3D SCAPULAR KINEMATICS AND SCAPULOHUMERAL RHYTHM IN SWIMMERS AND BASEBALL PITCHERS

Tanghuizi Du and Toshimasa Yanai[1]

Faculty of Sport Sciences, Waseda University, Tokorozawa, Japan[1]

The present study was conducted to describe characteristics of scapular kinematics and scapulohumeral rhythm (SHR) in baseball pitchers and swimmers. The participants were 16 swimmers, 19 baseball pitchers and 8 non-athletes. Each participant was asked to perform three tasks, arm abduction, shoulder horizontal abduction (HA) and shoulder internal/ external rotation (IR/ER). An electromagnetic tracking device was used to record the 3D data of shoulder complex. The SHR during the arm abduction and the range of motion for shoulder complex were determined for each task. The results showed that swimmers had significantly greater ranges of shoulder HA and scapular upward rotation while pitchers had a significantly greater range of shoulder ER and a significantly smaller range of shoulder IR. There was no obvious difference in SHR between the groups.

KEYWORDS: shoulder function, adaptation, athletes.

INTRODUCTION: The arm motion (motions of humerus relative to thorax) is achieved by the motion of glenohumeral joint and scapular motion relative to thorax. The scapula moves in harmony with the humerus and the ratio of the glenohumeral motion to the scapular upward rotation, termed scapulohumeral rhythm (SHR), is an important indicator for evaluating shoulder function. Generally, the SHR is about 2 to 1 in an arm abduction (Inman & Abbott, 1944). This ratio as well as the scapular motion was found to be altered by shoulder injuries and pain (Fayad et al., 2008; Scibek et al., 2009). Timmons et al., (2012) conducted a meta-analysis on scapular kinematics and subacromial impingement syndrome, and found that patients with subacromial impingement syndrome exhibit generally less scapular upward rotation and external rotation during arm abduction. On the other hand, overhead athletes with subacromial impingement syndrome were found to demonstrate a greater scapular posterior tilt. Based on these findings, they suggested that the population is a factor for the different results on scapular motions found in literature — athletes vs. non-athletes.

Athletes in overhead sports often use their shoulder joints over a large range at high speed, as seen in baseball pitching, tennis serve and swimming strokes. Previous researchers suggest that the SHR is altered by the movement speed of arm and/or the external load applied to the arm (Pascoal et al., 2000; de Groot et al., 1998), implying that overhead athletes may use an altered SHR in their daily training and competition. An adaptation of shoulder kinematics may occur as a result of these repeated shoulder movements. In fact, healthy athletes in overhead sports showed increased upward rotation and protraction during arm abduction than non-athletes (Hosseinimehr et al., 2015).

Each overhead motion requires unique shoulder motion specific to the athletes' technique. For example, baseball pitchers perform extreme external rotation of shoulder in throwing a ball and swimmers perform large internal rotation and large shoulder elevation during strokes. With a sports-specific shoulder motion repeated in their daily training and competition, a unique adaptation may occur in scapular kinematics. However, no evidence was provided to support that the different sports experience would alter the SHR during arm abduction. Therefore, the present study was conducted to describe three-dimensional scapular kinematics and the SHR in baseball pitchers and swimmers.

METHODS: Three groups participated in the study. They were 16 swimmers (Mean ± SD: 1.75 ± 0.04 m, 68.7 ± 4.3 kg, age: 19.9 ± 1.3 years), 19 baseball pitchers (1.78 ± 0.06 m, 77.4 ± 7.4 kg, age: 19.5 ± 1.2 years) and 8 controls who were healthy collegiate students with no training experience of upper limb sports (1.75 ± 0.04 m, 60.9 ± 7.3 kg, age: 26.3 ± 1.9 years). The swimmers and pitchers were from the collegiate sports team who were in team training more than 6 days per week. All participants were pain-free in shoulder.

