

Isokinetic muscle torque during glenohumeral rotation in dominant and nondominant limbs

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The purpose of this study was to evaluate the side-to-side differences of isokinetic muscle torque during shoulder rotation in healthy nonathletic subjects. The strength was examined at two angles of glenohumeral abduction in the scapular plane (45° and 90°, respectively) and at three velocities (180°/s, 120°/s, 60°/s) using Biodex System 3Pro dynamometer. The maximal torques were achieved on dominant side in 45° abduction at 60°/s velocity, both for external and internal rotation. A general pattern was observed: abduction angle and velocity increase provoked a decrease in torque values, but each antagonistic muscle group was sensitive to a different factor. Significant differences between dominant and non-dominant limb were not observed in nonathletic male.

Key words: glenohumeral rotation, isokinetics, nonathletic male

1. Introduction

The glenohumeral joint stability is controlled by passive and active restraining mechanisms that allow joint mechanics to be maintained. The capsulo-ligamentous structures are loose enough to ensure excessive mobility, but simultaneously they are not strong enough themselves to guarantee the coaptation of spherical articular surfaces [1]–[3]. Unlike other joints, the glenohumeral joint basically depends just on muscles, especially rotators, which actively stabilize the joint by compressing the humeral head against the glenoid fossa [1]–[5]. Concurrently rotator muscles determine dynamic joint function allowing voluntary rotation and participating in other movements.

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Although the European Society for Shoulder and Elbow Surgery (ESSES) and the Society of American Shoulder and Elbow Surgeons (ASES) recommended

conducting objective studies on rotation of the shoulder joint, no uniform standardized procedures have been established so far [6]. The dynamic nature of upper limb movements was a critical factor in choosing the isokinetic evaluation in the present study. All positions and testing velocities for glenohumeral joint were chosen on the basis of their potential importance and safety [7]–[9].

2. Material and methods

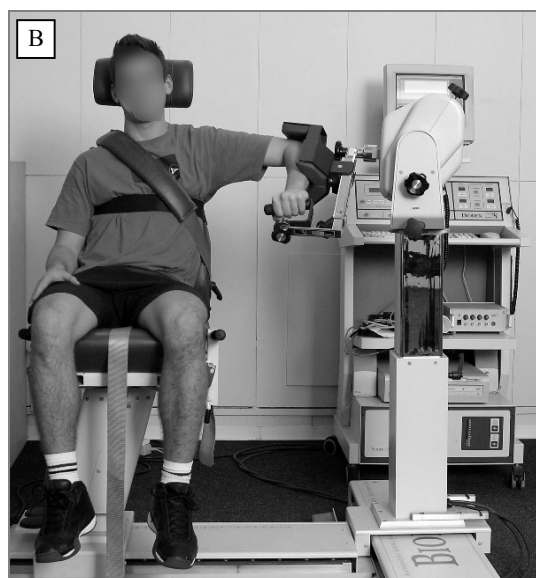
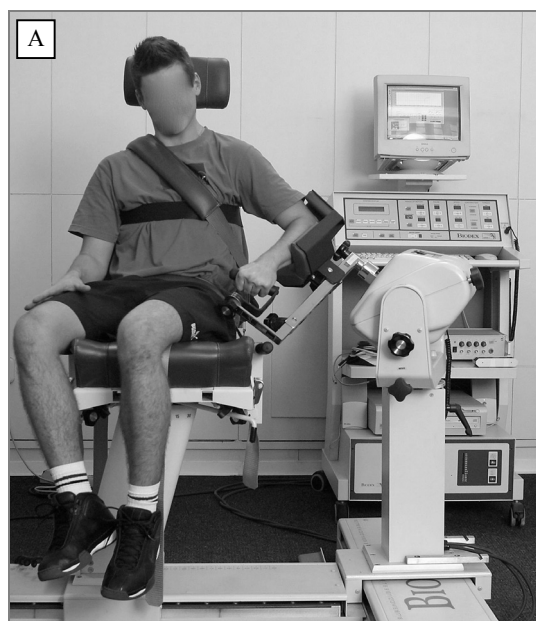
Twenty-six right-handed and four left-handed nonathletic male students of the University of Physical Education in Warsaw participated in the study (age of 20.9 ± 1.2 years; body height of 179.8 ± 6.3 cm; body mass of 76.5 ± 8.5 kg). All applicants were asked to fill in the health questionnaire that excluded all students with the shoulder, spine or thorax pain, injuries or diseases. Selected subjects were familiarized with the study aims and protocol and signed the agreement form before tests. Nevertheless they were allowed to withdraw from

