

The changes in shoulder rotation strength ratio for various shoulder positions and speeds in the scapular plane between baseball players and non-players

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Abstract. [Purpose] This study aimed to investigate the effect of shoulder positions and speeds on internal and external rotation torque of college baseball players and age-matched non-players. [Subjects] Twenty first-level collegiate baseball players and 19 college students were recruited. [Methods] A dynamometer system was used to evaluate the shoulder rotation strength in sitting postures. Three testing positions, namely shoulder abduction of 45°, 70°, and 90° in the scapular plane, were combined with three testing speeds at 60°/s, 120°/s, and 210°/s. [Results] The maximum external and internal rotation torques both occurred at shoulder abduction of 70°. However, only external rotation torque was affected by the speed, with the peak value observed at 60°/s. The internal rotation torque of baseball players was larger than that of the control group under all testing conditions, but the external rotation did not show any difference. The ratio of external to internal rotation torque changed with the testing positions and speeds in both groups. The ratio in the control group was greater than that in the player group. [Conclusion] The shoulder position could affect the rotational strength, and the baseball players could strengthen their external rotators for better performance and injury prevention.

Key words: Isokinetic, Joint stability, Muscular strengthening

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INTRODUCTION

Isokinetic evaluation of the shoulder joint is often used to assess functional dynamic stability and shoulder musculature performance, especially in overhead athletes¹⁻⁴. Moreover, it could also help to determine the profile of patients or athletes suffering from shoulder disorders and guide their therapy and rehabilitation^{5, 6}.

Imbalance in the strength of the internal rotators (IRs) and the external rotators (ERs) of the shoulder joint is regarded as a possible factor in shoulder dysfunction^{7, 8}. The ER:IR ratio, the agonist-antagonist strength balance, has been used to identify possible risk factors for shoulder pathology^{9, 10} and may help to formulate a suitable muscle-training program¹⁰. The initial value reported for the ER:IR ratio in normal subjects was about 0.66 and remained about the same throughout the velocity spectrum¹¹. This was also found in the baseball players^{12, 13}. However, the rotational joint

strength may be affected by the testing joint position¹⁴⁻¹⁸ due to the muscle length-tension relationship and rotational speed^{14, 15, 18, 19}, which may cause different ER:IR ratios in different exercise positions and at different speed. However, to the authors' knowledge, there has been little research investigating the ratio of change in the different positions and rotational speeds in the scapular plane that may be used to minimize the stress on the rotator cuff.

Shoulder injuries caused by overuse frequently occur in baseball players, who repeatedly perform internal arm rotation with very fast angular velocities (about 6000°/sec) during the throwing motion²⁰. The main agonists are the IRs being contracted concentrically in the acceleration phase, while the ERs have to maintain the stability of the shoulder joint dynamic. Therefore, it is important to evaluate the IR and ER strengths to develop injury prevention and rehabilitation programs and to design training programs for baseball players.

Different baseball players may throw the ball at various shoulder abduction angles. Given the high number of times a baseball player throws a ball, it is important to determine which shoulder position is the most stable, and this has not yet been discussed. Moreover, Soderberg and Blaschak (1987) suggested that by establishing a progression of difficulty according to isokinetic test positions, a rehabilitation program following that progression would be valuable¹⁵.

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Table 1. Peak torques of external and internal rotation in baseball players and the control group (N-m)

	Baseball players group						Control group	
	Velocity	Position						
		45°	70°	90°	45°	70°	90°	
External rotation	60°/s	24.42±3.70	31.47±5.90	30.40±4.71	24.12±4.30	29.64±6.55	27.89±5.85	
	120°/s	23.68±3.72	30.76±5.90	28.71±4.89	22.17±3.65	28.13±5.73	25.82±5.55	
	210°/s	23.28±3.94	28.97±4.94	27.77±4.65	20.36±2.61	25.98±5.18	23.83±4.65	
Internal rotation	60°/s	39.00±7.85	45.35±10.00	44.05±10.00	30.34±7.68	34.27±9.56	34.01±10.68	
	120°/s	39.49±7.76	44.01±10.25	44.87±9.48	29.40±7.18	32.82±8.59	32.30±8.57	
	210°/s	40.18±8.20	45.15±9.00	43.97±9.27	29.53±6.29	34.36±9.33	32.56±8.73	

Mean±SD

The same concept may apply in a training program. Therefore, the purpose of this study was to determine the isokinetic strength profiles and ER:IR ratio in baseball players at various shoulder abduction positions in the scapular plane and at different speeds and to compare these values with those of healthy non-players. It was thought that comparing baseball players' values to normal values would be helpful in determining the effectiveness of their training program and in preventing risk of injury.