The dominant shoulder of each participant was modelled as a thorax, a scapula and a humerus. An electromagnetic tracking device (LIBERTY, Polhemus, Colchester, VT) measured three-dimensional position and orientation of three segments at 240 Hz. Sensors were attached on the sternum, acromion and humerus of the dominant side for each participant (Konda et al. 2011). Glenohumeral joint motion was calculated as the humerus motion relative to the scapula and was represented by three Euler angles indicating the glenohumeral horizontal abduction angle (Gh-HA angle), glenohumeral elevation angle (Gh-EL angle) and glenohumeral internal/external rotation angle (Gh-IR/ER angle). Humerothoracic motion was calculated as the humerus motion relative to the thorax and was represented by three Euler angles indicating the humerothoracic horizontal abduction angle (HT-HA angle), humerothoracic elevation angle (HT-EL angle) and humerothoracic internal/external rotation angle (HT-IR/ER angle). Scapular motion was calculated as the scapular motion relative to thorax and was represented by three Cardan angle indicating the scapular retraction angle, scapular upward rotation angle and scapular posterior/anterior tilt angle. Each participant was asked to perform a full range of arm abduction in the frontal plane, shoulder horizontal abduction in the transverse plane at shoulder height and shoulder internal/external rotation in 90°arm abducted position. The range of motion for each joint was described by the variables as follows: the maximal values of HT-EL, Gh-EL and scapular upward rotation angles exhibited in the arm abduction measurement, the maximal and the minimal values of HT-HA, Gh-HA scapular protraction angles exhibited in the shoulder horizon abduction measurement, and the maximal values of HT-IR/ER, Gh-IR/ER and scapular anterior/posterior tilt angles in the shoulder internal/external rotation measurement. The SHR during arm abduction was represented as the ratio of the increment of Gh-EL to scapular upward rotation. The scapular kinematics during the full arm abduction were determined for each participant. The SHR was calculated at selected HT-EL angles (30°, 60°, 90° and 120°). For each variable, one-way analysis of variables (ANOVA) was used to determine the difference among swimmers, baseball pitchers and control group. The statistical significant level was set as $p < 0.05$.

RESULTS: Group ranges of motion for humerothoracic joint, glenohumeral joint and scapular motion are in Table 1. Range of motion was significantly different among the groups for HT-HA angle, HT-IR/ER angle, Gh-HA angle, Gh-IR/ER angle, scapular upward rotation angle and anterior tilt angle. Swimmers showed significantly greater ranges of motion for HT-HA angle, Gh-HA angle and scapular upward rotation angle than others. Baseball pitchers exhibited significantly smaller ranges of motion for HT-IR angle and Gh-IR angle, and significantly larger range of motion for Gh-ER angle than others. The control group showed significantly smaller range of motion for HT-ER angle than swimmers and pitchers.

Table 1: Range of motion for three groups (Unit: degree)

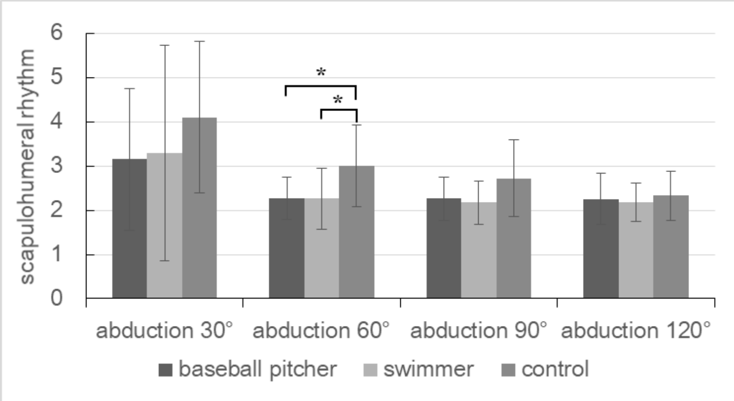
	Humerothoracic ROM					Glenohumeral ROM					Scapular ROM				
	EL	HA_{max}	HA_{min}	IR	ER	EL	HA_{max}	HA_{min}	IR	ER	UR	PR	RE	PT	AT
pitcher	141 (8)	106* (6)	29* (8)	19*† (11)	88* (11)	104 (11)	71* (7)	31* (7)	15*† (10)	73*† (11)	43* (8)	44 (8)	0 (7)	9 (8)	15* (6)
swimmer	146 (6)	128*† (16)	38*† (9)	46* (17)	77† (15)	103 (10)	88*† (10)	41*† (11)	49* (14)	60* (18)	53*† (7)	52 (10)	-3 (5)	14 (6)	12 (5)
control	147 (4)	112† (10)	24† (11)	40† (19)	62*† (19)	106 (11)	69† (10)	32† (9)	43† (10)	48† (20)	41† (8)	48 (10)	3 (13)	14 (5)	7* (9)

*†: p<0.05

The values in the table indicate the means and the values in the bracket indicate the standard deviations for each group. EL: elevation; HA+: horizontal adduction; HA-: horizontal abduction; IR: internal rotation; ER: external rotation; UR: upward rotation; PR: protraction; RE: retraction; PT: posterior tilt; AT: anterior tilt.

