked to shoulder joint injuries [5, 25]. Mayer et al. found a certain link between the posterior joint capsule tightness and the internal impingement syndrome. Posteroinferior capsule tightness causes the humeral head in the glenoid cavity to make a posterosuperior movement, which impinges the posterior rotator cuffs of the shoulder [18].

There is another adaptability in arm dominant overhead athletes which may develop retroversion at the humeral

head. The increased bone retroversion can heighten the range of shoulder external rotation. At the late phase of throwing where abduction is accompanied by maximum external rotation, a compression of rotator muscle internal fibers and posterosuperior labrum attached between greater tubercle and the margin of the glenoid cavity occurs as a result of retroversion [24]. It has also been demonstrated that athletes who exhibit increased external rotation ROM have enhanced laxity in the anteroinferior capsuloligamentous structures, raising the “micro-instability” of the shoulder and the athlete’s potential for pain [26]. These laxity structures lead to an increase in the anteroposterior movement of the humeral head, eventually causing more shoulder pain and injury [12].

Conclusion

These data suggest that athletes with shoulder impingement syndrome have a different functional ROM compared to athletes without shoulder impingement syndrome. The external rotation and abduction ROM in athletes with impingement syndrome were more than athletes without impingement syndrome. Further, the internal rotation ROM in athletes with impingement syndrome were more limited compared to athletes without impingement syndrome. These findings can be used to screen and identify high-risk athletes and assist the therapists to make more appropriate therapeutic plans in order to help the injured athlete to return sports as soon as possible.

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References

1. Wilk KE, Meister K, Andrews IR. Current Concepts in the Rehabilitation of the Overhead Throwing Athlete. *Am J Sports Med* 2002;(30):136-51
2. Cools AM., Johansson FR., Borms D & Maenhout A. Prevention of shoulder injuries in overhead athletes: a science-based approach. *Braz J Phys Ther* 2015;19(5), 331-339.
3. Frisch KE, Clark J, Hanson C, Fagerness C, Conway A, Hoogendoorn L. High Prevalence of Nontraumatic Shoulder Pain in a Regional Sample of Female High School Volleyball Athletes. *Orthop J Sports Med*. 2017, 23;5(6):2325967117712236.
4. Saadatian A, Sahebozamani M, & Mohamadipour F. comparison of internal-to-external ratios of strength rotation and rom rotation in injured and healthy professional male handball players. *J Res Rehabil Sci* 2013;9(7):1232-1243
5. Tyler TF, Nicholas SJ, Lee SJ, Mullaney M, McHugh MP. Correction of posterior shoulder tightness is associated with symptom resolution in patients with internal impingement. *Am J Sports Med* 2010; 38:114–19.
6. Cools AM, Declercq G, Cagnie B, Cambier D, Witvrouw E. Internal impingement in the tennis player: rehabilitation guidelines. *Br J Sports Med* 2008; 42:165–71
7. Cools AM, Johansson FR, Cagnie B, Cambier DC, Witvrouw EE. Stretching the posterior shoulder structures in subjects with internal rotation deficit: comparison of two stretching techniques. *Shoulder Elbow* 2012, 1;4(1):56-63.
8. Borsa PA, Laudner KG, Sauers EL. Mobility and stability

- adaptations in the shoulder of the overhead athlete: a theoretical and evidencebased perspective. *Sports Med* 2008; 38:17–36
9. Keller RA, De Giacomo AF, Neumann JA, Limpisvasti, O & Tibone JE. Glenohumeral internal rotation deficit and risk of upper extremity injury in overhead athletes: a meta-analysis and systematic review. *Sports health* 2018;10(2), 125-132.
 10. Nodehi-Moghadam A, Nasrin N, Kharazmi A & Eskandari, Z. A comparative study on shoulder rotational strength, range of motion and proprioception between the throwing athletes and non-athletic persons. *Asian J Sports Med* 2013; 4(1), 34- 40.
 11. Szyluk K, jasinski A, Koczy B, Widuchowski W, Widuchowski J, Subacromial impingement syndrome most frequent reason of the painful shoulder syndrome. *Pol merkur Lekarski* 2008. 25(146): 179-83
 12. Lewis JS, Green AS, Dekel S. The etiology of subacromial impingement syndrome. *Physiotherapy* 2001; 87(9): 458-69.
 13. Michener LA, McClure PW, Karduna AR. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clin Biomech (Bristol, Avon)* 2003;18(5): 369-39
 14. McConnell J, Donnelly C, Hamner S, Dunne J, & Besier T. Effect of shoulder taping on maximum shoulder external and internal rotation range in uninjured and previously injured overhead athletes during a seated throw. *J Orthop Res* 2011; 29(9), 1406-1411.
 15. Lewis JS, Wright C, Green A. Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. *J Orthop Sports Phys Ther* 2005;35(2):72-87.
 16. Mascarin NC, Vancini RL, Lira CA, Andrade MS. Stretch-induced reductions in throwing performance are attenuated by warm-up before exercise. *J Strength Cond Res.* 2015; 29:1393–8.
 17. McConnell J, Donnelly C, Hamner S, Dunne J, & Besier T. Passive and dynamic shoulder rotation range in uninjured and previously injured overhead throwing athletes and the effect of shoulder taping. *PM&R* 2012; 4(2), 111-116.
 18. Myers JB, Laudner KG, Pasquale MR, Bradley JP, Lephart S M. Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. *Am J Sports Med*,2006; 34(3), 385-391.
 19. Almeida GPL, Silveira PF, Rosseto NP, Barbosa G, Ejnisman B, Cohen M. Glenohumeral range of motion in handball players with and without throwing-related shoulder pain. *J Shoulder Elbow Surg* 2013; 22(5), 602-607.
 20. Reinold MM, Wilk KE, Macrina LC, Sheheane C, Dun S, Fleisig GS, et al. Changes in shoulder and elbow passive range of motion after pitching in professional baseball players. *Am J Sports Med* 2008; 36:523-7.
 21. Dwelly PM, Tripp BL, Tripp PA, Eberman LE, Gorin S. Glenohumeral rotational range of motion in collegiate overhead-throwing athletes during an athletic season. *J Athl Train* 2009; 44:611-6.
 22. Kibler WB, Chandler TJ. Range of motion in junior tennis players participating in an injury risk modification program. *J Sci Med Sport* 2003; 6:51-62
 23. Scher S, Anderson K, Weber N, Bajorek J, Rand K, Bey MJ. Associations among hip and shoulder range of motion and shoulder injury in professional baseball players. *J Athl Train* 2010; 45:191-197
 24. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: Spectrum of pathology. Part I: Pathoanatomy and biomechanics. *Arthroscopy* 2003; 19:404-420.
 25. Trakis JE, McHugh MP, Caracciolo PA, Busciacco L, Mullaney M, Nicholas JS. Muscle strength and range of motion in adolescent pitchers with throwing-related pain: implications for injury prevention. *Am J Sports Med* 2008; 36(11), 2173-78
 26. Borsa PA, Laudner KG, Sauers EL. Mobility and stability adaptations in the shoulder of the overhead athlete: a theoretical and evidence-based perspective. *Sports Med* 2008; 38:17–36.