ANGULAR MOMENTUM TRANSFER DURING A POWER TENNIS SERVE

Brian J. Gordon and Jesús Dapena

Biomechanics Laboratory, Dept. of Kinesiology, Indiana University,
Bloomington, IN, USA
E-mail: bgordon@indiana.edu

INTRODUCTION

The racquet speed needed for a power tennis serve requires a large amount of angular momentum in the hand+racquet segment just before impact. This angular momentum is a function of the angular momentum acquired by the legs from the ground, and its transfer through the body to the hand+ racquet segment. The purpose of this study was to measure the transfer of angular momentum to the hand+racquet segment in a power tennis serve.

METHODS

Eight NCAA Division I players were filmed with three motion-picture cameras. The DLT method was used to compute three-dimensional (3D) coordinates of body and racquet landmarks. The 3D coordinates were expressed in an orthogonal reference frame in which the X axis pointed to the right, the Y axis forward, and the Z axis up. Instantaneous angular momentum values were calculated for the individual body segments and for the racquet, relative to the body+racquet system center of mass (c.m.), from the instant of maximum knee flexion (MKF) to ball contact at 0.01 s intervals. Calculations were based on Dapena (1978). To simplify the analysis, the angular momentum terms for the segments and racquet were combined into six sub-systems: legs, trunk+head, left arm, hitting upper arm, hitting forearm, and hand+racquet. Transfers of angular momentum were expressed by the angular impulses exerted on each sub-system at its endpoints. These terms did not include the angular impulses of the sub-system weights about the system c.m. All values were averaged across subjects, and analyzed over three periods defined by: (1) MKF to racquet horizontal (HOR) in the backswing; (2) HOR to racquet head low point (RLP) at the end of the backswing; (3) RLP to contact.

RESULTS AND DISCUSSION

The Z components of angular momentum were small, and the Y components served mainly to position the system. The generation of racquet speed was driven primarily by the X components of angular momentum. Thus, the analysis focused on the acquisition and transfer of the X component of angular momentum, described as clockwise (CW) or counterclockwise (CCW) in relation to the view from the right side. To facilitate interpretations, CW values were considered positive.

The transfer of angular momentum between MKF and HOR is illustrated in Figure 1a. The legs received a large CW angular impulse from the ground. Most of it was transmitted to the trunk, where it accumulated. Only a small fraction was passed on to the hitting arm segments.

The transfer of angular momentum between HOR and RLP is illustrated in Figure 1b. The angular impulse to the system was much smaller. The trunk received angular momentum from the left arm and from the legs. Most of it was transmitted to the hitting upper arm, and half of this was passed on to the hitting forearm.

The transfer of angular momentum between RLP and contact is illustrated in Figure 1c. The legs lost angular momentum to the ground. Transfer of angular momentum into the trunk from the left arm was mostly negated by a small transfer from the trunk to the legs. The angular momentum stored in the trunk during the previous periods was transmitted through the hitting upper arm and forearm to the hand+racquet segment.

It has been speculated (Bahamonde, 2000) that the angular momentum transfer from the trunk to the hitting arm in the late part of the period between RLP and contact might be the result of torques exerted by the trunk extensor muscles. However, this would require the large transfer of CW angular momentum to the hitting arm to be coupled with a large transfer of CW angular momentum to the legs. In the present study, the transfer of CW angular momentum to the legs was very small. This suggests that the flow of CW angular momentum from the trunk to the hitting arm is due primarily to direct interaction of the trunk with the arm, and not a function of trunk extensor torque.

SUMMARY

Large amounts of angular momentum are first accumulated in the trunk during the backswing, and then transmitted to the racquet during the upward swing. Trunk extensor torques do not seem to play an important role in the final transmission of angular momentum to the hitting arm.

REFERENCES

Bahamonde, R.E. (2000). *J. Sport Sciences*, **18**, 579-592.

Dapena, J. (1978). *J. Biomechanics*, **11**, 251-256.

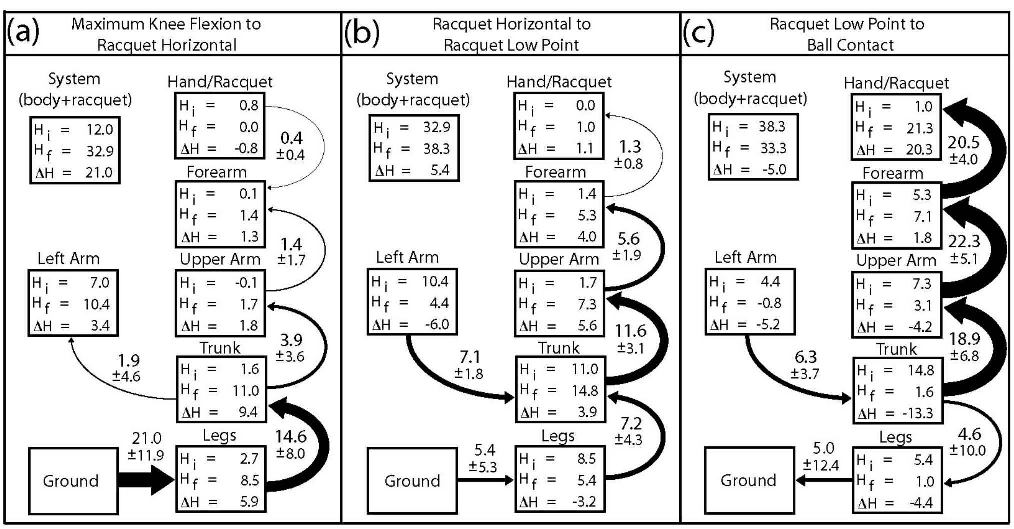

Figure 1: Angular momentum flow diagrams for the three periods: (a) MKF to HOR; (b) HOR to RLP; (c) RLP to contact. Boxes represent the six segment sub-systems, the body+racquet system, and the ground. Initial (H_i) and final (H_f) angular momentum (kg·m^2/s) about the X axis, and its change (ΔH), are given for each sub-system. The arrows and the values next to them show the directions and sizes of the angular momentum transfers (N·m·s).