A Pilot Investigation into a Measure of Table Tennis Movement Efficiency using Kinetic Data

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1 OBJECTIVES

The time between table tennis shot's is often very short (approximately 0.8 s) and therefore effective stroke mechanics can only be employed if the player has moved efficiently into the ready position (Yuza et al., 1992). The objective of this pilot investigation was to attempt to develop a movement efficiency score from a mathematical equation using kinetic data captured during an alternating forehand (FH) – backhand (BH) rally. The resultant score could be useful to objectively track skill development and movement efficiency in table tennis players.

2 METHODS

2.1 Subjects

Nine healthy, young male table tennis players, (age: 13.75 ± 1.24 y, height: 1.63 ± 0.13 m, body mass (BM): 58.7 ± 14.3 kg) volunteered for the study. All players were part of a national youth sports academy and trained approximately 13 hours a week and were familiar with the table tennis ball feeding robot.

2.2 Data Collection Protocol

The test was performed in a laboratory environment where an array of 6 force plates measuring 0.9 m x 0.6 m (Kistler 9287 CA, Switzerland) were mounted behind an official table tennis table. Figure 1 illustrates the force plate configuration. The force plates were covered with a high quality rubber mat (Mondo, Italy), for improved grip.

A table tennis robot (Butterfly Amicus 3000, Germany) was positioned centrally at the opposite end of the table and delivered alternate FH and BH balls at 80 balls.s^{-1}. Players performed a warm-up before the trials, including a number of practice shots. Data was captured for 15 s, aiming to capture 6 consecutive successful (ball was returned to the opposite half of the table) shots.

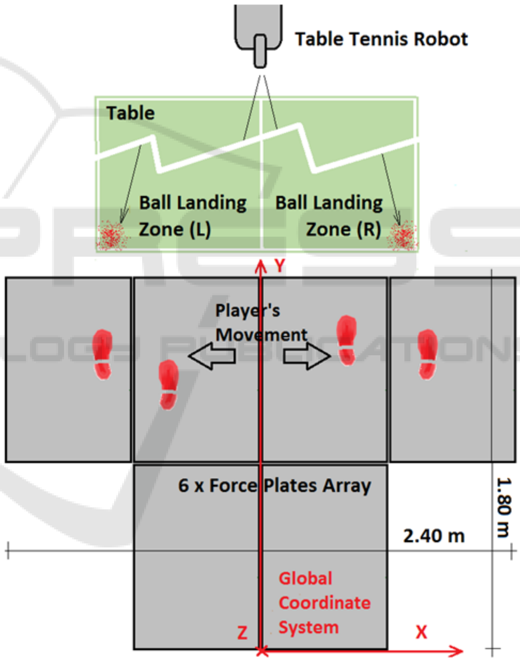

Figure 1: Experiment setup.

Force data was collected at 400 Hz simultaneously from 48 force channels (4 vertical and 4 shear per force plate) to calculate the center of pressure (CoP). The force plates were zeroed before every trial. A high speed camera (Casio Exilim Ex-F1) operating at 300 frames.s^{-1} was set-up behind the players to record the trials for post-analysis.

2.3 Analysis

The first 2 shots of each trial were disregarded to allow the player to get into a rhythm. Force curves were trimmed using the high speed video recording as a reference, aiming to get 6 consecutive successful shots (3 FH, 3 BH). The data was then filtered using a zero-lag, dual pass Butterworth low-pass filter; cut-off frequency 1.5 Hz (pass-band gain: -3 dB), stop-band frequency 5 Hz (stop-band gain: -10 dB). The filtering parameters were selected based upon numerous trials with various cut-off and stop-band frequencies as well as visual data inspection.

The 6 force plates were considered as one. Maximum forces produced in the player's medial-lateral axis (x axis) and the trajectories of the CoP on the floor were then calculated for every player using the following equation (1):

$$\mathrm{CoP} = \left(\frac{\mathrm{F_x\,a_{z0} - M_y}}{\mathrm{F_z}}, \frac{\mathrm{F_y\,a_{z0} + M_x}}{\mathrm{F_z}}\right) \qquad (1)$$

where:

F_x, F_y and F_z are the total forces in each direction as shown in Figure 1, obtained by adding the values of the respective channels of each force plate;

a_{z0} is the vertical offset of the top surface;

M_x and M_y are the total moments about the x and y axes respectively, calculated taking into account the individual position of every force channel from each plate in the array.

A number of variables were then calculated from the trajectories of the CoP: total distance (m), left and right maximum forces in the ML direction relative to body weight (BW) and area of the smallest ellipse containing 90% of the sampled positions of the CoP, A_{90} (m^2) (Takagi et al., 1985).

A coefficient representing movement efficiency (*MEf*) was formulated using the abovementioned independent variables as follows:

$$MEf = \left(\frac{D_t}{9.12}\, A_{90} \frac{|F_{Xmin}| + |F_{Xmax}|}{2\,BW}\right)^{-1} \qquad (2)$$

where:

D_t is the total distance travelled by the CoP;

9.12 is 6 times the width of the table, which was used to normalise D_t over the 6 repetitions analysed;

$|F_{Xmin}|, |F_{Xmax}|$ are the absolute maximum right and left ML forces respectively;

BW is being used to normalise the averaged forces;

A_{90} (m^2) is the area of the smallest ellipse containing 90% of the samples of the CoP.

The players were then ranked according to this score; the higher the score the more efficient the player was at moving during this task.

3 RESULTS

The results derived from the kinetic measurements and corresponding values used for the movement efficiency equation (2) are shown in Table 1.

Table 1: Efficiency coefficient and its components.

Player	$\frac{D_t}{9.12}$	$\frac{F_{L+R}}{2BW}$	A_{90}	MEf	Rank #
A	0.61	0.40	0.11	37.26	1
B	0.47	0.39	0.15	36.37	2
C	0.67	0.38	0.17	23.10	3
D	0.78	0.35	0.17	21.55	4
E	0.66	0.40	0.21	18.04	5
F	1.09	0.32	0.20	14.33	6
G	1.03	0.38	0.18	14.19	7
H	0.88	0.42	0.27	10.02	8
I	0.86	0.42	0.34	8.14	9

4 DISCUSSION

To be more efficient the players could have utilised the same path between shots. The A_{90} variable was chosen to represent this efficiency, with a smaller value being more efficient. The total distance travelled by the CoP (D_t) was used as a measure of total movement efficiency, the less distance travelled the more efficient. Left and right braking forces ($|F_{Xmin}|, |F_{Xmax}|$) were chosen as a measure of movement efficiency during the change of direction phase. The lower the forces the more efficient.

All three variables used in the *MEf* equation (2) are independent of each other, inversely related to optimal performance and represent different aspects of movement efficiency. After normalizing D_t and $|F_{Xmin}|, |F_{Xmax}|$ all variables also have a similar weight in order of magnitude (Table 1).

Further investigation is recommended with an increased number of players of differing ability to validate the proposed *MEf* equation. A validation study against kinematic data of the centre of mass could also be useful. Further development of the proposed *MEf* equation could incorporate a velocity variable or a test that is not task-repetitive in nature.

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