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What are the Winning Conditions in Sports Competition with a Predetermined Cumulative Point System

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Abstract: The objective of this study is to examine whether the empirical distributions of consecutive winning and losing points obtained in real games of badminton and table tennis in which the winner is determined by a predetermined cumulative point system are the same as the naturally occurring probability distributions of consecutive winning and losing points generated in simulations. In addition, this study suggests conditions in which winning is likely based on these consecutive winning and losing points. Pseudo-data for the comparison were generated using a Monte-Carlo simulation. The frequencies of consecutive winning and losing points for both real and simulated data were calculated and a χ^2 test was performed to test the homogeneity of the two groups of data. The findings showed that the empirical distributions of consecutive winning and losing points in the real games of badminton and table tennis were not different from the probability distributions of the simulated pseudo data (significance level $\alpha = 0.05$).

Key words: Predetermined cumulative point system, badminton, table tennis, consecutive winning points, consecutive losing points, Monte-Carlo simulation

INTRODUCTION

It is not easy to predict a win or loss in a sports game by using a quantitatively calculated probability. This is because every player in a sports game is different with respect to physical ability and psychological state and there exist an infinite number of scenarios created by the situational variables that occur during a game. Therefore, players and coaching staff require strategies that address a wide variety of game situations in order to play efficiently (Franks *et al*., 1983; Franks and Miller, 1986; Park and Kang, 2014).

When considering the decision-making processes by players and coaching staff during a sports game because game situations change rapidly during a game, the basis on which to determine the optimal tactic is unclear. In particular, devising tactics during a game by considering too many situational factors can conversely increase player's mistakes. Accordingly, it is necessary for players and coaching staff to generalize tactics by selecting core variables that have a direct impact on the game. Generalization is a process of establishing a concept or rule based on characteristics common across several individual situations. For instance, if there is a characteristic that commonly occurs in sports games, it can be generalized and utilized as a basis for a game strategy.

There are various ways to determine a winning player or team in a sports game. In some sports, the winner is determined by who arrives first at the end point of some distance (e.g., marathons or 200 m swimming). In other sports, a winner is determined by who scores more during some amount of time (e.g., football or basketball). In still others, a winner is determined by who first accumulates a predetermined amount of points (e.g., table tennis, badminton and volleyball). For instance, table tennis and badminton are played with predetermined cumulative points of 11 and 21, respectively. In this study, this method for determining a winner is called the Predetermined Cumulative Point System (PCPS). PCPS sports competitions use a binomial scoring, i.e., when a player (or team) scores a winning point, the other player (or team) loses a point. In other words, two players compete for a point and the winner takes the point. In the

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process, a player who reaches the cumulative point first becomes the winner. However, if both players in a competition successively gain one point in an alternating fashion such that the score is even, i.e., 1:1, 2:2, 3:3 , ..., 11:11 and so on a winner cannot be declared. Accordingly, if a winner is to be determined in a PCPS sports competition, one player must win points consecutively. Thus, consecutively winning points can be considered the most crucial factor of winning in a PCPS sports competition.

Winning points consecutively in PCPS is in an antagonistic relationship with consecutively losing points. The probability of winning is higher for a player who has more consecutive winning points and in contrast, the probability of losing is higher for a player who has more consecutive losing points. Hence, in PCPS sports competitions, the ability to reduce consecutive losing points and increase consecutive winning points, i.e., the ability to manage points is considered an important factor. The importance of consecutive winning and losing points in PCPS sports competitions has already been mentioned in several previous studies (Chen and Chen, 2008; Ming *et al*., 2008; Vallerand *et al*., 1988). Gernigon *et al*. (2010) reported that the ability to win or lose points consecutively was strongly associated with table tennis player's competitiveness because this ability is reflective of changes in the psychological momentum of players during a game.

