

CONCENTRIC AND ECCENTRIC ISOKINETIC STRENGTH PROFILE OF SHOULDER ROTATORS IN ELITE JUNIOR TENNIS PLAYERS

Michele Forgiarini Saccol, Rogério Teixeira da Silva*, Guilherme Gracitelli**, Cristiano Frota de Souza Laurino* and Marília dos Santos Andrade**

Faculdade de Medicina da Universidade de São Paulo, São Paulo, Brazil

*Orthopedic and Sports Medicine Research Center (NEO), São Paulo, Brazil

**Federal University of São Paulo, São Paulo, Brazil

The purpose of this study was to evaluate concentric (con) and eccentric (ecc) isokinetic strength of shoulder rotators in elite junior tennis players. Shoulder rotator strength was measured bilaterally in 40 junior tennis players (26 male and 14 female) at 60 and 180°/s. Dominant internal rotation (IR) strength development was found for both sexes. Boys also had a dominance effect in the external rotators (ER) in both modes. This discrepancy between sexes also was evident in the unilateral strength ratio (ERcon/IRcon), with girls within the normal range and boys at a recommend level. In both sexes, the functional ratios (ERecc/IRcon) were lower than the ideal to prevent joint overloading. Exercises involving concentric and eccentric strengthening of external rotators are necessary to restore shoulder imbalances, especially for females tennis players.

KEY WORDS: tennis, shoulder, torque, isokinetic.

INTRODUCTION:

Isokinetic muscular concentric profiles of shoulder movements during tennis have identified significantly greater dominant arm concentric internal rotation (IR) strength with no bilateral difference in external rotation (ER) in elite, collegiate and adult tennis players (Chandler et al, 1992; Ellenbecker, 1991,1992). While these studies provided strength profiles, most did not functionally correlate the strength profile to the throwing motion.

The posterior rotator cuff acts to decelerate and stabilize the humerus during the follow-through phase of tennis serving and throwing motions. During these motions, explosive concentric and eccentric contractions are common. Eccentric muscular contractions play a role that is equally significant to concentric muscular contractions in functional activities and athletics (Ellenbecker et al, 1988).

Some authors reported relevant findings from these studies, and recent examinations have tried to establish a functional relationship among the muscles (Scoville et al, 1997; Noffal, 2003; Yildiz et al, 2006). A "functional ratio" includes eccentric testing of the shoulder external rotator muscles and concentric testing of the internal rotator muscles (Scoville et al, 1997). Previously, studies in asymptomatic competitive and recreational overhead athletes reported ratios ranging from 1.08 to 1.17 for the dominant shoulder, supporting the premise that eccentric external rotation torque should be greater than concentric internal torque (Scoville et al, 1997; Noffal, 2003; Yildiz et al, 2006; Ng & Lam, 2002). This difference is necessary to overcome and to decelerate not only the strength of the concentrically active internal rotators but also the other segmental forces associated with the dynamic nature of the throwing motion (Noffal, 2003).

The aim of this study was to perform an isokinetic evaluation of eccentric and concentric strength of the internal and external rotator muscles in elite junior tennis players and to compare the functional ratio and variables of muscular performance in dominant and nondominant shoulders.

METHODS:

Data Collection: Forty junior tennis players (26 male, 14 female) with a mean age of 14 years (range 12–18) took part in the study. Mean (SD) weight was 57.9 (15) and 53.9 (9.3) kg for the male and female players respectively, and mean (SD) height was 168 (14) and 163 (5) cm.

To take part in the study, tennis players had to belong to the Brazilian Tennis Confederation as a junior, be among the 50 best players in his/her category, and have no pathology in the dominant or non-dominant shoulders. A consent form was signed by the legal guardians of the subjects agreeing to voluntary participation in the study, which was in accordance with the rules of the university's ethics committee. The ethics committee of the Federal University of São Paulo officially approved the study.

Evaluations were performed with an isokinetic dynamometer (Cybex 6000; Cybex, Ronkonkoma, New York, USA). Subjects were allowed a five-minute warm up at 60 W on a Cybex brand arm ergometric device, followed by specific stretching exercises for the shoulder. After the warm up, subjects were positioned supine on the upper body-testing table and stabilized with bandages around the thorax and waist. Shoulder internal and external rotation performance was measured using reciprocal motions of the internal and external rotation with the shoulder in 90 degrees of glenohumeral joint abduction. Isokinetic testing was performed with 0 to 60 degrees of external rotation and 0 to 60 degrees of internal rotation, since gravity correction was not possible.

Shoulder internal and external rotators were tested at 60 and 180°/s concentrically and eccentrically for both upper limbs. The sequence performed for each speed was: three submaximum repetitions of the movement for familiarization, followed by five repetitions at 60°/s and five repetitions at 180°/s, with a one-minute rest between sets.

