A Comparison of Two Positions for Assessing Shoulder Rotator Peak Torque: The Traditional Frontal Plane Versus the Plane of the Scapula

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Abstract:

The purpose of this study was to compare glenohumeral internal and external rotation concentric and eccentric peak torque values when assessed from both the frontal and scapular planes. Twenty-one men (mean age = 21.4 years, mean height = 180.47 cm, mean weight = 80.8 kg) had their nondominant shoulder isokinetically tested for shoulder concentric and eccentric internal and external rotator strength at 60 deg/sec. Subjects were tested in both the frontal and scapular planes in randomly assigned order during one test session. Eleven subjects returned 1 week later for an identical retest session to establish the reliability of the procedure ($r = .76$—.94). No differences were found in concentric and eccentric peak torque values between planes for either shoulder internal or external rotation ($p > .05$). Analysis of variance indicated that eccentric values were greater than concentric values and internal rotation values were greater than external rotation values in both planes. Because there may be some anatomical advantage to testing in the scapular plane, clinicians should consider placing patients in the scapular plane when testing shoulder rotator peak torque.

Article:

Isokinetic strength of the glenohumeral joint muscles is most often assessed from either the sagittal[24] or frontal[1,6,18,19,24] planes. The reason for this, in part, is because many anatomy and kinesiology texts define shoulder flexion as movement through the sagittal plane and shoulder abduction as movement through the frontal plane.[10,13] Clinicians are therefore inclined to position the upper extremity within the confines of the cardinal body planes, even when testing motions other than flexion and abduction (e.g., internal and external rotation).[1,16,19,22,24]

Johnston[11] disagrees with these standard definitions as applied to the shoulder because if adhered to, the shoulder would be the only joint in the body (except for the hip) in which the motion is defined in reference to something other than the distal bone—proximal bone (humerous—scapula) relationship. For example, elbow flexion and extension are universally described as movement around a transverse axis passing through the lower end of the humerus. As such, no matter where the humerus is positioned in space, movements around this axis are always regarded as movements of flexion and extension. However, in the case of the shoulder, movement is referenced to the trunk rather than the proximal bone, the scapula. According to Johnston, true abduction occurs in the plane of the scapula as opposed to the frontal plane.

The plane of the scapula has been investigated by a number of authors[8,9,11.12,20,21] and has been defined as a reorientation of the humerus to a position 30-45 deg anterior to the frontal plane.[20,21] The work of Kondo *et a1.*[12] with three-dimensional analysis of roentgenograms led them to state that "40 degrees is the exact degree of the scapular plane." This position is considered to be more functional because movement within the plane of the scapula appears to be less complex and more natural. When the upper extremity is elevated to a position of over the head in either the sagittal plane or in the frontal plane, the end result is exactly the same, namely, the medial epicondyle points forward and somewhat medially.[15] Codman[4] and Macgregor[14] agree and stated that flexion within the sagittal plane is accompanied by an appreciable degree of medial rotation, and abduction within the frontal plane requires significant external rotation. Elevation of the arm to a position of over the head performed in the plane of the scapula requires no rotation in either direction.

Isokinetic testing of the shoulder musculature is a common clinical practice,[1,5.6,16,18,19] with particular interest in evaluating internal and external rotation [3,9,22,24] The interest is justified by the fact that rotation plays a substantial role in throwing.[2,17,23] Pappas et al.17 measured peak angular velocities of shoulder internal rotation of 15 major league pitchers and reported a range from 3,340 to 9,198 deg/sec. Likewise, the posterior shoulder musculature is eccentrically stressed during the follow-through phase in order to decelerate the throwing limb. Deceleration values of —500,000 deg/sec are prominent at the shoulder and elbow.[17] Cook *et al*.[5] measured shoulder strength ratios in college baseball pitchers as well as age- and gender-matched nonpitchers and concluded that the act of pitching places unique stresses on a pitchers' throwing arm, especially on the external and internal rotators of the shoulder.

Concentric internal and external rotation has been assessed in the frontal and sagittal planes by many investigators[1,6,18,19,24] and in the scapular plane by Greenfield *et al*.[9] However, eccentric strength values for both internal and external rotation in the scapular plane have not been reported in the literature. Therefore, the purpose of this study was to compare concentric and eccentric peak torque values for internal and external rotation of the shoulder when obtained from both the frontal and scapular planes.

