GRF of table tennis players when using forehand attack and loop drive technique

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Abstract: the subjects were 10 excellent ping-pong players in China (20 ± 2 years old, with 11 ± 2 years of training). The table tennis techniques of the forehand attack and forehand loop drive were tested, using the measurement methods of the KISTLER force-plate system (two force-plates were used). Two groups of ground reaction force (GRF) data (peak and valley values of the vertical direction, left-right direction and the fore-aft direction) were analyzed and compared. The dynamic characteristics of table tennis player's forehand attack and loop drive techniques in three dimensions were described. The results showed that the biggest GRF of the attack technique in vertical direction was higher than the loop drive technique, and the biggest GRF of the attack technique in left-right direction and the fore-aft direction were mostly lower than the loop drive technique.

Keywords: table tennis, ground reaction force, forehand attack technique, forehand loop drive technique.

1. INTRODUCTION

Table tennis forehand attack technique and forehand loop drive technique are the main attack technology in table tennis. The data of external force through the ground reaction force (GRF) show the kinetic strategies of lower limbs [1]. GRF and EMG have been used to study the lower limbs activity during the power serve in tennis [3]. To understand the lower limbs' force in table tennis, the study of the characteristics of GRF of athletes in action is helpful. The GRF of table tennis players during the forehand loop movement were studied to explain how the player' lower limbs develop forces when driving the ball with the biggest force [2]. Players are easier to master the attacking technique than the loop technique in the table tennis teaching and training. The purpose of the study was to reveal the characteristics of GRF in two table tennis techniques and to find out the power differences between two techniques by the use of KISTLER three-dimensional measuring and testing system. This study will provide some theoretical service for the table tennis teaching and training.

2. METHODS

2.1 Subjects

The subjects were 10 elite table tennis players in the Beijing Sport University. The technique styles of the players were a combination of the cross grip loop and fast-attack techniques, using the reversed rubber.

2.2 Experimental methods

GRF in two kinds of table tennis techniques were recorded with two force platform systems (KISTLER 3-D). The length of each force platform was 0.6 m and the width was 0.4 m. The distance between the two centers of the platforms was about 0.5 m. The data acquisition frequency was 1000 Hz, and the time of acquisition was 5 s. The two force platforms were internally synchronized by the data acquisition system of the dynamometer test system. The force platform system was zero cleared, in order to eliminate the influence of athletes' different weight on the experimental results, when the athletes were standing on the force platform and prepared for the test.

The subjects were required to complete the forehand attack and forehand loop technique naturally, hit the ball with the biggest strength, and keep their two feet standing on the centre of each force platform. The testing of each action was not stopped until a high technical quality data for one technique was acquired at least three times.

2.3 Data processing

The KISTLER data analysis software has been used to process the original data, and then the data was analyzed and processed by Microsoft Excel software. Statistical method was the t-test for independent samples. The GRF of athletes during the process of completing two groups of table tennis techniques was recorded in three

dimensions. This paper analyzed one action cycle which was from the moment of the first restore to the next restore (reduction to four phases including five characteristic time changes). Characteristics of GRF were described. The peak and valley values of force in three directions were analyzed and compared. The horizontal axis of the figures was from the end moment of swinging the racket forward in the last action cycle to the end moment of swinging the racket backward in the next action cycle.

