Net-kill Opportunity Created by Smash in Badminton Doubles

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Abstract. Badminton is one of the most popular sports in the world. In this paper, we examined the assumption that smash in the badminton double discipline is tactically different from the single discipline and that there exists a powerful three-stroke sequence: cooperation of smash and net-kill (CoSN). Four evaluation criteria (direct scoring rate, create scoring rate, net-kill opportunity and awards) were proposed in this paper. Five smash parameters (height of impact-point, post-impact shuttlecock speed, distance from impact point to back boundary line, shuttle flight time and height of trajectory end-point) were measured and counted in a balls-into-bins model to investigate the link between scoring rate and smash parameters. We collected a dataset comprising 55,433 strokes from 46 world-class women doubles games. We found the most relevant smash parameter is shuttle flight time. The knowledge of low-cost-high-reward smash behaviour helps to improve training methods.

Keywords: Badminton, Double Discipline, Smash, Scoring Rate, Cooperation of Smash and Net-kill.

1 Introduction

Badminton is one of the most popular sports in the world. The coaches of the Chinese Badminton Association inspired us with a new research project. They assumed that the smash in the double discipline was tactically different from that in the single discipline. They requested us to find the quantitative difference between the successful *cooperation of smash and net-kill* (CoSN) and the normal smash without net-kill to improve the performance of their players.

Smash quality is influenced by many physiological, psychological, technical and tactical parameters, including anticipation skill[1], power of stroke[2], racket-shuttle impact location [3], grip, racquet angle [4], shuttle speed [5], height of impact point [6], body position [2], end-location of shuttle [1], shuttle clearance height [2], shots per second [7] and so forth. We ignored the smash parameters that cannot be directly measured (e.g. anticipation skill, power of stroke, grip, racket-shuttle impact location) by the monocular method [8] and focused on the technical and tactical parameters [9].

The Chinese national coaches were interested in the smash parameter that can be controlled by smash-stroke players because it is more useful to training. Body position, height of impact point and shots per second are controlled by both smash-stroke players and their opponents. As these three parameters cannot meet the requirement, we therefore devised two novel smash parameters in this paper.

The coaches were concerned about the scoring rate (SR) of the smash-stroke. This evaluation criterion is the key to understanding smash behaviour. It can be estimated by the following formula: SR = the number of scoring / the number of smashes. However, it cannot directly answer the question of "how to create a scoring opportunity" and ignores the points scored by the anti-smash strokes of the opponent. To overcome these two shortcomings, we devised one physical model and two evaluation criteria in this paper.

The contributions of this paper include the examination of the coaches' empirical assumption that the "smash is different between singles and doubles", a balls-into-bins model investigating the link between SR and smash parameters, two novel smash parameters (shuttle flight time and height of trajectory end-point), one physical model (net-kill opportunity belt), two novel evaluation criteria (net-kill opportunity and awards) and quantitative answers to the practical problem of "how to create net-kill opportunity".

2 Smash in Women Singles and Women Doubles

We collected 46 world-class women doubles videos and 41 world-class women singles videos. These badminton match videos were publicly available on the internet. The dataset contained 55,433 strokes from 46 women doubles matches and 36,526 strokes from 41 women singles matches. There were three type points (direct scoring, forced error and unforced error) in the last shot of each rally.

Direct scoring is the number of points when the shuttle touches the ground. Creating scores of smash is the number of points the shuttle touch the ground at time t+2 or forced error at time t+3. We then computed the direct scoring rate (DSR = direct scores / total strokes) and create scoring rate (CSR = creating scores / total scores). DSR shows the scoring efficacy, while CSR shows the scoring percentage in a three-stroke sequence [10].

In Table 1, the DSR of the smash was 4.03% in women doubles, which was lower than that in women singles (11.01%). Considering that the smash yields less scores, a smaller percentage of smashes was reasonably expected. The actual frequency of smashes (19.89%) in women doubles contradicted our expectation, as it was larger than that in women singles (12.81%). This logically incompatible result was explained by the CSR.

Table 1. Technique statistic in 46 women doubles and 41 women singles matches.