METHODOLOGY

Subjects

Twenty-one men (age = 21.4 ± 1.6 years, height =180.47 ± 6.50 cm, weight = 80.83 ± 8.7 kg) volunteered to participate in the study. All subjects were free from history of trauma or pathology to their non- dominant upper extremity. Each subject read and signed an informed consent form approved by a Unversity Human Investigations Committee.

Instrumentation

Strength was assessed with a Kinetic Communicator (KinCom, Chattecx Inc., Chattanooga, TN) dynamometer. This dynamometer is a hydraulically driven, microcomputer-controlled device that provides resistance via a rotating lever arm system. The unit is capable of testing in both concentric and eccentric modes of contraction. Force was expressed as peak torque and reported in Newton-meters. The mechanical reliability of the dynamometer (r = .948—.999) during dynamic testing has previously been reported.[7]

Procedures

Before testing, subjects were screened to confirm full pain-free range of motion within the nondominant shoulder girdle complex. The nondominant extremity was used to control for any history of considerable throwing experience. Subjects were tested in a seated position with their arm abducted to 90 deg and the elbow placed in 90 deg of flexion. The axis of rotation of the dynamometer was aligned so that it agreed with the longitudinal axis of the humerus. Subjects were stabilized with a belt around the waist and a strap around the upper trunk to minimize extraneous movement. An elastic bandage was used to help secure the elbow within the V-pad of the dynamometer. The feet of the subjects were propped in a chair in front of them to minimize use of the lower extremity to increase force production.

Subjects were randomly assigned to be tested from either the frontal plane or the scapular plane first. Once plane was determined, all subjects were tested for internal rotation peak torque first. The frontal plane position was defined as conventional abduction of the shoulder with no flexion so that the lateral epicondyle of the humerus was in a line with the ear lobe as the subject looked straight ahead. The plane of the scapula position was similar except that the humerus was allowed to move anteriorly 40 deg as measured by a hand-held goniometer aligned so that the axis of rotation passed through the acromiclavicular joint. Ninety degrees of shoulder abduction and 90 deg of elbow flexion were maintained in both planes.

To establish the range of motion to be used for data collection, the forearm was positioned so that it was horizontal to the floor. This became the 0 deg position and the computer was instructed to block the rotating lever arm from exceeding this position during internal rotation. The arm was then externally rotated 85 deg and blocked for external rotation. All tests were gravity corrected at the stationary 0 deg position.

Each subject was tested for concentric and eccentric peak torque of the shoulder internal and external rotators at 60 deg/sec. A 25 Newton preload force was used for all test conditions. Subjects performed three submaximal and one maximal concentric and eccentric contractions of both the internal and external rotators before data collection, which served to prepare the musculature for activity as well as to familiarize the subject with the equipment. Once adequately prepared, each subject was instructed to perform a maximal concentric contraction of the internal rotators through 85 deg of motion. Once the concentric internal rotation contraction was completed, 30 sec of rest was given to each subject to minimize fatigue. Each subject then maximally performed an eccentric contraction of the internal rotators through the same range of motion. Thirty seconds of rest was again allowed before the next contraction. Each subject continued this protocol until three maximal efforts were recorded for both concentric and eccentric contractions of the internal and external rotators. Each subject was then repositioned in relation to the dynamometer to test the other plane and the same protocol was repeated. Verbal instructions consisted of telling each subject to "push" (concentric) or "push and resist as hard as possible" (eccentric) before each maximal contraction. To establish reliability of the procedure, 11 of the 21 subjects were randomly selected to return 1 week later to be reassessed using the same protocol.

Statistical Analysis

The average of three maximal repetitions was used to analyze the data obtained during concentric and eccentric internal rotation, and concentric and eccentric external rotation. The peak torque values of each curve used for analysis were determined by electronically scanning the averaged curve according to manufacturer's recommendations for retrieving data from the system software.

Table 1 Data summary for concentric and eccentric internal and external rotation peak torque.

Test	Frontal plane (Nm)	Scapular plane (Nm)
Concentric internal rotation	36.24 ± 11.99	40.00 ± 10.85
Eccentric internal rotation	39.91 ± 10.68	42.95 ± 9.58
Concentric external rotation	30.14 ± 6.41	26.38 ± 6.82
Eccentric external rotation	30.48 ± 7.54	27.43 ± 7.19

Values are means ± SD.

