EFFECT OF GRIP MODELS ON REBOUND ACCURACY OF OFF-CENTER TENNIS IMPACTS

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INTRODUCTION

Shot accuracy is of primary importance in tennis play. This shot or rebound accuracy refers to the angle of rebound of the ball off the racket face which determines the placement of the shot in the opponent's court. Unfortunately, there are only a few studies that have examined the effect of string and impact conditions on rebound accuracy. For central impacts on the racket face, Knudson (1991a) found that string tension, the type of string, and the interaction of tension and string type all significantly affected the angle of rebound. String tension has also been found to significantly interact with impact location on the racket face in affecting rebound accuracy for central and off-center impacts (Knudson, 1993). Despite the complicated interactions of impact location with string type and tension, these studies indicated that lower string tension created more accurate rebounds. These results were opposed to the common perception of most tennis players.

Could these results be due to the clamped conditions used in these studies? In these studies, rackets were firmly immobilized with C clamps for experimental control. Recent modeling and theoretical evidence suggests that hand-held rackets in tennis may behave mechanically at impact as if they were unrestrained (Brody, 1987b; Casolo & Ruggieri, 1991; Hatze, 1992,1993). A recent study of rebound accuracy of off-center tennis impacts with free standing rackets found that higher string tensions created more accurate rebounds (Knudson, 1997). This supported player and expert opinion, and also suggested that previous rebound accuracy studies could be influenced by the clamped impact conditions. The purpose of this study was to compare the rebound accuracy of clamped, hand held, and free standing grip models in off-center tennis impacts. Impact conditions were modeled to be similar to tennis play with the ball approaching the racket at an angle (Brody, 1987a), and the impact occurring off-center (Knudson, 1991b; Ohmichi, Miyashita, & Mizumo, 1979; Plagenhoef, 1979).

METHODS

A Prince oversized racket was strung with nylon (16 gauge) at 311 **N** of tension. The racket was stood on end in a vertical position 0.76 m from a new Match Mate ball machine. Racket position was standardized with markings and a carpenters square attached to an immobilized bench. The ball approached the racket at a 14 degree angle (Figure 1) to simulate a stroke hitting the ball on the rise. The racket models studied were free standing (FS), hand held (H), and clamped (C). For the C model the racket was immobilized by two 0.15 m C clamps to a base that was secured to the bench. In the H model the racket was held in an eastern forehand grip with "moderate" grip pressure by a skilled tennis player.

Six new tennis balls were bounce tested and projected from the ball machine at 24.1 ± 0.2 **m/s.** Impact location on the racket face was checked by fifteen (five prior to each tension condition) measurements of ball imprints made on paper taped to the strings. ANOVA revealed that mean impact locations were not significantly different across models ($F = 0.97$, $p = 0.41$). Impacts occurred laterally off center (20 ± 5 mm).

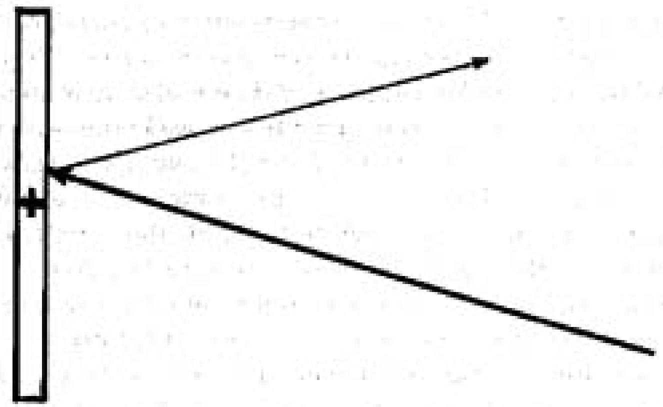

Figure 1. Top view schematic of impact conditions. Lateral deviation of ball rebound in this transverse plane was measured.

Rebound accuracy was measured as the lateral displacement of the ball when impacting the wall 1.52 m from the racket. Lateral displacement measurements were made to ball imprints made by carbon paper on poster board taped to the wall. The smaller this displacement, the more accurately the racket/grip system directed the ball back toward the ball machine. This horizontal plane measurement eliminated the effect of gravity, and simulated the vertical plane accuracy of ball rebound in tennis shots. Displacement data for twelve impacts for each model were analyzed with a one-way ANOVA and Tukey-Kramer HSD post hoc tests at the $p < .05$ level of significance.