	Smash	Clear	Dropshot	Net-kill	Lifting	Others

Women doubles	Strokes	11,028	3,382	3,958	2,056	8,317	26,692
	Frequency	**19.89%**	6.10%	7.14%	3.71%	15.00%	48.16%
	Direct scores	444	12	73	364	34	443
	DSR	**4.03%**	0.35%	1.84%	**17.70%**	0.41%	1.16%~7.86%
	Creating scores	802	66	182	179	175	1076
	CSR	**32.34%**	2.66%	7.34%	7.22%	7.06%	0.93%~10.08%
Women singles	Strokes	4678	4741	3877	568	6954	15708
	Frequency	**12.81%**	12.98%	10.61%	1.56%	19.04%	43.00%
	Direct scores	515	83	139	180	129	252
	DSR	**11.01%**	1.75%	3.59%	31.69%	1.86%	2.00%~4.47%
	Creating scores	394	344	362	45	569	1352
	CSR	12.85%	11.22%	11.81%	1.47%	18.56%	2.94%~10.01%

CSR is the proportion of scores using a specific technique at time t to the total scores at time t+2. It shows the proportion of creating a scoring opportunity using a specific technique. In Table 1, 11,028 smashes at time t created 802 scores at time t+2; the CSR is 32.34% (=802/2480). Notably, smash was the highest CSR technique. Hence, the actual frequency of smashes (19.89%) contradicted our expectation because smash is used for creating scores in badminton doubles rather than direct scoring in badminton singles.

Moreover, net-kill was the highest DSR technique (17.7%) in women doubles. The cooperation of smash and net-kill (CoSN) [13] can be deduced to be a powerful three-stroke sequence in badminton doubles.

Fig. 1 is an example of a CoSN. Player A makes a smash at time t, yields to the defence of opponent C at time t+1 and then player B makes a Net-kill at time t+2.

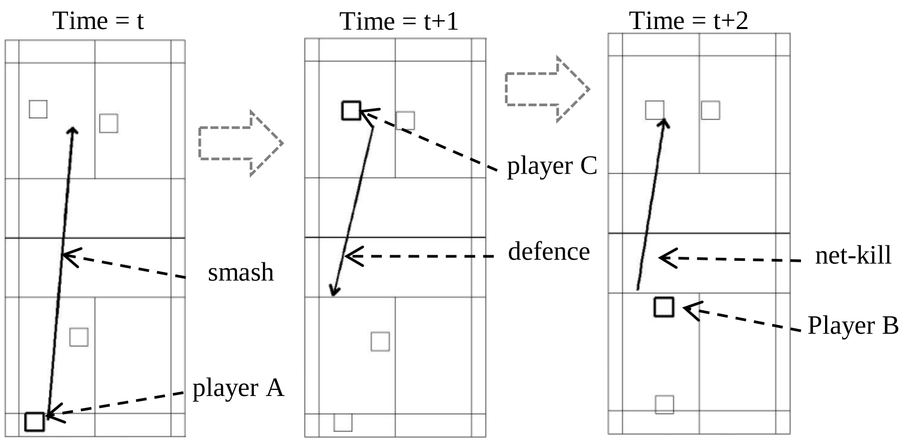

Fig. 1. Example of a Cooperation of Smash and Net-kill.

3 Net-kill Opportunity Belt

The Chinese national coach assumed that a good smash yields net-kill opportunity. To quantitatively measure the probability of net-kill opportunity, we collected 55,433 3D data (four player positions and one shuttle trajectory for each stroke). We modelled the net-kill opportunity as the green coloured belt in the vertical plane P at the short service line (Fig. 2). The height of this green coloured belt ranges from 1.6 m to 2.8 m. Player B can easily make a net-kill stroke if defence trajectories fly through this belt. We named it the *net-kill opportunity belt*. The upper belt is the region over the upper boundary 2.8 m in the vertical plane P. The lower belt is the region bellow the lower boundary 1.6 m in P.

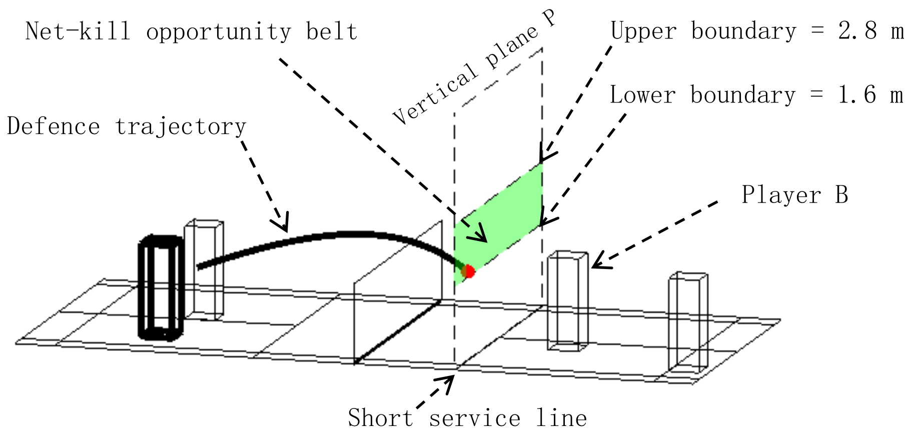

Fig. 2. Net-kill opportunity belt model.

For each smash stroke at time t, we simulated the succeeding defence trajectory at time t+1 using aerodynamic model [12]. The simulated defence trajectory always have an intersection point despite some of them may not even exist if player B intercepts the shuttle in the range from the short service line to the net.