The muscle performance descriptive data analyzed in this study were peak torque in relation to body weight (PT/BW) in N.m per kg body mass and peak torque (PT) ratios between external and internal rotators of concentric (ERcon/IRcon) mode. We also calculated the PT functional ratio: eccentric strength of external rotator and concentric strength of internal rotation (ERecc/IRcon).

Data Analysis: Values are given as mean (SD) and comparisons were made for modes (concentric and eccentric), dominance, movement (internal and external rotators) and sex. The statistical analysis included paired samples *t* tests and an analysis of variance with repeated measures. A significance level of 0.05 was used.

RESULTS:

Table 1 presents the muscle performance and comparative data of concentric and eccentric evaluations for boys and girls. The data were significant for sex in all variables, with male players showing better results than female players ($p < 0.05$).

Comparing concentric and eccentric modes, the eccentric muscle action of ER produced significantly greater values than concentric action ($p < 0.001$). The eccentric internal rotation strength was significantly higher than concentric for both shoulders at 180°/s ($p < 0.05$).

DISCUSSION:

During athletic activity, concentric work to accelerate the limb forward, and eccentric work to control and decelerate this motion are critical for dynamic stability and optimal function (Yildiz et al, 2006). By assessing both types of muscle contraction, isokinetic studies can approach the functional throwing motion, although such studies cannot reproduce the complexity of the kinetic energy chain and angular velocity involved (van der Hoeven & Kibler, 2006).

As expected, eccentric isokinetic testing had a greater force production compared with concentric contraction at the same velocity. This result can be explained by the contribution of the noncontractile elements of the muscle-tendon unit to force generation under eccentric conditions (Ellenbecker and Davies, 2000).

Table 1 Peak torque over body weight (PT/BW) and peak torque ratios (external rotation percentage of internal rotation) of dominant and nondominant shoulder rotators in junior tennis players. Values are mean (SD).

	BOYS		GIRLS	
	Dominant	Non-dominant	Dominant	Non-dominant
CONCENTRIC				
IR at 60°/s	48,3 (9,1)	40,9 (9)**	40,2 (5,9)	27,9 (5,6)**
IR at 180°/s	42,6 (9,5)	35,8 (8,4)**	35,4 (5)	24,4 (4,9)**
ER at 60°/s	38,1 (6)	35,2 (6,7)*	30,3 (5,6)	27,3 (5,1)
ER at 180°/s	33,1 (6,1)	29,7 (6,8)**	24,2 (4,1)	23,2 (4,9)
ECCENTRIC				
IR at 60°/s	53,8 (14,6)	42,7 (11)**	41,8 (7,6)	30,9 (8,4)**
IR at 180°/s	49,6 (14)	43,2 (8,5)*	41,6 (7,8)	31,9 (8,2)**
ER at 60°/s	43,2 (9,3)	39 (7,7)*	36,1 (6,3)	31,1 (5,2)*
ER at 180°/s	45,3 (8,3)	41,6 (7,9)*	36,1 (4,2)	35,5 (7,8)
ERcon/IRcon				
at 60°/s	80 (14)	86 (9)*	75 (13)	97 (11)**
at 180°/s	79 (14)	83 (10)	68 (7)	96 (18)**
ERecc/IRcon				
at 60°/s	84 (42)	111 (31)*	91 (12)	103 (13)*
at 180°/s	97 (16)	120 (29)**	112 (16)	145 (16)**

ER, external rotation; IR, internal rotation; ecc, eccentric; con, concentric
 *Significant at the 0.05 significance level; **Significant at the 0.001 significance level

There was a significant effect of dominance and velocity for both sexes in internal rotation concentric and eccentric modes. The internal rotation strength increases are considered an adaptation to the serving motion (Chandler et al, 1992; Ellenbecker, 1991,1992, Ellenbecker et al, 1988; Gozlan et al, 2006).

Boys had a dominance effect for external rotators in both concentric and eccentric modes. Girls also had this dominance effect, but only in eccentric mode and at 60°/s. No previous study reported a finding that muscle function to decelerate demonstrated an increase in the dominant arm. We believe that this occurred as an effect of the range of motion that we used for testing: a middle range of throwing motion (60° of internal rotation to 60° of external rotation – a total of 120 degrees of freedom). This range of motion was used since gravity correction is not possible, and the majority of studies evaluating shoulder rotators strength do not provide gravity compensation data.

To provide muscular balance, ER/IR concentric ratio typically ranges between 66-75% for normal subjects and recreational athletes (Ivey et al, 1985 and Ng & Kraemer, 1991). Our results demonstrated that girls had dominant concentric ratios comparable with these values. Ellenbecker and Davies (2000) recommend a 10% increase in this normal ER/IR ratio to create a posterior-dominant motion that will stabilize the shoulder dynamically, preventing anterior glenohumeral translation. Boys had dominant external rotation strength development relative to the non-dominant side, changing the concentric ratios to the recommend level.