3. RESULTS

3.1 GRF in the vertical direction

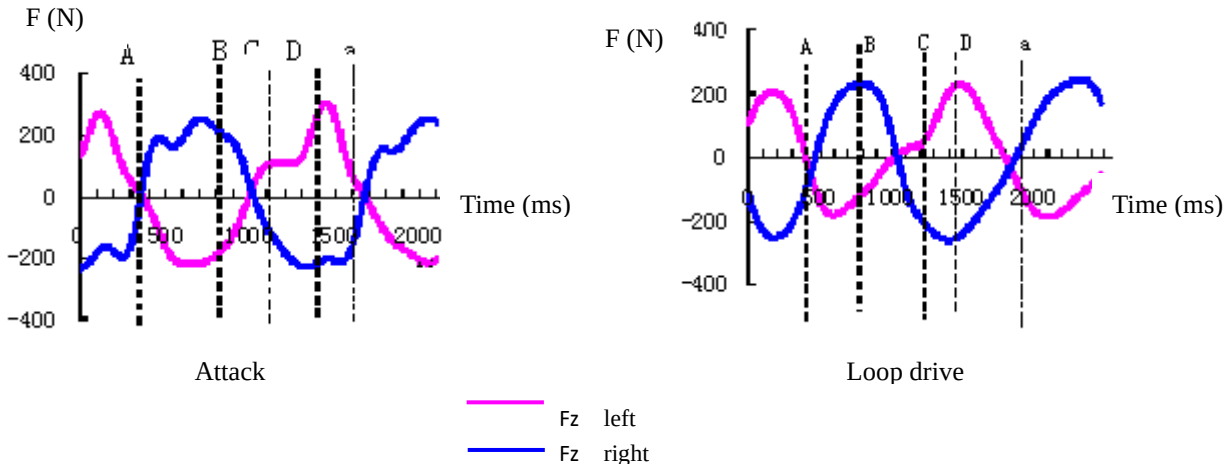

Fig. 1 GRF of two feet in vertical direction

Note：（1） Fz left means the GRF of the left foot in vertical direction, Fz right means the GRF of the right foot in vertical direction. The 0 line is the weight line. Positive values are above and negative values are below the 0 line.

(2) Point A is the restore moment, B is the end moment of swinging the racket backward, C is the moment of hitting the ball, D is the end moment of swinging the racket forward. And a is the next restore moment.

(3) A-B is the phase of swinging the racket backward. B-C: swinging and hitting the ball. C-D: swinging the racket forward. D-a: returning to the original condition (the same for the following figures).

Table 1 Peak values (N) of vertical GRF in two techniques (n = 10)

	Attack (M ± SD)	Drive (M ± SD)
Peak value of right foot	272.44 ± 21.15*	226.67 ± 19.55
Peak value of left foot	303.35 ± 33.30*	207.97 ± 27.20

* $p < 0.05$ when comparing attack and drive

The GRF in the vertical direction was maximum during the process of completing the table tennis movement. Vertical reaction forces and changes depended on three factors: (1) the body mass, (2) the body center of gravity moving up and down, (3) sequences of the movement. During the movement, the feet were always standing on a force platform. In the different phases of movement, the body center of gravity shifted from foot to foot constantly, and from left to right, and the center of gravity of the body was constantly moving up and down, thus the characteristic curves in vertical direction was formed.

As shown in Fig. 1, GRF on the left foot of the two techniques in the vertical direction showed the same variation, but the peak values of two techniques were different. The two force platforms should display “0” at the moment of returning to the original condition, because the body center of gravity is in the centre of

two feet and the speed is very slow at that time.

The changes in GRF of the right foot in one action cycle was analyzed first. The right foot is the main force of action. At the moment of swinging the racket backward, the body center of gravity gradually moved to the right foot. The GRF of the right foot began to be higher than zero, and the curve was upward. The GRF of the right foot increased gradually and reached a maximum value around the moment of B point, which was the end moment of swinging the racket backward. And then the GRF of the right foot began to decrease, the body center of gravity began to transfer to the left foot . The GRF of the right foot became lower than weight line after the body parallel stations moment, hitting the ball. And then the center of gravity of the body continued to move to the left foot, and the GRF of the right foot continued to decrease and reached a minimum value around the point D, which was the end moment of swinging the racket forward. And then the body began to turn right, the center of gravity began to transfer to the right foot. GRF on the right foot reaction force began to increase again. At a point (restore moment), the GRF of the right foot was close to zero again, which was the body weight. All these formed an action cycle.

3.2 GRF in the horizontal direction

As a support leg in the action process, the changes of GRF of the left foot in the vertical direction was contrary to the right foot. Fig. 2 shows that the areas by two feet and the horizontal axis were located above and below the horizontal axis, and the area is basically the same, just the direction was opposite. The sum of the momentum in two feet should be zero, because the two feet always stand in the force platform, and the body did not fly. The two kinds of techniques' peak and valley values were the same, but in the reverse direction.

Analyzed through t-test, the peak GRF value in the forehand attack technique was bigger than that of the loop drive technique. The peak GRF value of left and right foot in attack technique was 303.35 ± 33.30 N and 272.44 ± 21.15 N. The peak GRF value of left and right foot in loop drive technique was 207.97 ± 27.20 N and 226.67 ± 19.55 N (Table 1). The difference is significant. The result suggestedd that the body centre of gravity in the forehand attack technique was moved to contralateral foot more , compared with the forehand loop drive technique, at the end moment of swing rackett backward and forward.