We counted the total defence trajectories and the points scored by player B in each of three belts. There were 9,361 defence trajectories after smash. Among them, 3906 (41.6%) trajectories flied through the net-kill opportunity belt, which enabled player B to score 352 points by net-kill. Thus, the SR was 9.02% (=352/3903), which was larger than the SR of 2.86% (=57/1993) of lower belt and larger than the scoring rate 0.69% (=24/3465) of the upper belt.

This result shows that player B can easily make a net-kill stroke and has a high possibility of scoring if defence trajectories fly through the net-kill opportunity belt. The net-kill opportunity belt range (from 1.6 m to 2.8 m) is reasonable.

4 Smash Parameters in Women Doubles

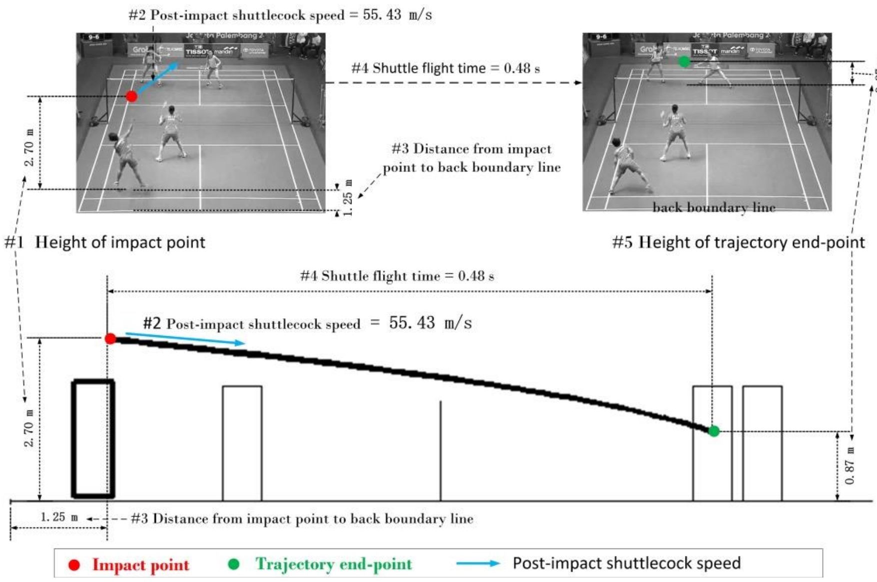

Fig. 3. Smash parameters in a 3D badminton court.

We assumed five parameters were relevant to smash scoring rate: height of impact-point (#1), the post-impact shuttlecock speed (#2), distance from impact point to back boundary line (#3), shuttle flight time (#4) and height of trajectory end-point (#5).

The geometric interpretations of these parameters are shown in Fig. 3, and they can be computed geometrically given the 3D data of each stroke.

We developed five balls-into-bins models for each smash parameter. Balls-into-bins models are extended versions of histograms. Similar to balls falling into bins, 9,361 balls (defence trajectories) were distributed to 20 bins ranging from 0.0 to 2.0 m according to the height of trajectory end-point (#5). The bin size (or bin width) were 0.1 m. In each bin (i.e. 0–0.1, 0.1–0.2, 0.2–0.3 m, etc.), we counted the number of smashes (N5) and number of defence trajectories through the net-kill opportunity belt (N6), the number of points scored via net-kill (N7) and the number of points scored via the anti-smash technique (N8).

DSR equals N7/N5 per bin. However, the DSR distribution cannot answer the question of how to create a net-kill opportunity by smash. It also ignores the points scored by the anti-smash strokes of the opponent. Thus, we designed two novel evaluation criteria: *net-kill opportunity* (E1=N6/N5) and *awards* (E2=N7/N5 - N8/N5).

Intuitively, E1 quantitatively evaluates the probability of defence trajectories through the net-kill opportunity belt (i.e. net-kill opportunity). E2 evaluates the probability that player B seizes the net-kill opportunity and wins 1 point on the condition that the opponent's anti-smash is not scoring.

We computed the Pearson correlation between the five smash parameters and two evaluation criteria.

Table 2. Pearson correlation between five parameters and two evaluations criteria.

Smash Parameters	Opportunity (E1)	Awards (E2)
Height of impact point (m)	0.11	0.70
Post-impact shuttlecock speed (m/s)	**0.81**	**0.92**
distance from impact point to back boundary line (m)	0.36	0.42
Shuttle flight time (s)	**-0.97**	-0.75
Height of trajectory end-point (m)	-0.35	**-0.84**

In Table 2, the distance from impact point to back boundary line (#3) was less relevant to the net-kill opportunity and awards of CoSN. To show more details about the smash parameters, we plotted their central values and evaluation values in Fig. 4.

