RELIABILITY OF AN ECCENTRIC ISOKINETIC PROTOCOL INVESTIGATING THE SHOULDER INTERNAL AND EXTERNAL ROTATORS AT HIGH VELOCITIES

Guillermo J. Noffal, California State University Fullerton, Fullerton, CA USA

The purpose of this study was to determine the reliability of peak torque, total work and work ratios eccentrically at 300º/sec using the Biodex isokinetic dynamometer. Thirty healthy men and women volunteers who exhibited no prior history of glenohumeral injury were studied. The subjects were tested bilaterally, in the scapular plane, for eccentric internal and external rotation while seated. Three total sessions using identical protocols and separated by seven days were used to calculate intraclass correlation coefficients. The results indicated reliable coefficients ranging from 0.86 to 0.96 for peak torques and total work for the dominant and non-dominant shoulder as well as the internal and external rotators. However, the coefficients for the work ratio demonstrated low reliability and ranged from 0.01 to 0.29. Another protocol is needed to identify the fatigue properties of the shoulder rotators.

KEY WORDS: isokinetic, eccentric, work, scapular plane, fatigue, peak torques

INTRODUCTION: One in seven Americans has a musculoskeletal impairment costing the U.S. $215 billion yearly (Premer et al., 1999). In 1997, more than 5.9 million visits were made to physicians' offices due to shoulder problems (Premer et al., 1999). A large percentage of individuals participating in sports in which rapid shoulder rotations are employed (e.g. tennis, baseball, softball, volleyball) will develop a debilitating shoulder injury at some time. The exact mechanisms of the injury are still unknown yet the damage is often associated with one of the four small muscles on the posterior aspect of the arm, known as the rotator cuff. It is these muscles that are responsible for maintaining stability of the shoulder joint (Noffal, 1997). Many recent articles have addressed the need to strengthen this muscle group so it will better withstand the high forces associated with the dynamic nature of a fast arm swing, such as when throwing a ball for maximum speed. However, these strengthening programs do not address the fact that these injuries may be a result of overuse and research has indicated that strength alone is not sufficient to prevent repetitive motion injuries. Instead, the muscle may be better trained to exert sub-maximal efforts over a large number of repetitions and/or a prolonged period of time. Therefore, strong shoulders may not necessarily be fatigue resistant (i.e. capable of preventing overuse injuries.) Therefore, the need to test, strengthen and rehabilitate shoulders with the type of training that involves multiple repetitions rather than a maximal force paradigm may be worth investigating. The purpose of this study was to determine the reliability of a test/protocol used to fatigue the shoulder musculature. This study was unique in several ways. Firstly, the shoulder musculature was sampled as the muscles lengthened (eccentric activity) instead of past protocols which required the muscle to shorten (concentric activity). The advantage of this method is that the functional role of the rotator cuff musculature (in addition to maintaining shoulder stability) is to decelerate the arm during high-speed rotations, and it provides this deceleration as it lengthens. Secondly, this deceleration occurs in a short period of time, which signifies that the musculature should be tested at high speeds. The protocol used for this study utilized the fastest speed (i.e. 300 º/s) the isokinetic dynamometer was capable of generating. No previous studies have sampled the shoulder both as it lengthens and at this high speed. The reliability of the protocol was examined with intraclass correlation coefficients (ICCs) of several dependent variables. One of these dependent variables, a fatigue index, was calculated by dividing the work done in the last 10 repetitions by the work done in the first 10 repetitions. The lower this ratio the more the musculature has fatigued. The purpose of the present study was to determine the consistency or reliability of this fatigue measure over the course of three separate testing sessions.

METHODS: Thirty subjects (19 females [22.4± 1.9 years, 165.6± 6.8 cm, 62.0± 10.0 kg], 11 males [23.7±2.8 years, 179.9±6.8 cm, 87.6±16.2 kg]) signed a consent form and warmed-up on

an upper body ergometer prior to each testing session. A total of three visits to the lab were necessary to complete the study. The three sessions consisted of placing the subject in a seated test position (see Figure 1), comfortably accommodating the subject's arm and stabilizing the waist and trunk with straps to eliminate force contributions from these segments. The subjects were then instructed to exert maximal efforts over a range of 140º consisting of reciprocal internal (60º) and external (80º) rotations for 20 repetitions. Eccentric measures were determined at 300º/sec using the Biodex isokinetic dynamometer (Biodex Corp, Shirley, NY) in the passive mode. Subjects were given standardized verbal instructions (resist the movement of the handle as hard and as smoothly as possible throughout the entire range of motion) prior to commencing the test, and no visual feedback was allowed during the testing procedure. Subjects were positioned so the shoulders moved within the scapular plane and detailed measurements that included seat height, head tilt angle, head rotation, seat angle were taken so the exact position could be replicated in subsequent sessions.

