THE EFFECTS OF THE KINEMATIC LINK PRINCIPLE ON PERFORMANCE

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INTRODUCTION

Newton's Third Law of Action-Reaction has been widely cited as the law that is in operation in striking activities such as smashing a badminton shuttlecock or serving a volleyball (Northrip et al., 1983; Adrian and Cooper, 1989; Gowitzke and Milner, 1988; Kreighbaum and Barthels, 1990). Traditionally, athletes in these striking activities are instructed to "plant" their feet firmly against the ground so that all the reaction forces generated can be harnessed as the effective force.

On the other hand, Gowitzke (1979) pointed out that success in many physical activities often depends upon maximum speed of movement, especially of an extremity. Indeed, the Kinematic Link Principle stated that when maximal force is desired in the striking activities, the striking implement should accelerate to the maximal velocity at the instant of impact. Since the motions of one body segment are affected by the motions of the proximal and distal segments, all body parts should ideally be accelerating sequentially.

The Kinematic Link Principle was not widely used by the coaches and the players. The dilemma for a badminton player who attempts to smash the shuttlecock is whether to stay on the ground to smash, as prescribed by Newton's Third Law, or jump to smash, as suggested by the Kinematic Link Principle in order to allow more segments to be employed in the maneuver. Game situations aside, a volleyball player faces the same predicament as the badminton player when serving a volleyball.

The purpose of this study was to determine and compare the effects of the Kinematic Link Principle on performance. More specifically, the purpose of this investigation was to determine and compare the effect of the Kinematic Link Principle on executing the standing smash and the jump smash
in badminton.

METHODOLOGY

A high speed locam camera operating at 200 fps was used to film three highly skilled badminton players performing the smashes. The subjects were required to smash as powerfully as possible with the shuttlecock being served high to them. A successful trial was recorded if the shuttlecock cleared the net and landed in the opponent's court. A Vanguard Motion Analyzer was used to digitize the films. In both the jump smash and the standing smash, three successful trials with the fastest initial shuttlecock velocity were used for further analyses. The same camera, operating at 150 fps was used to film three collegiate volleyball players performing serves. The subjects were required to serve the ball as powerfully as possible. A successful trial was recorded if the ball cleared the net and landed in the opponent's court. In both the jump serve and the standing serve, three successful trials that produced the fastest initial ball velocity were used for further analyses.

RESULTS and DISCUSSION

The kinematic data from this study indicated that in both the jump smashes (serves) and the standing smashes (serves), the Kinematic Link Principle was indeed at work. The velocities of the lower extremities were transferred to the trunk, and the trunk to the upper extremities, and finally, the racket (hand).

A comprehensive comparison of the badminton smashes and the volleyball serves is shown in Table 1 and graphically represented in Figure 1 and 2. The overall mean of the racket parameters in the badminton smashes and the overall mean of the hand parameters in the volleyball serves were used for the comprehensive comparison because these parameters were directly proportional to the initial shuttlecock or ball velocity. Also, the hand was compared to the racket because both were used as the striking implements.

Table 1. Comprehensive comparison of the badminton smashes and volleyball serves.

	Initial Projectile Velocity (m/s)	Linear Velocity at contact (m/s)	Angular Velocity at contact (rad/s)	Ave. Angular Vel. (rad/s)
Badminton				
Jump	65.72	58.79	113.36	41.33
Stand	54.26	52.37	65.15	38.05
Ratio	1.21	1.12	1.74	1.09
Volleyball				
Jump	22.67	23.12	52.97	28.13
Stand	19.99	20.84	34.38	22.08
Ratio	1.13	1.11	1.54	1.28

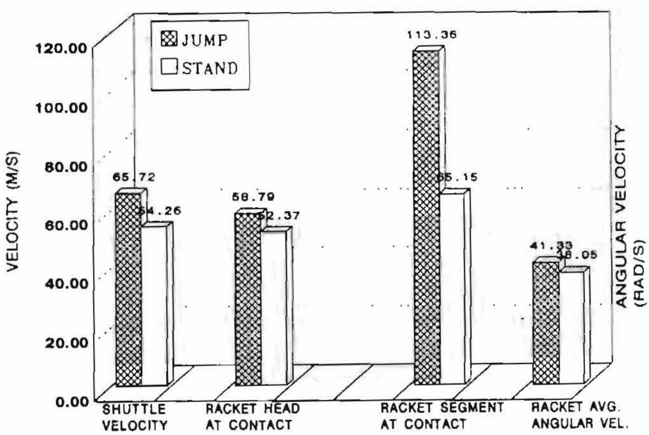

Figure 1. Comprehensive comparison (badminton).

The data for the jump smashes were consistently higher than that of the standing smashes. The transfer of the velocities of the body segments was apparently more effective during the jump smashes. The differences in producing the initial shuttlecock velocity were due mainly to the differences in range of motion (ROM). The larger ROM in the jump smashes resulted in faster angular velocities in the trunk, upper extremities, and the racket. The faster racket velocity was translated into a faster initial shuttlecock velocity. The ROM was greater in the jump smashes because the lower extremities were free to rotate while airborne. Therefore, the data from this study suggest that the Kinematic Link Principle was more effective when a badminton player jumped to smash.