SUBJECTS AND METHODS

The control group comprised 39 subjects including 20 first-level collegiate baseball players and 19 college students of matched ages. All of these subjects were male, and none had experienced a shoulder musculoskeletal injury within six months or any shoulder discomfort or weakness during activity. The average age of the baseball players group was 19.5±0.6 years. The average height was 176.8±5.1 cm, and the average weight was 73.2±7.3 kg. The average age of the control group was 20.6±2.2 years. The average height was 174.4±4.7 cm, and the average weight was 71.8±10.2 kg. All subjects were briefed on the study's procedures and its possible risks, and they provided written consent voluntarily before participation. The present study was approved by the Institutional Review Board of Kaohsiung Medical University Chung-Ho Memorial Hospital.

A Biodex isokinetic dynamometer (System 3, Biodex Medical Systems, Shirley, NY, USA) was used in the evaluation of shoulder muscle strength. This system's test velocity ranged from 0.25°/s to 300°/s, and torque could be measured from 0.7 N-m to 680 N-m in a concentric and eccentric testing mode.

1. Before testing, anthropometric parameters were recorded. During testing, the subjects were seated, and their trunks were stabilized by anterior straps stretched diagonally from just above the shoulder level to the opposite pelvic side. An additional strap was used to stabilize the pelvis. The axis of the dynamometer arm was aligned with the glenohumeral joint. The elbow was maintained at 90° of flexion by the device. Strength was tested through a 150° range of motion, between 60° of internal rotation and 90° of external rotation, in both the internal and external rotation test. After the test procedure was presented, subjects stretched their shoulders as a warm-up and performed five to ten submaximal trials to familiarize themselves with the testing conditions. Each test

session comprised three repetitions of external and internal rotation in concentric movement. Three testing positions with shoulder abduction of 45°, 70°, and 90° combined with three testing speeds of 60°/s, 120°/s, and 210°/s were tested. These test speeds were chosen because they represented various functional speeds of motion¹³). The order of positions was randomized, as was the order of testing speeds at each position. A two-minute rest period was given between each trial. Gravity compensation was considered during the test.

Descriptive statistics (mean and standard deviation) including age, height, weight, peak torque of the ERs and IRs, and ER:IR ratio of the subjects are presented. Two-way repeated measure ANOVA was used to analyze the effect of the testing positions and the exercise speeds on the peak torques of external rotation and internal rotation and the ratio of the peak torque of the ERs to that of the IRs within the two groups. A one-way ANOVA test was used to determine whether there was a significant difference in any testing parameter between the two groups. Statistical significance was set at the level of $\alpha < 0.05$.

RESULTS

Table 1 shows the peak torques of the ERs and IRs in the three testing positions at three different speeds in the baseball players group and the control group. The ER peak torque generated in the different positions and speeds revealed significant differences. The maximum ER peak torque for the three testing positions was found with shoulder abduction of 70°, while the maximum value occurred at the speed of 60°/s for both groups. The maximum IR peak torque was also found with shoulder abduction of 70°; however, there was no significant difference in peak torque according to testing speed. There was a significant difference in IR peak torque among the different positions in both groups. But the testing speed and interaction of the testing positions and speeds showed no significant differences (Table 2).

Table 3 shows the ratios of the two groups for the peak torque ER:IR in different testing positions and speeds. The maximum ratio was also found with the shoulder abduction of 70° and at the velocity of 60°/s. The ratio varied with the testing positions and also with the testing speeds in both groups (Table 4). However, there was no interaction between the testing positions and speeds.