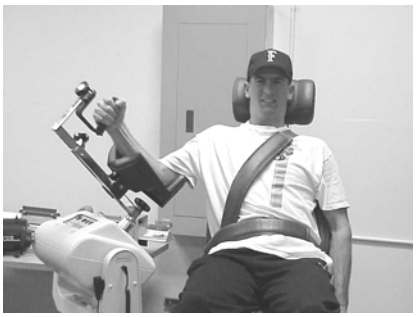

Figure 1 - Subject positioning for shoulder internal and external rotation in the plane of the scapula.

The sequence of testing the dominant versus the non-dominant shoulder was randomized to eliminate an order effect biasing the data. The same protocol was used for the remaining visits, which were spaced exactly one week apart reducing the effects of day-to-day changes in the development of force. The raw data was extracted from the system and input into a custom program for further analysis which included filtering, windowing and calculations of peak torque, work and work ratios. Intraclass correlation coefficients (ICCs) were calculated on several variables including, peak torque, total work, and a fatigue index (defined as the ratio of the work performed by the subject during the last ten repetitions and the first ten repetitions). These variables were calculated for the dominant and non-dominant arms, and, for the internal and external rotator musculature.

RESULTS AND DISCUSSION: Results are presented in Table 1 and Figures 2-3. The ICCs indicated good reliability of peak torques and total work ranging from 0.85 to 0.96, while the coefficients for the work ratio ranged from 0.01 to 0.29. The reliability of peak torque values found in this study is higher then the only other study investigating internal and external eccentric rotations. Frisiello and colleagues (1994) found ICCs ranging from 0.75 to 0.86 for dominant and non-dominant shoulders at velocities of 90 and 120º/s. The lower coefficients may have been related to the positioning of the subject in the Frisiello study. Subjects were placed in 0º of shoulder abduction and also stood next to the dynamometer. The contribution from the trunk musculature while in a standing position may have been harder to replicate in a test-retest design. The subjects in the present study were seated and the same procedure was followed to ensure that subsequent testing sessions replicated the original positioning by identifying the exact angles and distances between the dynamometer head and the subject's chair.

Table 1 Eccentric Internal and External Rotation Correlations for Peak Torque, Total Work and Work Ratios at 300 deg/s Between Testing Sessions 1, 2 and 3 (N=30)

	Internal						External					
	Dominant			Non-Dominant			Dominant			Non-Dominant		
	1-2	2-3	1-3	1-2	2-3	1-3	1-2	2-3	1-3	1-2	2-3	1-3
Peak Torque	0.90	0.90	0.91	0.92	0.89	0.88	0.95	0.95	0.94	0.96	0.91	0.90
Total Work	0.91	0.86	0.89	0.92	0.90	0.88	0.92	0.89	0.94	0.94	0.85	0.88
Work Ratio	0.29	0.04	0.10	0.14	0.29	0.29	0.01	0.11	0.02	0.28	0.15	0.01

Malerba et al. (1993) also reported mixed results for reliability of peak torques and total work. Their coefficients ranged from 0.44 to 0.92 and results indicated higher ICCs for the involved limb over the uninvolved limb and lower ICCs for external rotation compared to internal rotation. Montgomery and colleagues (1989) studied the reliability of absolute and relative endurance measures and reported ICCs of 0.92 for absolute measures, such as total work and average power, and low ICCs for relative endurance measures such as a work ratio comparing the first five repetitions to repetitions 21-25 on a leg flexion and extension concentric protocol. A possible explanation of the low ICCs found in both the present study, and those reported by Montgomery, may be partially explained by the fact that it was common for a subject to have a lapse or weak repetition during the course of the testing session. Both the fourth and fourteenth internal rotation repetitions, seen in Figure 2, are examples of this dramatic decrease in work when compared to the repetitions prior and just following them. These lapses influenced the work ratio as they occurred at different times over the three different sessions.

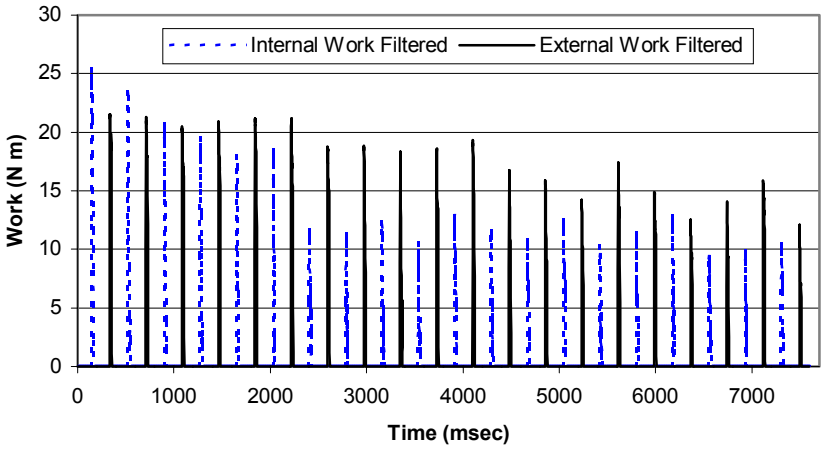

Figure 2 - Eccentric work of internal and external rotators during a 20 repetition testing session.