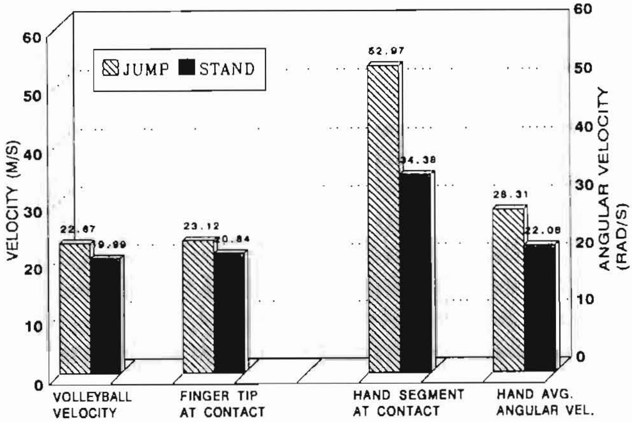

Figure 2. Comprehensive comparison (volleyball).

The data for the jump serves were consistently higher than that of the standing serves. The data suggested that the transfer of the velocities of the body segments was more effective during the jump serves. The differences in producing the initial ball velocity were also due mainly to the differences in ROM. The larger ROM resulted in a faster angular velocities in the trunk, upper extremities, and the hand. The angular velocity of the hand was then transferred to the ball, resulting in faster initial volleyball velocity. The ROM was greater in the jump serve because the lower extremities were free to rotate while airborne. The data from this study indicated that the Kinematic Link Principle was more effective when a volleyball player jumped to serve the ball.

Since the mass of the shuttlecock and the mass of the volleyball represent two extremes on a continuum, the relative effect of the Kinematic Link Principle on the badminton jump smash and the volleyball jump serve was further analyzed. The ratios presented in Table 1 were obtained by dividing the kinematic data from the jump performance by the kinematic data from the standing performance. Hence, the ratios represent the relative change from standing to jump performance.

The ratio of the overall mean of the initial badminton shuttlecock velocity was higher than the ratio of the overall mean of the initial volleyball velocity. This suggests the relative effect of the Kinematic Link Principle was more effective for the badminton players. This is partly due to the fact that the mass of the shuttlecock was relatively lighter and thus required less force to propel it forward, thus making the Action-Reaction Law less important. The relatively heavier mass of the volleyball required the subjects to exert a greater force to serve the ball, thus making the Kinematic Link Principle less important.

The ratio of the racket head velocity at contact during the badminton jump smash was higher than the ratio of the finger tip velocity at contact during the volleyball serve. This suggests that the Kinematic Link Principle was more effective during the badminton jump smash because the racket head velocity at contact was the result of more effective summation of velocities from the other segments. During the badminton smash, the velocities of the upper extremities, in particular, were increasing from the elbow to the wrist, and from the wrist, to the racket head.

The ratio for the angular velocity at contact for the hand/racket segment was higher during the badminton smash. This suggests that the Kinematic Link Principle was more evident during the badminton performance because the subjects were able to generate a relatively faster angular velocity during the badminton jump smash when compared to the volleyball jump serve.

The ratio of the average angular velocity between the jump performance and the standing performance were higher for the volleyball subjects. This is due to the fact that the volleyball subjects were moving through a larger range of motion during the jump serve. Also, to overcome the Action-Reaction Law during the jump serve, a more dynamic movement is needed than in the badminton jump smash. In addition, the badminton subjects were jumping straight up and down during the jump smash. Since the average angular velocity was obtained primarily through the movement along the x-axis, the movements of the badminton subjects were not as revealing.

CONCLUSIONS

Within the limitations of this study, the following conclusions seem pertinent:

1. The Kinematic Link Principle operates in both the standing smashes (serves) and the jump smashes (serves).
2. The Kinematic Link Principle is more effective during the jump smashes (serves) when compared to the standing smashes (serves).
3. The Kinematic Link Principle is relatively more effective in the badminton jump smash than in the volleyball jump serve.
4. The Kinematic Link Principle is more effective when striking a lighter object (shuttlecock) when compared to striking a heavier object (volleyball).
5. While Newton's Law of Action-Reaction is more effective in the standing serve/smash, the advantage of the Kinematic Link Principle in the jump serve/smash more than offsets the advantage extended by Newton's Law of Action-Reaction.

REFERENCES

Adrian, M. J. and Cooper, J. M. (1989). The Biomechanics of Human Movement. Indianapolis, IN: Benchmark Press.

Gowitzke, B. A. (1979). Biomechanical principles applied to badminton stroke production. In Science in Racquet Sports. J. Terauds (ed.). pp. 7-15. Del Mar, CA: Academic Publishers.

Gowitzke, B. A. and Milner, M. (1988). ScientificBases of Human Movement (3rd ed.). Baltimore, MA: Williams & Wilkins.

Kreighbaum, E. and Barthels, K. M. (1990). Biomechanics (3rd ed.). New York: Macmillan.

Northrip, J. W., Logan, G. A., McKinney, W. C. (1983). Analysis of Sport Motion (3rd ed.). Dubuque, IA: Wm. C. Brown.