The ER peak torques of the baseball players with shoulder

Table 2. Analysis of variance results for the peak torques of external and internal rotation in different positions at various speeds

		Baseball players group		Control group	
		F-value	Remarks	F-value	Remarks
External rotation	Position* (deg)		70>45		70>45
			90>45	31.01	90>45
			70>90		70>90
	Velocity* (°/s)		60>120		60>120
			60>210	29.36	60>210
		120>210		120>210	
	Angle velocity	1.32		0.16	
Internal rotation	Position* (deg)		70>45	7.48	70>45
			90>45		90>45
	Velocity (°/s)	0.17		5.42	
	Angle velocity	1.44		0.88	

*p<0.05

Table 3. The ratios of external rotation/internal rotation peak torque in different positions at various speeds (%)

Velocity	Baseball players group			Control group		
	Position					
	45°	70°	90°	45°	70°	90°
60°/s	64.27±11.92	71.13±12.34	71.16±12.97	81.71±12.59	89.06±14.31	86.16±18.51
120°/s	61.33±11.26	71.33±10.65	65.37±10.50	77.86±13.94	88.14±15.83	82.01±14.04
210°/s	59.31±10.87	65.34±9.82	64.34±8.89	70.93±12.63	78.36±15.26	75.77±14.66

Mean±SD

Table 4. Analysis of variance results for the ratios of external rotation/internal rotation peak torque in different positions at various speeds

	Baseball players group		Control group	
	F-value	Remarks	F-value	Remarks
Position* (deg)	6.22	70>45	4.74	70>45
Velocity* (°/s)	4.07	60>210	12.84	60>210
		120>210		120>210
Position velocity	2.52		0.44	

abduction of 45° and a velocity of 210°/s and with abduction 90° and a velocity of 210°/s were higher than those of the control group. The baseball players' IR peak torques were greater than those of the control group under all testing conditions (3 angles × 3 speeds). The results for the ER:IR ratio were opposite of those for the IR peak torque; the ratios of the control group were greater than those of the baseball players under all testing conditions (Table 5).

DISCUSSION

The internal shoulder rotators were found to be significantly stronger than the external rotators under all nine testing conditions (3 positions × 3 speeds) in both groups. This is in agreement with the results presented in previous studies^{11, 21-23}. This is consistent with the muscle-size differences between the two rotator muscle groups. The muscles

Table 5. Analysis of variance results for comparisons of test parameters between baseball players and the control group

Velocity	Position		
	45°	70°	90°
External rotation peak torque			
60°/s	0.827	0.390	0.166
120°/s	0.227	0.185	0.107
210°/s	0.013*	0.086	0.016*
Internal rotation peak torque			
60°/s	0.002*	0.002*	0.006*
120°/s	0.000*	0.001*	0.000*
210°/s	0.000*	0.001*	0.001*
ER:IR			
60°/s	0.000*	0.000*	0.008*
120°/s	0.000*	0.001*	0.000*
210°/s	0.006*	0.004*	0.008*

with a larger cross-section area could produce more muscle force. The large internal rotators such as the latissimus dorsi and pectoralis major are stronger than the external rotators such as the infraspinatus and teres minor. The lever arm of the internal rotators is usually also larger than that of the external rotators²⁴.

Previous studies have shown that shoulder joint positions could affect muscle activation²⁵⁻²⁷ around the shoulder and the shoulder's rotational strength^{14, 15, 18}. The present