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the study at any moment due to pain or discomfort. The study received the approbation of the local Committee of Ethics. All subjects were told to refrain from sport and other unusual activities for at least 24 hours before the examination. Both limbs were tested, with the nondominant being tested first.



The initial internal rotation position (-30°) for the isokinetic evaluation of the glenohumeral external rotation torque 45° (A) and 90° of abduction in the scapular plane (B)

The examination of isokinetic strength was preceded by 10-minute warm-up consisting in the upper limb exercises (in an open and closed kinematic chain) with a low intensity, the same for all subjects. The study was conducted for both sides, in two abduction positions in scapular plane and at three ve-

locities using the Biodex System 3Pro dynamometer (Biodex Inc, Shirley, NY). Each subject was placed into the Biodex chair and stabilized by three straps across the unmeasured shoulder, chest and pelvis. Lower limbs were flexed in hip and knee joints (110° and 90° , respectively), feet were left free, the hand of the unmeasured side was laid on the subject's lap. The tested limb was placed on the lever arm with the elbow joint flexed to 90° and the hand holding the handle (figure). Subject's arm was oriented in the 30° scapular plane and then abducted in the glenohumeral joint to 45° or 90° (depending on examination phase). Both positions were achieved by a proper orientation of the lever arm and confirmed with the Saunders Digital Inclinometer (The Saunders Group Inc, Chaska, MN).

The whole testing consisted of four subtests (with 2-minute rest intervals between them), two for the nondominant limb (test in 45° and in 90° of abduction) and two for the dominant limb (test in 45° and in 90° of abduction). Each subtest was completed according to the same mode. The dynamometer axis was made coincident with the glenohumeral rotation axis in scapular plane. The lever arm was initially positioned in -30° of glenohumeral internal rotation and then concentric external rotation was requested up to 90° of glenohumeral external rotation. After two seconds the subject rotated his limb internally toward -30° internal rotation position. Two repetitions of each internal and external rotation move were carried out at the same velocity. Three velocities chosen in this study were completed in a given order: $180^\circ/s$, $120^\circ/s$ and $60^\circ/s$ with 1-minute rest interval between them. The subject was supposed to make the maximal effort. Moderate verbal encouragement was provided during the testing. Torque values were recorded with gravity correction.

3. Results

The isokinetic strength of rotator muscles was examined at two angles of glenohumeral abduction in the scapular plane (45° and 90° , respectively) and at three velocities ($180^\circ/s$, $120^\circ/s$, $60^\circ/s$). Two repetitions of each concentric internal and external rotations were carried out at each velocity for the dominant and nondominant limbs. The maximal value of the torque was used in data analysis.

An analysis of variances (ANOVA) was used to determine the influence of abduction angles and angular velocities on the muscle torque. Post hoc Duncan

test was used to reveal the significance level of possible differences. The differences between muscle torques for the dominant and nondominant limbs at the same abduction angle were calculated. The significance level was accepted at $p < 0.05$.

