JOINT POWER PRODUCTION DURING FLAT AND SLICE TENNIS SERVES

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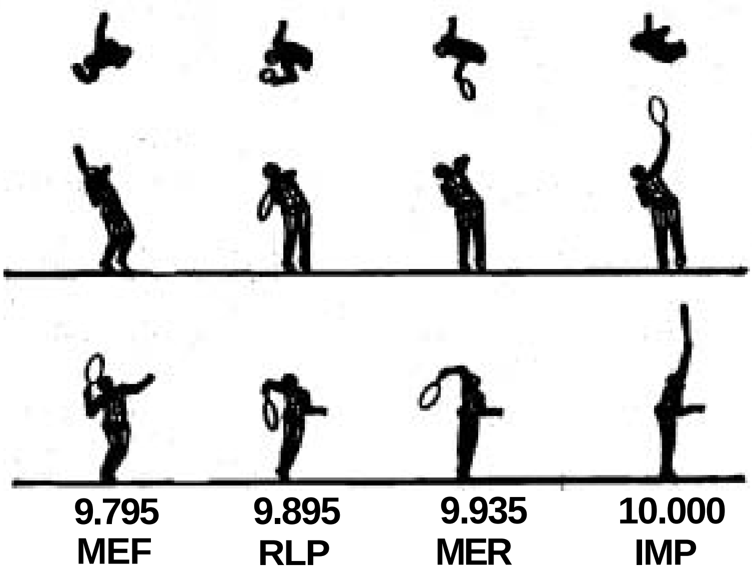
INTRODUCTION

Joint power calculations not only are related to muscle force, but they also provide information on the changes in muscle length and the type of load produced (eccentric/concentric) (Andrews, 1983; Winter, 1990). Of the kinetic analyses of the serving arm in tennis (Legnani & Marshall, 1993; Bahamonde, 1994) none have looked at mechanical power produced by the joints. Therefore, it was the aim of this study to compute the joint power developed at the wrist, elbow, and shoulder joints during the performance of flat and slice tennis serves.

METHODS

Five male, right-handed collegiate tennis players were filmed using the DLT method of 3D cinematography. Film analysis procedures and quintic spline flinctions were used to calculate and to smooth the 3D coordinates of the landmarks, respectively. The following events were defined: ball toss (BAT); maximal elbow flexion (MEF); racket lowest point (RLP), start of forward swing; maximum external rotation (MER); and impact (IMP) (Figure 1 below).



The serving arm was modeled as three-link kinetic chain made by the racket/hand, forearm, and upper arm segments. Rigid body kinematics and the inverse dynamics approach were used to calculate the resultant torque and force at each joint (Bahamonde,1994; Feltner & Dapena, 1986). Joint power (Pj) was calculated as the product of the components of the resultant joint torque (Tj) and the joint angular velocity (ωj) (Winter,1990).

RESULTS

Table 1 shows the average joint power values for each joint during the periods of BAT-MEF and MEF-RLP (backswing phase) and RLP-MER and MER-IMP (forward swing phase). Tables 2-3 show the mean joint power values at the specific events. Positive values indicate concentric muscular contractions (joint tarque and joint angle acting in the same direction) while negative values indicate eccentric muscular contractians (joint torque or joint angle acting in opposite directions).

Table 1.

Average Joint Power (Watts) Values for tht: Flat and Slice Servt:s

Period	Wfl/ext	Wul/rad	Pro/Sup	Elfex/ext	Int/ext rot	Hor ab/ad	Ab/add
BAT/MEF	0±1	1±1	1f2	15s	4±6	4±5	3±7
	1±1	1±1	1±1	15k7	5k6	6±8	4±9
MEF/RLP	4±4	-2±8	5±5	8±15	-204±86	65±38	-21±49
	-3±4	41±1	4f4	11±5	-164±75	18±73	-9±38
RLP/MER	4k7	4±21	-21±5	67±49	-220±72	-16±64	-118±82
	4k7	44±52	15±15	41±59	-205±116	-16±57	-101±53
MERIIMP	214±150	331±293	38±351	388±345	1154±1779	-11±262	59±331
	121±135	160±121	178±455	317±187	723±931	-33±63	53±179

Table 2.

