A COMPARATIVE STUDY BETWEEN CROSS AND DOWN-THE-LINE FOREHAND DRIVES UNDER CHOICE REACTION CONDITION IN SOFT-TENNIS

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The purpose of this study was to clarify the mechanics involved in making two different shots, namely, cross (C) and down-the-line (D), under a two-choice reaction condition in soft-tennis. Using the images from two high-speed cameras, forehand drive motions under these conditions were analyzed with the direct linear transformation procedure. The authors considered that for the selected objects of analysis, the experimental environment significantly affected the actions. Anatomical rotations of the upper extremity and center of gravity (COG) of the subjects during forehand motions were compared between C and D. Some differences were observed in the external rotation of the shoulder and the lateral component of COG. The results were discussed from the perspective of the way in which expert players made ball-racket contact under the choice reaction condition. This was considered to be a high time-pressure condition.

KEY WORDS: choice reaction condition, soft-tennis, cross and down-the-line shot

INTRODUCTION: Soft-tennis is played using a light racket and with rubber balls. Usually, the doubles game is played in the one-up-one-back formation. With this formation, the baseline player is faced with an opponent's volley for the most part of the match and has to avoid losing points during volleys or by smashes executed by the opponent. For this purpose, the baseline player has to identify the position of the opponent's volley prior to initiating the forward swing. Thus the baseline player has to execute his or her drives, under a high time-pressure (HTP) due to a time constraint. Skilled players, however, are able to execute passing shots in the opposite direction to where the opponent's volley is moving. The question arises as to what means they use to execute such shots. Whether they are forehand mechanics to direct balls into cross (C) or down-the-line (D) that are used under such conditions is not known yet.

The purpose of this study was to clarify which forehand mechanics are used in soft-tennis to make two different shots, C and D, under a two-choice reaction condition, which is a highly time-pressured condition.

METHODS: Subjects and apparatus. Four male and two female highly skilled soft-tennis players (mean age 30.9 years) served as subjects (Ss). One female player was the winner of the Japanese soft-tennis championship in 1995. The authors developed a two-choice reaction apparatus consisting of three lights that were to provide the stimuli for the subjects. These were set co-linearly on the net. First, the middle stimulus was presented, and then it faded away. Finally, the right or left stimulus was presented just before the ball was projected from the ball machine.

Procedures. The subjects were instructed to execute shots at the target areas at the back of the opponent's court in the opposite direction of the final stimulus. The experimenter purposely adapted the table of random numbers in this experiment described below, and the presenting order of the right or left stimulus was based on this. An inter-stimulus interval was 8 sec. Each of subject executed 50×(3 or 4) drives. Using two high-speed cameras operating at 200 Hz, forehand drive motions were filmed under the above conditions.

According to subjects' self-reports, they could not anticipate which of the stimuli would be presented. The authors assumed that, if the experimental environment significantly affected subjects, the typical characteristics of forehand motion under HTP condition would also appear. Thus for the analysis of forehand motions, the authors selected the motions which were considered to be significantly affected by the environment. Namely, sequential effects of the stimulus (Kirby, 1980) were considered among other factors of the environment. The same experimental apparatus and procedures as reported by Kusubori et al. (1999) were used also in the current study. In their research findings, it was reported that if the same stimulus was repeated more than four times in C, subjects were significantly affected. Therefore, in the case of the highest velocity forehand, it was selected in both directions, and finally 11 drives were obtained (C, n=5; D, n=6). Note that selected forehand action did not necessarily represent effective motions.

Data analysis. The film images of both cameras were digitized, and analyzed with the direct linear transformation procedure. The first contact point relative to the right shoulder was computed. Next, from the filtered 3D coordinates, initiation of forward swing (IFS) in each forehand was determined, and anatomical rotations of the upper extremity and center of gravity (COG) of subjects using Japanese athletes' body segment parameters (Ae et al., 1992), were computed. IFS was defined as the moment when the velocity of right elbow joint exceeded that of the middle point of right and left shoulders in the forward direction. Figure 1 shows the definition of anatomical rotations of the shoulder and elbow joints. Then the absolute value of the angle between the trajectory of COG during forward swing phase and the sideline (Figure 2), was computed. Wilcoxon signed-rank test was used to test for differences between C and D, because the number of subject in each group was small.

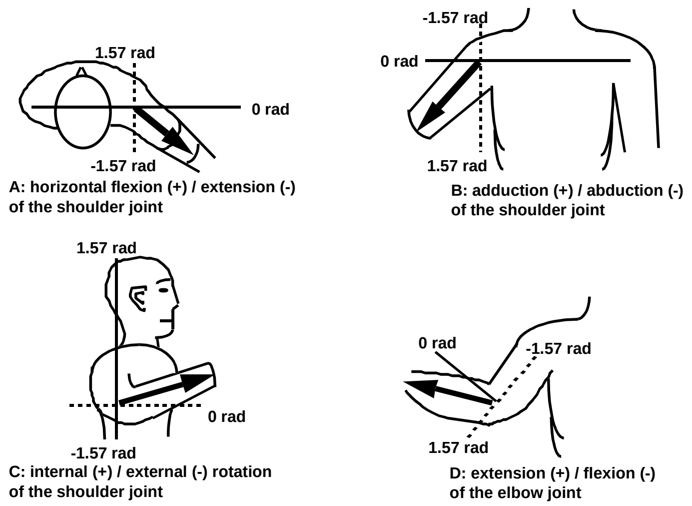

Figure1 - Definitions of anatomical rotations of the upper extremity.