Table 2 ANOVA

Source of variance	Sums of squares	Mean square	
Plane error	0	0	0
	384.25	19.21	
Rotation error	5137.17	5237.17	80.0*
	1297.08	64.85	
Contraction error	168.00	168.00	16.57*
	202.75	10.14	
Plane x Rotation	5.36	5.36	.60
x Concentric error	178.39	8.92	

* p < .05.

This study used a repeated measures design with the three independent variables being plane (frontal and scapular), rotation (internal and external), and contraction (concentric and eccentric). A three-way analysis of variance was used to analyze differences in peak torque values collected over the eight possible combinations. Level of significance was established at $p < .05$. Intraclass correlation coefficients (ICC) were calculated for the 11 subjects who were retested.

RESULTS

The peak torque values and standard deviations for shoulder concentric and eccentric internal and external rotation are presented in *Table 1*. There was not a main effect for plane, but significant differences were found for rotation (internal rotation > external rotation) and contraction (eccentric > concentric). The three-way interaction between plane, rotation, and type of contraction was not statistically significant (*Table 2*).

Table 3 displays the intraclass correlation coefficients for the eight test positions. The correlation coefficients ranged from $r = .76$-$.94$, with an average ICC of $r = .93$ for the frontal plane and $r = .85$ for the scapular plane.

Table 3 Test-retest reliability intraclass correlation coefficients for concentric and eccentric internal and external rotation in the frontal and scapular planes.

Test	Frontal plane	Scapular plane
Concentric internal rotation	.90	.89
Eccentric internal rotation	.94	.80
Concentric external rotation	.93	.76
Eccentric external rotation	.94	.93

DISCUSSION

The major finding of this study was that no significant differences existed between peak torque values obtained from the frontal and scapular planes. Isokinetic strength testing of the shoulder internal and external rotators within the scapular plane has several advantages to testing in the frontal plane. Abducting the arm within the frontal plane tends to place the glenohumeral joint into more of a closed packed position. This position may place undesirable stress on the soft tissues of an injured joint, and may even be uncomfortable for healthy subjects. Movement within the scapular plane minimizes tension/rotation of the inferior portion of the capsule and enhances stability of the glenohumeral joint by allowing a maximal amount of congruity between the head of the humerus and the glenoid fossa.[21] Because greater stability and increased comfort are important factors to consider when strength-testing or rehabilitating the shoulder, the scapular plane should be the preferred position.

Greenfield *et a1.*[9] found that assessing isokinetic strength of the shoulder internal and external rotators in the scapular plane changes the peak torque to body weight ratios for concentric external rotation. They evaluated the right extremity of 20 subjects (14 women and six men) in 45 deg of abduction in both the frontal plane and 30 deg anterior to the frontal plane. A test velocity of 60 deg/sec was used via the Merac system (Universal Gym Corporation, Inc., Cedar Rapids, IA). Subjects were tested in the standing position with no external stabilization. Only concentric measures were taken, but all measurements were found to be reliable *(r* = .81—.94) as evidenced by a test—retest procedure. They found external rotation peak torque to body weight ratio values to be significantly higher in the plane of the scapula than in the frontal plane.

Our findings of no significant difference in concen-

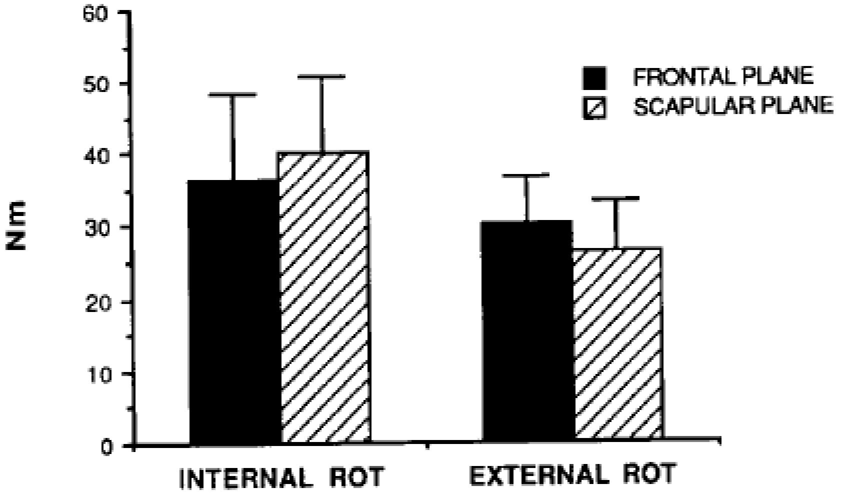

Figure 1 Concentric peak torque of the shoulder internal and external rotators (ROT) in the frontal and scapular planes.