RESULTS AND DISCUSSION

Grip model significantly ($F_{2, 33} = 11.4$, $p < 0.05$) affected lateral displacement of ball rebound. Tukey-Kramer HSD post hoc tests demonstrated that the rebound accuracy of the C model was significantly ($p < 0.05$) more accurate than the H and FS models. There was no significant difference in rebound accuracy 'between the F and H models. Figure 2 illustrates the mean and SD of observed lateral displacement. These displacements correspond to mean angles of rebound (measured normal to the racket face) of 14.6, 16.3, and 17.0 degrees for C, H, and FS respectively.

The ANOVA analysis demonstrated that 41% of the variance in rebound accuracy was due to grip model ($h2 = 0.409$). It is clear that gripping condition affects the ball angle of rebound in quasi-static tennis impacts, like volleys or service returns. It is unknown if this grip effect will also apply to dynamic strokes, where ball rebound angles are pulled more in line with normal to the racket face (Brody, 1987a). Since tennis players experience significantly increased upper extremity loading in off-center impacts (Hennig, Rosenbaum, & Milani 1992; Knudson, 1991b; Plagenhoef, 1979), their perception of a loss in shot accuracy in volleys impacted off-center Knudmay be exaggerated. If the nonsignificant difference in rebound accuracy observed in FS and H conditions generalizeto other impact conditions, player perceptions about errant off-center shots being related to a lack of grip pressure may be in error.

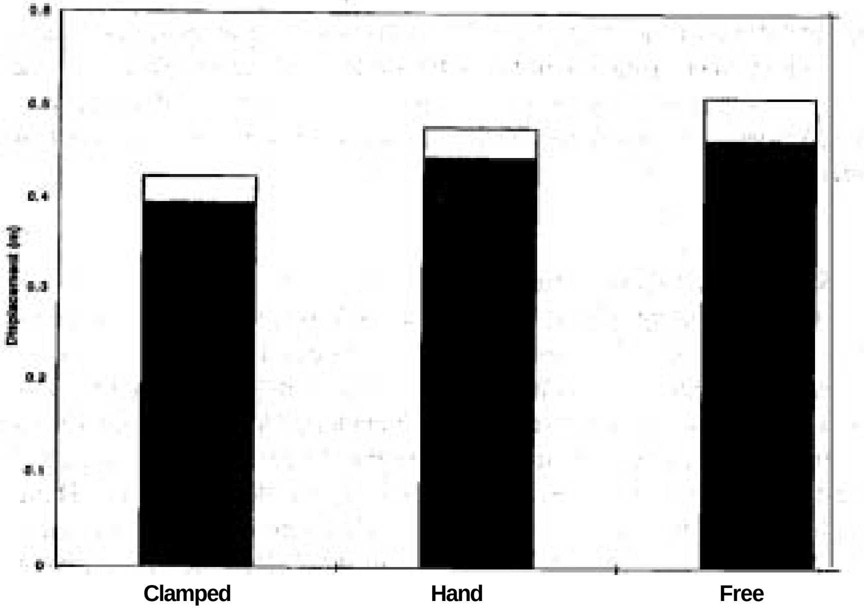

Figure 2. Mean and SD lateral displacements of the three grip models. The smaller the displacement, the more accurate the ball rebound. The Clamped condition was significantly more accurate ($p < 0.05$) than the hand held or free standing conditions.

CONCLUSIONS

The present study supported the hypothesis that C grip models significantly affect rebound accuracy of off-center impacts. The C grip model created significantly ($p < .05$) more accurate rebounds than the FS or H models. These data are the first experimental confirmation that rigidly clamped models of tennis impacts do not accurately represent the rebound accuracy of hand held rackets. Since most impacts occur off-center on the racket face during tennis play (Knudson, 1991b; Plagenhoef, 1979), studies of rebound accuracy in tennis should use H or FS models rather than C models. Previous studies of tennis impact mechanics using clamped racket models should be interpreted with caution.

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