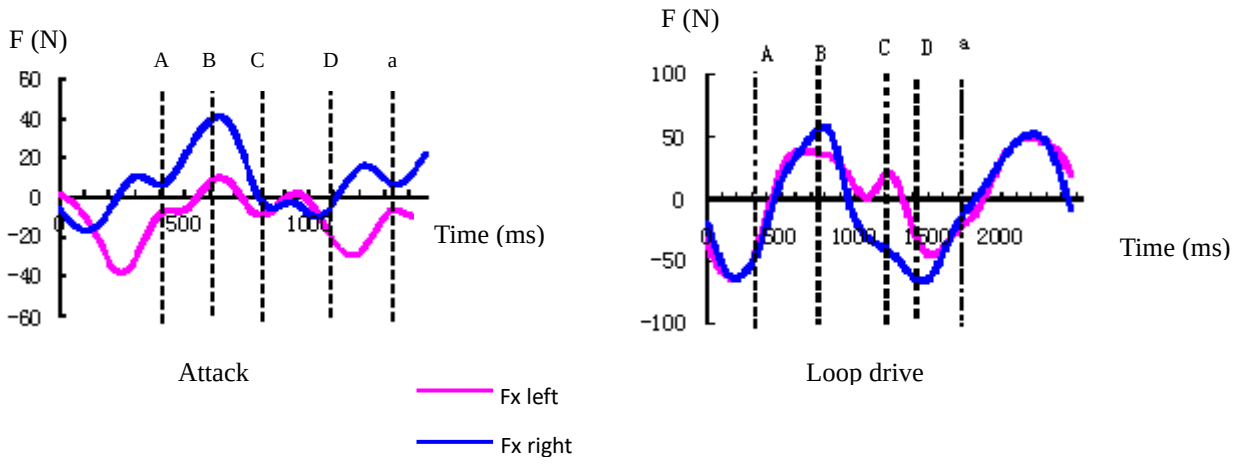

Fig. 2 GRF in the horizontal direction. Positive value is the right direction.
Fx left is the GRF of the left foot in horizontal direction, Fx right is the GRF of the right foot in horizontal direction.

Table 2 Peak and valley values (N) of horizontal GRF in two techniques (n = 10)

	Attack (M ± SD)	Drive (M ± SD)
Peak value of right foot	40.45 ± 2.45*	63.78 ± 7.56
Peak value of left foot	9.39 ± 2.37*	41.54 ± 5.70
Valley value of right foot	- 16.15 ± 2.58*	- 41.77 ± 3.56
Valley value of left foot	- 35.01 ± 5.34*	- 63.59 ± 7.23

*p < 0.05

The GRF in the horizontal direction was small (see Fig. 2). The two techniques showed the similar change trend of the curve. The force directions of two feet were almost the same, which ensured the body an easier turn in left and right direction. The GRF of the right foot was bigger than that of the left foot in the right direction. The GRF of left foot was bigger than that of the right foot in the left direction. At the moment of the returning to the original condition, GRF on the two feet in horizontal direction were about 0. And then in the phase of swinging the racket backward, the body began to turn right, the GRF on the right foot began to increase. The GRF on the left foot in left direction decreased and changed into the GRF on the right direction. The two GRF in right direction reached maximum about the end moment of swinging the racket backward. In the phase of swinging and hitting, the body center of gravity gradually transferred from the right foot to the center of the body. Two feet braked in the right direction, and moved to the balanced position respectively. The direction of GRF changed from right to left gradually after zero point, which aimed to match the body turn left to hit the ball. During the phase of swinging the racket forward, the center of the body gravity continued to turn to the left. And then GRF on the two feet in the left direction reached the maximum. And then entered the phase of returning to the original condition. GRF on the two feet in left direction decreased to zero gradually, with the body turn to the right.

As seen in Fig. 2 and Table 2, the maximum value of right foot GRF in right direction in forehand loop drive technique (63.78 ± 7.56 N) was higher than that in attack technique (40.45 ± 2.45 N). The maximum value of right foot GRF in left direction in forehand loop drive technique (41.77 ± 3.56 N) was higher than that in attack technique (16.15 ± 2.58 N). The maximum value of right foot GRF in right and left direction in forehand loop drive technique (41.54 ± 5.70 N, 63.59 ± 7.23 N) were higher than that in attack technique (9.39 ± 2.37 N, 35.01 ± 5.34 N) respectively. The differences were significant by t-test. This suggested that we should pay more attention to the force of thrusting against the ground during the completion of forehand loop drive technique.