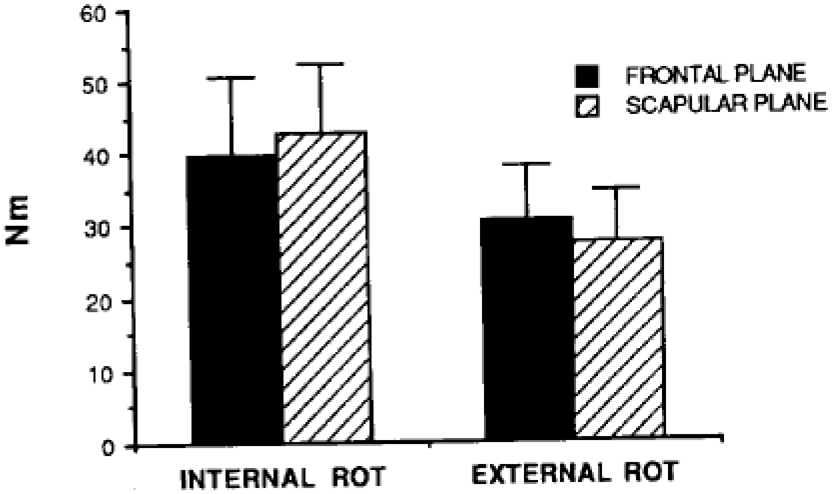

Figure 2 Eccentric peak torque of the shoulder internal and external rotators (ROT) in the frontal and scapular planes.

tric external rotation between the scapular and frontal planes *(Figure 1)* appears to be contradictory to those of Greenfield *et a1.*,[9] who found significantly higher external rotation values in the plane of the scapula. Direct comparison of the data from the two studies is difficult because of differences in methodology. Several factors could contribute to the apparent discrepancy, including subject positioning and stabilization, amount of abduction within the glenohumeral joint, and definition of the plane of the scapula position. Greenfield *et a1.*[9] concluded that placing the arm 30 deg anterior to the frontal plane may have changed the line of muscular pull for the infraspinatus and teres minor muscles. We defined the plane of the scapula to be 40 deg anterior to the frontal plane, as suggested by Kondo,[13] and expected to see results similar to, or even greater than, those of Greenfield *et al.*

Another possible explanation for differences between our study and the Greenfield *et al.* study is the method of testing. Their instrumentation allowed for the internal and external rotators to be assessed via continuous reciprocal contractions. That is, subjects concentrically contracted the external rotators immediately after concentrically contracting the internal rotators. Thus, each muscle group was placed on stretch immediately before maximal contraction, which may invoke the stretch reflex. With our instrumentation, the arm was statically positioned (for 30 sec in this study) before any contraction (concentric or eccentric) of either the internal or external rotator muscle group.

Also the preload requirements of our study as well as dynamometer variation could be significant. More research is necessary to determine the effect of preload (stretch) and mode of testing on the ability to generate torque.

No other investigations could be found that compared the frontal and scapular planes through an eccentric mode of contraction. In our study, the relationship between muscle groups and planes is similar for both eccentric and concentric mode's of testing *(Figure 2).*

ICCs calculated between the initial test and a retest performed 1 week later demonstrated the procedures followed in this study to be quite reliable. Farrell and Richards' reported ICCs of $r = .94—.99$, but their study examined the reliability of the KinCom independent of a human subject providing force to the dynamometer. No studies could be found on the reliability of upper extremity assessment using a KinCom dynamometer. The ICCs for our study ranged from $r = .90—.94$ for the frontal plane, but were lower for the scapular plane ($r = .76—.93$), with no evident pattern existing between rotation or type of contraction. A possible explanation may relate to the subjective nature of determining whether or not the subject was positioned within the scapular plane.