The consistency of the peak torques across days and the persistent greater peak torques in internal rotation over external rotation are demonstrated in Figure 3. Malerba et al. (1993) also reported higher eccentric internal over external peak torques in their study. The consistency of peak torque curves is linked to the high correlations found for that variable in this study yet the fluctuations across repetitions are linked to low correlation coefficients found in work ratios.
Some of the factors that may have also influenced the results include an element of fatigue or incomplete recovery between sessions. Several subjects reported prolonged soreness (varying from 4-8 days) after the first testing session. Apprehension towards equal amounts of discomfort or fear of injury in subsequent sessions may have affected their motivation. Thus, seven days of recovery may be too short for this particular population of untrained subjects. Another element

affecting concentration and motivation during a testing session may be related to the distracting nature of a busy laboratory conducting other activities concurrently.

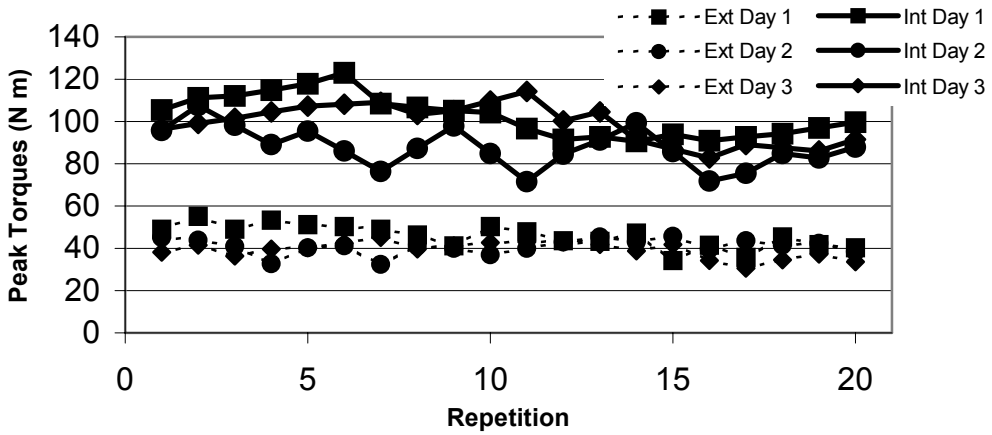

Figure 3 - Eccentric peak internal and external torques during a 20 repetition testing session of a representative subject.

CONCLUSION: Eccentric isokinetic testing of 30 volunteers using a fatigue protocol of 20 maximal-effort repetitions at 300º/s has identified reliable values for peak torque and total work, yet fatigue ratios remain unreliable. Results from this study indicate that a different protocol to measure fatigue in the shoulder internal and external rotators should be utilized. Once a reliable test to measure fatigue in the shoulder musculature has been established, athletes, coaches and clinicians may be better prepared to examine the relationship between injury and conditioning.

REFERENCES:

Frisiello, S., Gazaille, A., O'Halloran, J., Palmer, M. L., & Waugh, D. (1994). Test-retest reliability of eccentric peak torque values for shoulder medial and lateral rotation using the Biodex isokinetic dynamometer. *The Journal of Orthopaedic and Sports Physical Therapy,* **19**(6), 341-344.

Malerba, J. L., Adam, M. L., Harris, B. A., & Krebs, D. E. (1993). Reliability of dynamic and isometric testing of shoulder external and internal rotators. *The Journal of Orthopaedic and Sports Physical Therapy,* **18**(4), 543-552.

Montgomery, L. C., Douglass, L. W., & Deuster, P. A. (1989). Reliability of an isokinetic test of muscle strength and endurance. *The Journal of Orthopaedic and Sports Physical Therapy,* **10**, 315-322.

Noffal, G. J. (1997). Three dimensional kinetics of the shoulder and elbow joints in the high performance tennis serve: Implications for injury. *Unpublished doctoral dissertation, The University of Western Australia, Nedlands, WA.*

Premer, A., Furmer, S., & Rice, D. (1999) *Musculoskeletal Conditions in the U.S., second edition,* American Academy of Orthopaedic Surgeons, Rosemont, Ill.