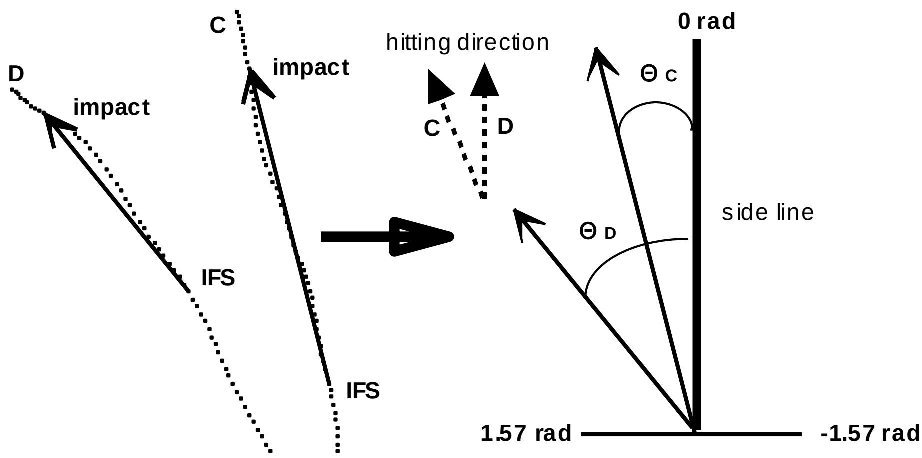

Figure 2 - Examples of the trajectory of COG (dotted line) for subject W. A. in C and D, and the absolute value of the angle between the trajectory of COG during forward swing phase and the sideline in C and D are | Θ C| and | Θ D|, respectively.

RESULTS AND DISCUSSION: The mean contact point relative to the right shoulder was significantly further forward in C (0.42 (±0.11) m) than D (0.18 (±0.04) m) ($P < .05$). These results are consistent with those observed in previous studies (Blievernicht, 1968; Elliott et al., 1989) indicating contact point relative to the body is an important factor which decides the direction of the ball. For IFS, although upper arm orientation at impact was horizontally extended in C (-0.26 (±0.44) rad) and horizontally flexed in D (0.07 (±0.53) rad) (Table1), no significant difference was found. On impact, on the other hand, a significant difference was found in the angle of external rotation between C and D ($P < .05$; Table1). While Elliott et al. (1997) reported that upper arm orientation at impact was externally rotated (1.01 to 1.53 rad), irrespective of the methods used to hold the racket and the forehand techniques used, the results of this study, indicated that there was considerable external rotation of the upper arm, in both C (1.65 (±0.42) rad) and D (2.14 (±0.40) rad). The main difference between Elliott et al. and the current study is due to that of the experimental conditions. Namely, subjects had to impact at the proper positions in order to direct balls into C or D in a short time. In this experiment, the data suggests that internal-external rotation of the shoulder joint is likely to be involved in executing shots such as C or D under HTP condition. This observation, however, might not be applied to tennis, because the load on the shoulder joint when executing a forehand shot would be less in soft-tennis, which uses lighter rackets than those used in tennis.

The mean absolute values of angles of COG trajectory (Figure 2) in C and D were 0.43 (±0.18) rad and 0.80 (±0.41) rad, respectively. Thus the lateral component of COG trajectory was greater in D than in C. The Wilcoxon test, however, failed to reach a significant difference ($P = .0796$). Although significant difference was not found, absolute values of angles of COG trajectory in each subject were higher in D than in C. This result indicates that forward movement of the whole body was restrained in D. With a more forward contact point, subjects needed to move forward aggressively in C. In D, on the other hand, subjects needed simultaneously to bring the ball nearer to the body, and to make a posture to impact effectively in a short period of time. Therefore, the rate of the forward component in COG trajectory tended to decrease in D. This difference in COG would be the result of the subject attempting to make ball-racket contact at the proper position easier under HTP condition.

Table1 Angles of the Upper Extremity Joints at the Initiation of Forward Swing (IFS) of Each Ss and at Impact in Cross (C) and Down-the-line (D) Shots (rad, M ± SD)

	IFS		impact	
	C	D	C	D
horizontal flexion (+) / extension (-)	-0.26	0.07	0.51	0.49
at the shoulder joint	(0.44)	(0.53)	(0.31)	(0.41)
adduction (+) / abduction (-) at	0.56	0.51	1.02	1.11
the shoulder joint	(0.32)	(0.40)	(0.29)	(0.37)
internal (+) / external (-) rotation	1.17	1.26	1.65	2.14*
at the shoulder joint	(0.30)	(0.47)	(0.42)	(0.40)
extension (+) / flexion (-) at	0.21	0.33	1.11	1.05
the elbow joint	(0.27)	(0.30)	(0.31)	(0.27)

Note: * indicates a significant difference between C and D at an α level of .05.

CONCLUSION: Forehand activity in soft-tennis were analyzed kinematically, and comparisons were made between cross and down-the-line shots under choice reaction conditions. A significant difference in internal / external rotation of the shoulder joint at impact was recorded. This suggests that internal / external rotation of the shoulder joint would be related to the mechanics that determine the direction of the shots under high time-pressure condition. Trajectory of the center of gravity (COG) revealed that the forward component of COG movement was restrained in down-the-line shots. This would be the result of the strategy that subjects employed to make ball-racket contact easier under high time-pressure condition.

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