EFFECT OF THE MOTOR FUNCTION OF UPPER EXTREMITY ON THE VELOCITY OF TENNIS FLAT SERVE

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The purpose of this study was to investigate the effect of motor function of upper extremity on the velocity of tennis flat serve in young tennis athletes. Twenty adolescent tennis players without any shoulder injury or problems were recruited. The flat serve velocity, isokinetic strength of shoulder rotators, active shoulder joint motion and a series of physical factors were measured. Statistically significant relationships were found between serve velocity, and age, height, body weight, and circumferences of upper arm and forearm. The internal rotator strength in concentric contraction at 180°/sec isokinetic exercise, external rotator strength in eccentric contraction, and active shoulder abduction and flexion angles were also related to serve velocity. These findings may be useful in providing the basic guidelines for tennis training and evaluation.

KEYWORDS: tennis, flat serve, flexibility, shoulder rotator strength, upper extremity

INTRODUCTION: A powerful serve is one of the most effective weapons in today's tennis tournament. In the development and training of adolescent tennis player, most coaches want to achieve his/her faster serving velocity. Tennis serving is one kind of chain torque transfers action. Some reports showed that in the projectile motion like baseball pitching and tennis serving, an explosive contraction of the internal rotator was associated with accelerating linkage of trunk to extremity ultimately. It has been assumed that stronger muscle strength either powers the motion or provides joint stability during the torque transfer (Pappas, et al., 1985). However, the complex series motion has made it difficult to determine the physical factors affecting ultimate performance in these athletes. Some researchers had found that athletic performance has been related to muscular strength in certain activities (Wooden et al., 1992,). Other investigators have demonstrated differences in upper extremity flexibility between ballistic athletes and other individuals (Chandler, et al., 1990, Cohen, et al., 1994). As we know, only limited literature about the relationships between the serving velocity and muscle strength and shoulder flexibility in adolescent players has been available. Therefore, the purpose of this study was to investigate the effect of motor function of upper extremity on the velocity of tennis flat serve in young tennis athletes.

METHODS: Twenty adolescent tennis players aged from thirteen to twenty years, without any history of upper extremity symptoms, were recruited in this study. All of these subjects have at least two-year tennis practice experience. Before testing, all subjects were informed the detailed procedures and signed an informed consent form that described the possible risks and benefits of participation. Anthropometric parameters including height, weight, percent body fat and circumference of upper arm and forearm were recorded. Goniometric measurements included active wrist flexion/extension, forearm pronation/supination, elbow flexion/extension, shoulder flexion/ extension, shoulder abduction, and shoulder internal/external rotation at 0° and 90° of abduction. A hydraulic hand dynamometer was used in grip strength test and the average of three measurements was recorded. Serving was performed in a standard tennis court. Each subject was allowed to warm up his serving mechanics as necessary until ready for maximal effort serving. The subjects were asked to stand at baseline in one standard location and perform maximal serving attempts. The radar gun recorded five serves in an effective area. In data reduction, the highest and lowest serving velocity were excluded and the average of the remaining serves was obtained. With one-week interval, each subject also had isokinetic strength testing of his dominant shoulder. The Kin-Com isokinetic dynamometer (Chattanooga Corp., Chattanooga, TN) was used to measure maximum strength of both internal and external rotators in both concentric contraction and eccentric contraction while performing the isokinetic exercise at two different speeds, 60 and 180 deg/sec, respectively. Before testing, each subject performed submaximal warm-up contractions to become familiar with the machine. Three repetitions were made at each testing. Twenty seconds of rest were given between contractions, whereas two minutes of rest were given between velocities. The arithmetic mean was calculated. All measurements were corrected for gravity and the order of testing items were random. After completion of every testing, correlation analyses between serve velocity and anthropometric parameters such as age, height, weight, and circumferences of upper arm and forearm, active shoulder motion, shoulder rotator strength and grip strength were performed.

RESULTS: The anthropometric parameters of all subjects were shown in Table 1. Among these parameters, age, body weight, circumference of upper arm, and circumference of forearm have higher level of correlation with serve velocity with the correlation coefficient 0.821 for weight and 0.815 for circumference of forearm, respectively. In the isokinetic testing, internal rotation in eccentric contraction had the maximal torque followed by internal rotation in concentric, external in eccentric, and the minimum occurred in external rotation in eccentric contraction. In isokinetic testing, internal rotator strength in concentric contraction had higher correlation with serving velocity at 180°/sec (Table 2). The grip strength in dominant hand was greater than non-dominant hand. Statistically, the correlation between grip strength in dominant hand and serve velocity was significant (Table 3). The shoulder flexion and abduction had the largest values in flexibility measurements and shoulder flexion correlated highest with serving velocity (Table 4).