3.3 GRF in the fore-aft direction

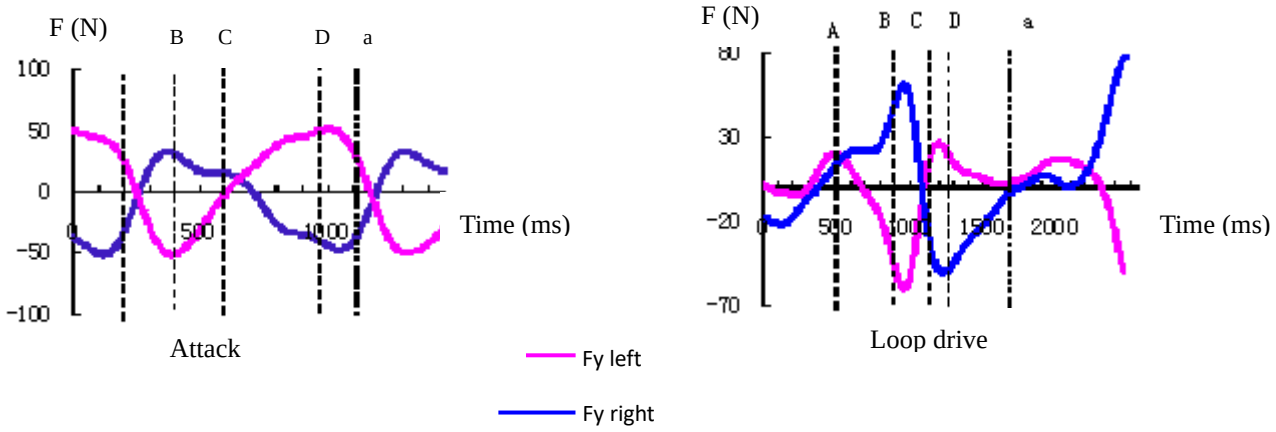

Fig. 3 GRF in the fore-aft direction. Positive value is the backward direction.
Fy left is the GRF of the left foot in fore-aft direction, Fy right is the GRF of the right foot in fore-aft direction.

Table 3 Peak and valley values (N) of two techniques in fore-aft direction (n = 10)

	Attack (M ± SD)	Drive (M ± SD)
Peak value of right foot	36.88 ± 2.98*	59.89 ± 7.05
Valley value of left foot	−51.43 ± 6.82*	−61.09 ± 4.76
Valley value of right foot	−52.89 ± 5.23*	−63.54 ± 7.90
Peak value of left foot	52.44 ± 7.89*	23.11 ± 2.46

*$p < 0.05$

The value of GRF in the fore-aft direction was small. GRF on left and right feet of two kinds of technical movements in fore-aft direction showed opposite direction changes (Fig. 3). Once one foot pushed off the ground forward, the other foot would push off the ground in the opposite direction at the same time, in order to keep the body stability. GRF curve trends of two kinds of techniques in the fore-aft direction were almost similar, but there are some differences between the two techniques.

Comparing the peak and valley values of GRF in fore –aft direction, there were significant differences between the two technical actions. The maximum of forward GRF on the right foot of the forehand attack (36.88 ± 2.98 N) is less than that of the loop drive (59.89 ± 7.05 N). This suggests that the center of gravity in loop drive technique moved backward more fully, compared with the attack technique, during the process of swinging the racket backward.

4. CONCLUSION

(1) The mechanical characteristics of GFR in forehand attack technique and loop drive technique were similar: GRF in the vertical direction was big, and GRF in horizontal and fore-aft direction were small. GRF changes on the left and right foot showed the form of the opposite direction in the vertical and fore-aft direction, in order to keep the body stability. Direction of GRF on two feet in the horizontal direction was the same, in order to ensure the body twist to the left and right direction easily.

(2) There were differences in some biomechanical indexes between the forehand attack and loop drive technique. The maximum GRF of the attack technique was bigger than that of the loop drive technique in vertical direction. The maximum GRF of the loop drive technique was bigger than that of the attack technique in the horizontal and fore-aft direction. This suggests that the forehand attack technique should be paid more attention to push off the ground downward, and the forehand drive technique should be paid more attention to push off the ground in the horizontal and fore-aft directions.

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