study also found that the ER and IR strengths of the shoulder changed with the shoulder abduction angles in the scapular plane. With the arm away from the trunk, the length-tension relationship of the rotator cuff and surrounding musculatures and the tension of the ligament and joint capsule were changed. Moreover, the changes in the ligaments and capsule also caused a variable fulcrum point during humeral movement¹⁵). Several studies investigated the effect of testing positions on shoulder strength production or testing reliability^{14–18}). However, few of them focused on the strength changes at various positions in the same plane^{14, 15}). Soderberg and Blaschak (1987) found that both the ER and IR had maximum rotation strength in the neutral position, followed by 90° of abduction and 45° of abduction¹⁴). Forthomme et al. (2011) also found that rotational strength was greater at 90° of abduction than at 45° of abduction¹⁵). The results of the current study were in agreement with previous studies. Moreover, the maximum rotational strength was found at 70° of abduction in both groups not tested in the previous study. In Brown's study (1988), the subjects were often apprehensive of producing full effort at 90° of abduction, since this position is inherently less stable. It was found that apprehension usually increased when the arm was externally rotated²²). Moreover, a previous study found that a ball was usually thrown at just lower than 90° of abduction during throwing motion²⁰). This may mean there was less constraint from the soft tissue of the shoulder, resulting in the ability to perform with greater rotational strength. Several researchers also suggested modifying the traditional shoulder isokinetic positions by keeping the humerus below 80° abduction to reduce the risk of injury^{15, 28}). Therefore, application of this position in the athletes' training program should be considered to achieve more effective training and to prevent injury.

Several researchers found that as speed increases, torque decreases during concentric muscle contractions due to the muscle force-velocity relationship^{14, 15, 18, 19}). However, we did not find a significant difference in shoulder IR strength at various speeds. This conflict in the results may come from the speeds of shoulder internal rotation in the daily throwing motion usually being above 2000–3000°/s and even reaching as high as 6000°/sec in the pitching motion, which is far faster than our testing speeds (210°/s was the maximum). Therefore, the muscle contraction may exhibit a speed adaptation. Moreover, testing in the sitting position may result in trunk compensation during the IR strength test.

With respect to examining ER:IR strength ratios, the results of this study were similar to those of previous reports describing this ratio as between 0.53 to 0.91^{1, 15, 21, 23, 29}). The authors found a significantly lower ratio in baseball players than in normal subjects in the present study. This is in agreement with previous studies^{1, 29}). The lower ratio is attributed to a greater IR strength without a concomitant increase in ER strength^{1, 12}). In this study, we also found the strength of the internal rotators in baseball players was greater than in normal subjects, while ER strength in baseball players was not significantly greater than that in normal subjects under most testing conditions. A possible explanation for the greater IR strength is that most players do resistance strength training with greater focus on the larger muscles such as the latissimus dorsi and the pectoralis major, which are internal

rotators, and ignore the small external rotators. Moreover, it is possible that a gain in IR strength may result from the shortened repeated stretch cycle of the throwing motion. The baseball players need to generate a large amount of torque in the IRs to pitch or transfer the ball with sufficient velocity. Conversely, the external rotators are shortened during the late cocking phase before lengthening rapidly during the acceleration and follow-through phase. In our study, contraction of the external rotators was reduced during the deceleration phase, as the ER torque was produced primarily by the elastic elements of the musculature³⁰). The effect of training on the external rotators may be less than that on the internal rotators.

The external rotators had a high activity level during baseball pitching, especially during deceleration of the pitching arm in the follow-through phase. Alderink and Kuck (1986) suggested that perhaps training programs should strive to increase the ER:IR ratio²¹). Increasing the concentric ER:IR ratio to 76% has been suggested¹⁰). Increasing the external rotation could effectively bias this ratio and add greater stability to the shoulder joint in athletes performing overhead activities and possibly prevent shoulder injuries. Moreover, the results of this study further suggest that the physical activity required of baseball players does indeed place special demands on the shoulder as compared with the demands placed on nonplayers' shoulders.

The results of this study showed that the shoulder abduction position was a significant factor in the generation of IR and ER strength. The maximum torque occurred with abduction of 70°, and IR strength showed no significant difference between the testing positions with shoulder abduction of 70° and 90°. Speed had a significant effect on ER strength only. The baseball players had greater IR strengths than the control group; however, this was not the case with respect to ER strength. It was shown that baseball players need to improve the external rotators to improve shoulder joint stability. The ER:IR strength ratio was affected by the shoulder abduction positions and rotational speeds. The baseball players had a lower ratio than the control group. Positioning was found to affect torque production, and selecting a position for training or rehabilitation based upon the degree of difficulty could have a positive effect on training.

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