The greatest torques were achieved on dominant side in 45° abduction at 60°/s velocity, both for external and internal rotation (table 1). A general pattern was observed: an increase in abduction angle and velocity provoked a decrease in torque values, but the analysis of variances and post hoc test revealed that each antagonistic muscle group was sensitive to a different factor. In relation to the abduction angles only, the internal rotator muscle torque values changed significantly. On the nondominant side the level of torque decrease significance was $p < 0.01$ at 60°/s velocity and $p < 0.05$ at 120°/s and 180°/s velocities. In the dominant limb, internal rotators were weaker with the significance level $p < 0.05$ at 60°/s velocity, and showed high tendencies toward significant changes at the other velocities ($p = 0.07$ at 120°/s, $p = 0.08$ at 180°/s). Any significant changes of torque for external rotator muscles were not observed.

Table 1. Mean \pm SD value of isokinetic muscle torques [Nm] for glenohumeral external (ER) and internal (IR) rotation at different angular velocities (60°/s, 120°/s, 180°/s) and the angle of abduction in scapular plane (45° and 90°) for dominant (DOM) and nondominant sides (N-DOM)

Velocity		DOM		N-DOM	
		45°	90°	45°	90°
60°/s	ER	36.3 \pm 5.6	34.4 \pm 5.3	35.2 \pm 6.8	33.8 \pm 6.0
	IR	50.6 \pm 11.8	44.0 \pm 11.7	47.6 \pm 10.2	38.4 \pm 7.3
120°/s	ER	33.4 \pm 5.3	32.1 \pm 4.8	32.2 \pm 5.9	31.1 \pm 5.9
	IR	46.9 \pm 10.2	41.8 \pm 10.4	44.6 \pm 9.6	38.7 \pm 8.4
180°/s	ER	30.1 \pm 4.5	28.4 \pm 4.2	29.7 \pm 5.5	28.0 \pm 5.4
	IR	46.7 \pm 9.2	41.8 \pm 10.1	43.7 \pm 7.	37.6 \pm 6.6

The influence of angular velocities on the glenohumeral rotator muscle torque was quite different. In such a case, no significant changes in the values of internal rotator muscle torque were observed. The values of torque for external rotator muscle differed significantly between the 60°/s and 180°/s velocities ($p < 0.001$) for the both sides, and additionally between 120°/s and 180°/s velocities ($p < 0.05$) for the dominant limb.

The differences between the dominant and nondominant sides at the same abduction angle varies from 1.3% to 3.6% for external rotator muscles and from 5.2% to 14.8% for internal rotator muscles. The only significant ($p = 0.046$) difference was noted for the internal rotator muscles in abduction of 90° and at the velocity of 60°/s (table 2).

Table 2. Per cent differences in muscle torque for external (ER) and internal (IR) glenohumeral rotation side-to-side (%) and significance levels (p) at two angles of abduction at different angle velocities (60°/s, 120°/s, 180°/s)

Velocity		45°		90°	
		%	p	%	p
60°/s	ER	2.9	ns	1.7	ns
	IR	6.4	ns	14.8	0.046
120°/s	ER	3.6	ns	3.2	ns
	IR	5.2	ns	7.8	ns
180°/s	ER	1.3	ns	1.5	ns
	IR	6.7	ns	10.5	ns

4. Discussion

In Polish literature, we had no data about the glenohumeral isokinetic performance. Most of the other available studies were focused on overhead athletes or symptomatic subjects with healthy nonathletes involved as controls matched against them. The present study was conducted for healthy and active (but nonathletic) young males. The results obtained cannot be easily compared because of the variety of iso-

kinetic devices, testing procedures, data-processing factors and population groups.

Velocity-dependent and side-to-side differences were found non-significant by HILL et al. [6]. They measured the shoulder isokinetic rotational strength of 11 normal, healthy volunteers (28.4 \pm 1.3 years) using the Cybex 770 dynamometer. The study was performed in two positions at 60°/s and 120°/s velocity. In sitting position with the glenohumeral joint abducted to 45° in the scapular plane, the subjects produced greater internal and external muscle torque in both limbs at lower velocity (DOM: IR = 47.6 Nm, ER = 25.3 Nm; N-DOM: IR = 44.1 Nm, ER = 24.8 Nm) than at higher one (DOM: IR = 44.7 Nm, ER = 19 Nm; N-DOM: IR = 43 Nm, ER = 19.2 Nm); the nondominant side was weaker. In lying position with the glenohumeral

joint abducted to 90° in the frontal plane, the torque-velocity dependent tendency was observed as well although subjects produced greater external muscle torque and smaller internal muscle torque in both limbs at both velocities compared with sitting position.