The role of the antagonist muscle is to fire in an eccentric manner to decelerate the motion of the agonist (Scoville et al, 1997). For medial rotation, this refers to the lateral rotators firing eccentrically (antagonists) to decelerate the concentrically firing medial rotators (agonists). Since an eccentric antagonist should be sufficiently strong to overcome and decelerate the agonist and forces accompanying the motion, a ratio greater than 1:1 would be expected (Scoville et al, 1997). These higher ratios are a function of greater external rotation eccentric

force production compared with concentric force at the same velocity (Ellenbecker et al, 1988).

Except for girls at 180°/s, the functional ratios on the dominant side were lower than 1 (100%), indicating that the eccentric strength of the external rotator muscles was not greater than the concentric strength of the internal rotator muscles. In addition, shoulder dominant functional ratios were significantly lower than ratios for the non-dominant shoulder.

Previous reports of tennis players are available only for ER/IR concentric ratios. To our knowledge, this is the first study describing functional ratios in tennis players. Test equipment, testing method (range of motion, velocity), populations (baseball, boxing, badminton and military overhead athletes) and age are factors that may account for the differences between our results and those of previous studies. Regarding this difference, all subjects demonstrated functional ratios above 1 in asymptomatic athletes. We suggest that our junior tennis players should achieve this ratio to prevent shoulder injuries.

CONCLUSION:

Bilateral concentric and eccentric isokinetic testing of junior tennis players showed significantly greater internal rotation strength on the dominant shoulder. Boys also had dominant external rotation strength development. This selective strength development increased the concentric ratios to a recommend level for males while the ratio for females remained only at the normal range. However, in both sexes, the functional ratios were lower than that considered necessary to prevent joint overloading. The restoration of shoulder adaptation involves strengthening the external rotator concentrically and eccentrically with minimal gains to internal rotator muscles.

REFERENCES:

- Chandler, J.T, Kibler, W.B, Stracener, E.C, Ziegler, A.K & Pace, B. (1992). Shoulder strength, power, and endurance in college tennis players. *American Journal of Sports Medicine*, 20(4),455-8.
- Ellenbecker, T.S, Davies, G.J & Rowinski, MJ (1988). Concentric versus eccentric isokinetic strengthening of the rotator cuff. Objective data versus functional test. *American Journal of Sports Medicine*, 16(1), 64-9.
- Ellenbecker, T.S (1991). A total arm strength isokinetic profile of highly skilled tennis players. *Isokinetic Exercise Science*, 1,9-21.
- Ellenbecker, T.S (1992). Shoulder internal and external rotation strength and range of motion of highly skilled tennis players. *Isokinetic Exercise Science*; 2,1-8.
- Ellenbecker, T.S. & Davies, G.J. (2000). The application of isokinetics in testing and rehabilitation of shoulder complex. *Journal of Athletic Training*, 35(3),338-50.
- Ivey, F.M., Calhoun, J.H., Rusche, K. & Bierschenk, J. (1985). Isokinetic testing of shoulder strength: normal values. *Archives of Physical Medicine and Rehabilitation*, 66(6),384-6.
- Ng, L.R. & Kraemer, J.S. (1991). Shoulder rotator torques in female tennis and nontennis players. *Journal of Orthopedic Sports Physical Therapy*, 13:40-7.
- Ng, G.Y., Lam, P.C. (2002). A study of antagonist/agonist isokinetic work ratios of shoulder rotators in men who play badminton. *Journal of Orthopedic Sports Physical Therapy*; 32(8), 399-404.
- Noffal, G.J. (2003). Isokinetic eccentric-to-concentric strength ratios of the shoulder rotator muscles in throwers and nonthrowers. *American Journal of Sports Medicine*; 31(4), 537-41.
- Scoville, C.R, Arciero, R.A., Taylor, D.C. & Stoneman, P.D. (1997). End range eccentric antagonist/concentric agonist strength ratios: a new perspective in shoulder strength assessment. *Journal of Orthopedic Sports Physical Therapy*; 25(3), 203-7.
- van der Hoeven, H. & Kibler, W.B. (2006). Shoulder injuries in tennis players. *British Journal of Sports Medicine*, 40(5), 425-40.
- Yildiz, Y., Aydin, T., Sekir, U., Kiralp, M.Z., Hazneci, B. & Kalyon, T.A. (2006). Shoulder terminal range eccentric antagonist/concentric agonist strength ratios in overhead athletes. *Scandinavian Journal of Medicine and Science in Sports*; 16(3), 174-80.