Table 1 Basic Anthropometrical Data of Subjects Enrolled in this Study and Their Correlation Coefficients with Serve Velocity

Parameters	Mean	Range	SD	Correlation coefficient
Age (years)	15	13-20	1.7	0.752
Height (cm)	169	159-177	5.1	0.659
Weight (kg)	56	41-70	7.5	0.821
% Body fat	14.2	3.8-20.9	4.0	0.582
Circumference of forearm (cm)	24.8	21-28	1.7	0.815
Circumference of upper arm (cm)	24.6	20-30	2.6	0.701

Table 2 Peak Rotator Strength in Isokinetic Exercise and Their Correlation Coefficients with Serve Velocity in the Dominant Shoulder

Speed	Contraction mode	Motion	Peak torque (Nm)	SD	Correlation coefficient
60°/sec	Concentric	IR	26.6	6.9	0.51
		ER	18.3	6.2	0.30
	Eccentric	IR	34.9	11.9	0.42
		ER	22.9	7.5	0.60
180°/sec	Concentric	IR	23.1	6.3	0.68
		ER	15.6	6.1	0.28
	Eccentric	IR	34.2	11.9	0.55
		ER	22.6	7.4	0.56

IR: internal rotation; ER: external rotation

Table 3 Grip Forces and Their Correlation Coefficients with Serve Velocity

Hand Dominance	Force (N)	SD	Correlation coefficient
Dominant	41.63	7.33	0.64
Non-dominant	35.89	5.90	0.55

Table 4 Goniometric Measures of Joint Motion in the Dominant Upper Extremities

Joint	Movement	Range of Motion (deg)	Correlation Coefficient
Wrist	Flexion	72.11	0.25
	Extension	77.53	0.03
Elbow	Flexion	136.84	0.27
Shoulder	Flexion	172.21	0.74*
	Extension	70.3	0.52
	Abduction	172.53	0.52
	Internal rotation at 0° of abduction	62.11	0.34
	External rotation at 0° of abduction	82.26	0.28
	Internal rotation at of 90° abduction	66.32	0.15
	External rotation at 90° of abduction	105.79	0.09

DISCUSSION: Tennis serving is one kind of chain of torque transfers action. That which factors are related to the ultimate serving performance is still controversial. Some researchers had found that several factors including technique, muscular strength, and flexibility were related to serving velocity. In this study, we attempted to analyze the effect of these factors on serving velocity at the adolescent players.

Some authors attempted to correlate strength measurements with athletic performance, most of them demonstrated that significant relationships between throwing speed (Wooden, et al., 1992) or serving speed (Cohen, et al., 1994) and strength. In the present study, we also found the strength of internal rotator in concentric contraction also correlated highly with serving velocity. It showed that in adolescent or elite player, stronger rotator strength would have faster serving

speed.
Some research in muscular biomechanics has showed that the physiological cross-sectional area (PCSA) of the muscle is proportional to its strength. Athletics usually have thin skin fat, the larger circumference of upper arm and forearm could also represent it has larger muscle PCSA. We also found significant relationships between the circumferences of upper arm and forearm and serve velocity. It is suggested that circumferences of upper arm and forearm may be used to evaluate the potential of player performance in serving. In addition, grip strength also highly correlated with serving velocity.
In the flexibility measurements, we found the shoulder flexion angle significantly correlated with serving velocity. The greater shoulder flexion angle provides longer period in acceleration phase. This parameter may be also a useful factor in evaluation of adolescent tennis player.

CONCLUSION: The effectiveness of a complex chain of motions such as tennis serve obviously depends on the technique as well as a complex interrelation of upper extremity strength and flexibility. We found that internal shoulder rotator strength in concentric contraction, age, height, body weight, circumferences of upper arm and forearm, and active shoulder flexion angle correlated significantly with the serving velocity in adolescent tennis player. The results could be able to provide the basic guidelines of the tennis training criteria during the long-term developmental process and the tennis evaluation.

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