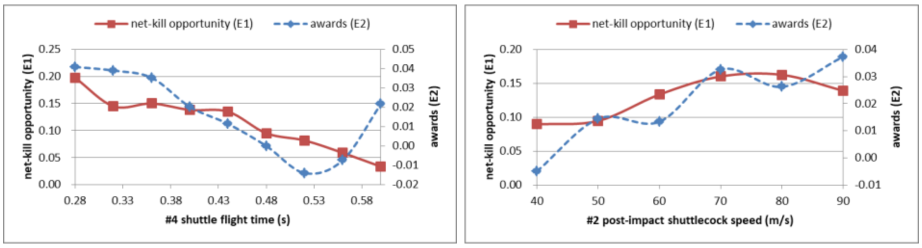

Fig. 4. Evaluation of shuttle flight time and post-impact shuttlecock speed.

In Table 2, shuttle flight time (#4) was the most important factor to the net-kill opportunity (E1). In Fig. 4, net-kill opportunity decreased from 19.7% to 3.3% if the shuttle flight time increased from 0.28 s to 0.6 s. Distance from player to net and post-impact shuttlecock speed may contribute to shuttle flight time, and their influence should be researched in the future

In Table 2, post-impact shuttlecock speed (#2) was the key to both net-kill opportunity (E1) and net-kill awards (E2). In Fig. 4, high speed smash (90 m/s) increased net-kill awards from -0.5% to 3.7% and increased the net-kill probability from 9% to 13.9%.

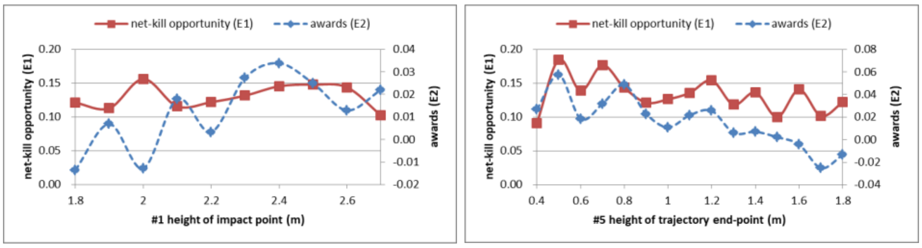

Fig. 5. Evaluation of the height of impact point and trajectory end-point.

In Table 2, the height of impact-point (#1) and height of trajectory end-point (#5) were the secondary important parameters. In Fig. 5, the most comfortable height of impact point was 2.4 m, which leaded to the maximal awards (3.4%) and was better than the minimal awards (-1.4%) at 1.8 m. The most efficient height of trajectory end-point was 0.8 m.

The previous result shows that the proposed evaluation criterion (E1) provides a direct insight into the problem of how to create a net-kill opportunity by smash.

5 How to Create a Net-kill Opportunity

Finally, we obtained a 7764–smash subset (D1) and a 1597 CoSN subset (D2) from the 55,433-stroke dataset. The basic descriptive statistics of the four smash parameters in D1 and D2 were shown in Table 3.

Table 3. Descriptive statistics of smash parameters.

Smash Parameters	D1 (N=7764)	D2 (N=1597)
Height of impact point (m)	2.46±0.215	2.469±0.211
Post-impact shuttlecock speed (m/s)	69.718±16.289	72.103±15.731
Shuttle flight time (s)	0.427±0.068	0.408±0.059
Height of trajectory end-point (m)	1.111±0.295	1.118±0.291

Since these smash parameters can be controlled in the training process, the numerical range of these parameters in Table 3 shows us the knowledge of how to create a net-kill opportunity.

6 Conclusions

The first contributions of this paper is the examination of the coaches' empirical assumption that the "smash is different between singles and doubles" and "cooperation of smash and net-kill is a powerful skill in badminton doubles".

The key contribution of this paper is a physical model, net-kill opportunity belt, which captures the idea that "the scoring opportunity is seized by forecourt player with net-kill". It provides not only a quantitative measurement about the opportunity itself but also two novel evaluation criteria. To the best of the author's knowledge, this study is the first to investigate the net-kill opportunity by using a physical model.

Smash parameters were selected by two evaluation criteria (net-kill opportunity and net-kill awards). The balls-into-bins model shows the complex relationship between smash parameters and evaluation criteria. This model is an extended version of histogram, which is widely used in previous studies. It can be easily used in any other sports. The non-linear curve between smash parameters and evaluation criteria provides useful knowledge for training purposes.

The correlation of shuttle flight time (#4) and net-kill opportunity (E1) was -0.97. It is the most important factor and the key finding in this paper. Many other parameters (the distance from player to net, shuttle speed, placement of stroke, etc.) are associated with shuttle flight time. The relationship between these parameters and shuttle flight time should be researched in the future.

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