The mean value of SHR during arm abduction was 2.2 ± 0.5 for swimmers, 2.4 ± 0.5 for baseball pitchers and 2.4 ± 0.6 for control group. A significant difference was found between controls and athletes at 60° of arm abduction, but no difference between swimmers and pitchers was observed at any levels of arm abduction (Figure 1). The result of scapular motion during the arm abduction showed that swimmers exhibited a significantly larger scapular upward rotation (53° ± 7°) than others (43° ± 8° for baseball pitchers and 41° ± 8° for controls). Baseball pitchers exhibited a significantly smaller value of scapular anterior tilt angle (7° ± 7°) than others (12° ± 5° for swimmers and 19° ± 7° for controls).

Figure 1: Scapulohumeral rhythm in arm abduction for each group



DISCUSSION: The study showed; (a) Swimmers had greater ranges of motion for HT-HA angle, Gh-HA angle and scapular upward rotation angle whereas baseball pitchers had smaller ranges of motion for HT-IR angle and Gh-IR angle and a significantly larger range of motion for Gh-ER angle, (b) there was no difference between swimmers and pitchers in SHR during arm abduction, and (c) during arm abduction, swimmers exhibited greater scapular upward rotation while baseball pitchers exhibited smaller scapular posterior tilt angle.

Previous studies reported baseball pitchers had limited range of shoulder internal rotation and extremely large range of external rotation (Myers et al., 2005; Borsa et al., 2006). Our results agree with these studies. The difference between baseball pitchers and others may be due to the adaptation of pitching motion in which an extremely large external rotation is necessary during the late cocking phase. For swimmers, large range of motion for scapular upward rotation was observed. This may be due to that swimmers need large mobility of scapula to extend the arm to reach far in a hand entry and subsequent catch. These results suggest that swimmers and pitchers have altered the shoulder range of motion to adapt their sport activities. This alteration of shoulder range of motion in swimmers and pitchers may come from their sports techniques repeated in the daily training and/or the normal physical training which is necessary to the performance such as the functional stretch of shoulder.

Previous studies reported that the SHR was about 2 to 1 (Inman & Abbott, 1944; Fayad et al., 2008). Depending on the measurement methods, such as arm elevation plane and condition of participants, the SHR may vary from 1.3 to 8.2 (Fayad et al., 2008; Hosseinimehr et al., 2015). Our results are within this range. Hosseinimehr et al., (2015) reported that the SHR was different between the overhead athletes (handball and volleyball players) and non-athletes during all levels of arm abduction (abduction to 45°, 90° and 135°). In our results, however, such difference was observed only when the arm abduction angle was 60°. This may be due to the different method used in data collection. Hosseinimehr et al. (2015) calculated the glenohumeral joint motion as the difference of the values recorded by the inclinometers on the upper arm and on the scapula, while we determined the glenohumeral joint motion in three-dimension by the electromagnetic tracking device. Two-dimensional measurement method may not be accurate in describing three-dimensional shoulder kinematics (de Groot & Brand, 2001). Besides, the participants in the previous study were volleyball and handball players, while we focused on swimmers and pitchers. These differences in methodology and participants may have led to a different result on SHR between overhead athletes and non-athletes.

The results of SHR showed that the control group had significantly higher SHR at arm abduction of 60° than swimmers and pitchers, while there was no difference in SHR between swimmers and pitchers. This suggests that swimmers and pitchers adapted to the overhead sports activities and showed a different in the SHR from non-athletes. The different shoulder actions used in swimming strokes and baseball pitching may not cause a specific SHR adaption to the sports technique for swimmers and pitchers. During arm abduction, swimmers were observed to exhibit larger scapular upward rotation angle than others and pitchers exhibited smaller scapular anterior tilt angle. Both swimmers and pitchers had different scapular motion compared to the control group during arm abduction. The different scapular motion among groups suggests that the swimming and pitching daily training may affect the motions of the glenohumeral joint and scapula during arm abduction.

CONCLUSION: Swimmers and baseball pitchers have different shoulder range of motion specific to their sports' technique but not for their scapulohumeral rhythm. Swimmers have greater ranges of motion for humerothoracic and glenohumeral horizontal abduction angle and scapular upward rotation angle. Baseball pitchers have a larger range of motion for glenohumeral external rotation angle and a smaller ranges of motion for humerothoracic and glenohumeral internal rotation angle. The scapulohumeral rhythm during the arm abduction was similar between swimmers and baseball pitchers, and was different from that of non-athletes only at 60° abduction. When examine the shoulder function for athletes, we should adware that different range of motion between athletes and normal people or within athletes in different sports like swimmers and pitchers may not indicate a pathology or dysfunction. In addition, although the swimmers and pitchers have different shoulder range of motion and sports techniques, their scapulohumeral rhythm are similar.

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