The dominant side was stronger (however differences were small and non-permanent) according to the results presented by CODINE et al. [10], who tested twelve nonathletic subjects (25.6 ± 3.1 years) on the Biodex dynamometer. This study was conducted in sitting position with 45° glenohumeral abduction in the scapular plane at 60°/s, 180°/s and 300°/s velocities. Gradual decline in torque values was observed when the velocity of motion increased, with the exception of the internal rotation at 180°/s. However all differences were not significant.

MAYER et al. [11] showed that non-dominant values of shoulder rotation torque were slightly smaller for 32 normal untrained men at various velocities (60°/s, 180°/s, 240°/s and 300°/s). The muscle torque decreased with an increase in angle velocity, but changed only slightly after exceeding 180°/s. The dominant side external rotation changed from 24 Nm at 60°/s through 22 Nm at 180°/s to 20 Nm at the other velocities, and internal rotation changed from 42 Nm at 60°/s through 37 Nm at 180°/s, 35 Nm at 240°/s to 34 Nm at 300°/s. No significant differences between dominant and nondominant sides and between velocities were determined.

LEROUX et al. [12] evaluated 15 asymptomatic volunteers (an average age of 47.6 years) on the Biodex dynamometer in sitting position with arm 45° abducted in the scapular plane at 60°/s and 180°/s velocity. Group was gender-mixed (10 men, 5 women) and only combined data were given. Muscle torques obtained at 60°/s were significantly ($p < 0.001$) greater (DOM: IR = 43.6 Nm, ER = 32.1 Nm; N-DOM: IR = 40.3 Nm, ER = 32.1 Nm) than those at 120°/s (DOM: IR = 39 Nm, ER = 28 Nm; N-DOM: IR = 36.5 Nm, ER = 29.3 Nm). The internal rotators on the nondominant side were weaker, but all side-to-side differences were insignificant. Similar results were obtained by KRAMER et al. [13]. Using Kinetic Communicator dynamometer they examined 20 healthy volunteers (57.9 ± 8.8 years) in sitting position with 45° glenohumeral abduction in the scapular plane at 60°/s and 120°/s velocity. Combined data for both limbs revealed that torque values decrease with an increase in velocity (at 60°/s: IR = 44 Nm, ER = 37 Nm; at 120°/s: IR = 43 Nm, ER = 33 Nm).

Based on our study it can be inferred that the maximal muscle torque of the glenohumeral rotation

(both external and internal) occurred in 45° of abduction at 60°/s velocity and displayed a tendency to decrease when the velocity increased, but significant changes were characteristic of the external movement. This part is similar to the result presented above. Significant differences were obtained between the values of torque for the abduction of both shoulders. When the abduction angle increased the muscle torque decreased, but only internal rotator muscles were significantly sensitive. HARTSELL et al. [9] showed similar effect for sitting and standing positions with 45° glenohumeral abduction in the scapular plane. In standing position, subjects produced greater external muscle torque and smaller internal muscle torque at all velocities compared with sitting position.

Our paper demonstrated that only with respect to the internal rotator muscles in 90° of glenohumeral abduction at 60°/s, the values of torques for both of the limbs differed significantly (14.8%). Side-to-side comparisons made for other factors (velocity and glenohumeral abduction) are not significantly different.

5. Conclusion

1. Velocity of motion and glenohumeral abduction were the factors that significantly influenced muscle torque differences ($p < 0.001$).
2. Side-to-side variations of internal rotator muscles are accidental. Significant differences between dominant and non-dominant limbs do not exist in non-athletic male.

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