Shoulder Joint Power (Watts) Values for the Flat and Slice Serves at the Events of MEF, RLP. MEF IMP.

Event	Int/ext rot.	Hor ab/ad	Ab/add
MEF	-62±55	-21±112	4±9
	-21±65	·12B8	8±27
RLP	447±106	41±228	-102±87
	-388±102	-18±176	104±57
MER	125±85	47±4	8±141
	74±214	-8±80	-33±132
IMP	6190±9963	271±1359	-411±1047
	4145±6002	-119±501	426±1187

Table 3.

Wrist & Elbow Joint Power (Watts) Values for the Flat and Slice Serves at the Events of MEF RLP MEF. IMP.

Event	Wfl/ext	Wul/rad	Pro/Sup	Elflex/ext
MEF	-5±10	3±7	21±16	10±14
	-1±6	-1±10	3+6	2±6
RLP	-11±14	-33±27	8±13	6±14
	-11±20	-27±22	8±19	4±40
MER	1±20	146±165	25±22	148±127
	-7±5	-62394	25f18	67±85
IMP	1144±1010	845±1207	-354±2338	1010±890
	776±1451	294±435	1722±4978	1125±748

DISCUSSION

The joint power values for all joints during the period between BAT-MEF were small and were the result of concentric contractions of the muscles to place the arm in MEF. From MEF to RLP, the rotation of the trunk produced a forced external rotation of the upper arm (Bahamonde, 1994; Feltner & Dapena, 1986; Chung, 1988). To prevent the forced external rotation of the upper arm, the internal rotation musculature produced large eccentric contractions (Tables 1-2). The internal rotation muscles continued to contract eccentrically until the event of MER. During the period of MEF-RLP the external rotation of the upper arm and the upward thrust developed by the legs, which is transmitted through the trunk and shoulder, horizontally abducted the upper arm (see Figure 1, RLP) (Elliot, 1994). To cancel out this effect the horizontal adduction musculature contracted concentrically to elevate the upper arm to the elbow high position (Figure 1 MER). Meanwhile, due to the external rotation of the upper arm, eccentric contraction of the adductors muscles were necessary to prevent the backward movement of the upper arm in the transverse plane (normally horizontal adduction).

From RLP-MER the internal rotators continued to produce large eccentric contractions, while the power generated by the horizontal abdiadductors changed directions due to the development of small horizontal abduction torques, probably used to slow down the upward motion of the upper arm. It is also during this period that the shoulders rotation was at its peak. This rotation produced an inertial lag of the upper arm, but because of the excessive external rotation of the upper arm and the tilting of the trunk ,the adductors muscle contracted eccentrically, preventing the inertial lag and accelerating the upper arm downward in a hammering type of motion. From MER to IMP most of the joint power was developed by the shoulder internal rotators which produced large concentric contractions.

The elbow joint produced concentric contractions throughout the serving motion. From BAT to MEF the joint power was used to flex the elbow, then from RLP-MER the elbow began a slow extension followed by a forceflil concentric contraction of the elbow extensors prior to impact (Tables 1 & 3). The forceful pronation of the forearm prior to impact was also achieved through concentric muscular contractions.

The wrist joint power values were relatively small until the period of MER-IMP, when the ulnar deviation and flexor muscle produced large concentric contractions to accelerate the racket prior to impact.

CONCLUSIONS

Large eccentric loads (pre-stretching) were placed on the internal rotator muscles during the late portion of the backswing and the early forward swing, changing into concentric loads prior to IMP. Elbow loads (extension and pronation) were concentric throughout the forward swing. Wrist concentric (flexion and ulnar deviation) loads increased in magnitude near impact (MER/IMP). In general, the magnitude of the joint power values were larger for the flat serves than for the slice serves. The joint power needed to accelerate the racket was the result of shoulder internal rotation and adduction, elbow extension and pronation, and wrist flexion and ulnar deviation.

This information would be valuable to coaches and teachers for the improvement of the performance of players and students. It would also be useful for athletic trainers and sports medicine professionals in the assessment and rehabilitation of injuries related to the tennis serve.

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