CONCLUSION

Twenty-one men were tested for nondominant shoulder rotation strength in the frontal and scapular planes using an isokinetic testing device. No significant differences were found for peak torque values between the two planes. Because there may be anatomical advantages to testing in the scapular plane, our findings of no difference support the clinical efficacy for testing shoulder rotator peak torque in the scapular plane rather than in the frontal plane.

REFERENCES

1. Bartlett L, Storey M, Simons B: Measurement of upper extremity torque production and its relationship to throwing speed in the competitive athlete. Am J Sports Med 17:89-91,1989.
2. Braatz J, Gogia P: The mechanics of pitching. J Orthop Sports Phys Ther 9:56-69,1987.
3. Brown L, Niehues S, Harrah A, Yavorsky P, Hirshman H: Upper extremity range of motion and isokinetic strength of the internal and external shoulder rotators in major league baseball players. Am J Sports Med 16:577585,1988.
4. Codman E: The shoulder. Boston, MA: Thomas Todd Co., 1934.
5. Cook E, Gray V, Savinar-Nogue E, Medieros J: Shoulder antagonistic strength ratios: a comparison between college-level baseball pitchers and non-pitchers. J Orthop Sports Phys Ther 8:451-461,1987.

6. Elsner R, Pedegana L, Lang J: Protocol for strength testing and rehabilitation of the upper extremity. J Orthop Sports Phys Ther 4:229-235,1983.
7. Farrell M, Richards J: Analysis of the reliability and validity of the kinetic communicator exercise device. Med Sci Sport Exer 18:44-49,1986.
8. Freedman L, Munro R: Abduction of the arm in the scapular plane: scapular and glenohumeral movements. J Bone Joint Surg 48A:1503-1510,1966.
9. Greenfield B, Donatelli R, Wooden M, Wilkes J: Isokinetic evaluation of shoulder rotational strength between the plane of the scapula and the frontal plane. Am J Sports Med 18:124-128,1990.
10. Hollinshead W, Rosse C: Textbook of anatomy. Fourth edition. Philadelphia, PA: Harper & Row, 1985.
11. Johnston T: The movement of the shoulder-joint—a plea for the use of the plane of the scapula as the plane of reference for movements occurring at the humoscapular joint. Br J Surg 25:252-260,1937.
12. Kondo M, Tazoe S, Yamada M: Changes of the tilting angle of the scapula following elevation of the arm. In: Bateman J, Welsh R, editors: Surgery of the shoulder. Philadelphia, PA: CV Mosby Company, 1984.
13. Lehmkuhl L, Smith L: Brunnstrom's clinical kinesiology. Fourth edition. Philadelphia, PA: FA Davis Company, 1983.
14. Macgregor A: Rotation at the shoulder—a critical inquiry. Br J Surg 24:425-438,1937.
15. Martin C: A note on the movements of the shoulder- joint. Br J Surg 20:61-66,1932.
16. Otis J, Warren R, Backus S, Santner T, Mabrey J: Torque production in the shoulder of the normal young adult male. Am J Sports Med 18:119-123,1990.
17. Pappas A, Zawacki R, Sullivan T: Biomechanics of baseball pitching. Am J Sports Med 13:216-222,1985.
18. Pawlowski D, Perrin D: Relationship between shoulder and elbow isokinetic peak torque, torque acceleration energy, average torque, and total work and throwing velocity in intercollegiate pitchers. Athletic Training 24:129-132,1989.
19. Perrin D, Robertson R, Ray R: Bilateral isokinetic peak torque, torque acceleration energy, power, and work relationships in athletes and nonathletes. J Orthop Sports Phys Ther 9:184-189,1987.
20. Poppen N, Walker P: Normal and abnormal motion of the shoulder. J Bone Joint Surg 58-A:195-201,1976.
21. Saha A: Mechanics of shoulder movements and a plea for the recognition of 'zero position' of glenohumeral joint. Clin Orthop 173:3-10,1983.
22. Soderberg G, Blaschak M: Shoulder internal and external rotation peak torque production through a velocity spectrum in differing positions. J Orthop Sports Phys Ther 8:518-524,1987.
23. Tullos H, King J: Throwing mechanism in sports. Orthop Clin North Am 4:709-720,1973.
24. Walmsley R, Szybbo C: A comparative study of the torque generated by the shoulder internal and external rotator muscles in different positions and at varying speeds. J Orthop Sports Phys Ther 9:217-222,1987.