Until now, many attempts such as the acquisition of psychological skills and strategy diversification have been made to increase consecutive winning points and reduce consecutive losing points. However, the causes of consecutive winning and losing points have not received much attention. For instance, depending on the cause of consecutive lost points, e.g., an unstable psychological state, excessive training or poor equipment, the strategy to address it should be different. However, because an understanding of the causes of consecutive losing points is lacking, strategies to address them are also absent.

In this study, we are interested in whether naturally occurring probability distributions (random numbers generated by chance) could explain the occurrences of consecutive winning and losing points in PCPS sports competitions. On one hand, if the empirical distributions of consecutive winning and losing points in PCPS sports competitions are the same as naturally occurring probability distributions, it can be inferred that the consecutive winning or losing of points is not affected by intrinsic or extrinsic factors like player's psychological states or game situation on the other hand if the distributions are different from each other, it can be inferred that factors intrinsic or extrinsic to players greatly affect consecutive winning and losing points.

The objective of this study is to investigate whether naturally occurring probability distributions simulated for consecutive winning and losing points in PCPS sports competitions are the same as the empirical distributions of consecutive winning and losing points that occur in real games. If empirical distributions of consecutive winning and losing points observed in real games are the same as simulated probability distributions, point management is an important factor in winning a PCPS sports competitions. A second objective is to suggest winning conditions based on consecutive winning and losing points in PCPS sports competitions. We assume that the effects of various sports game situations and the strategies and tactics used in those situations can be simulated using a naturally occurring probability distribution. An additional objective of the study is to suggest generalised winning conditions based on consecutive winning and losing points by studying table tennis and badminton games.

MATERIALS AND METHODS

To address the study objectives, we collected data regarding consecutive winning and losing points in real PCPS games and also generated pseudo data for consecutive winning and losing points by computer simulation. The specific methods to obtain the real and simulated data are described.

Sources of real data with PCPS: Real data were obtained in actual badminton and table tennis games in which the PCPS rule was applied with a predetermined score of 21 points for badminton and 11 points for table tennis. To obtain badminton data, the series of cumulative points earned was obtained for a total of 273 sets across 117 games (132 sets in 57 male badminton games and 141 sets in 60 female badminton games) from 2014 and 2015 official Badminton World Federation (BWF) games. All the games were played by players with a world ranking of 15 or better. Additionally, table tennis data were obtained from a total of 173 sets across 28 games (96 sets in 15 male table tennis games and 77 sets in 13 female table tennis games) from 2014 and 2015 official International Table

Tennis Federation (ITTF) games. All the table tennis games were played by players with a world ranking of 5 or better. The player's world ranking values were limited because if there is a large discrepancy in player's skill level, the competition environment of the players is unbalanced and thus consecutive winning and losing points is be less meaningful with respect to the winning conditions. The data was obtained from videos provided by the BWF and ITTF and the winning and losing points were recorded in a computer file.

Generation of pseudo data with PCPS: The consecutive winning and losing point pseudo data were generated by Monte-Carlo simulation. Monte-Carlo simulation is a simulated sampling technique that iteratively generates random numbers according to the probability distribution assumed by the pseudo data generating model. In this study, we used a pseudo data generating model with a 0.5 probability of winning or losing a point, assuming that the skill levels of the players are similar. Here, if a player wins a point, the other player loses a point. The process was iteratively performed until a player reached a predetermined score (21 points for badminton and 11 points for table tennis). That player was then recorded as the winner, the other player was recorded as the loser and the iterative process was terminated. Each of the badminton and the table tennis games was simulated 1 m times based on the assumption that players at the same skill level were playing the game under the same conditions. The Monte-Carlo simulation process is presented in Fig.1.

Data analysis: The series of consecutive winning and losing points obtained from the videos of real games provided by BWF and ITTF were recorded into the IBM SPSS Ver 21.0 program as cumulative points. To generate pseudo-data to compare with the real game data, Oracle Crystal Ball Ver 1.0 was used to perform the Monte-Carlo computer simulations. The frequencies and proportions of the real and simulated data were computed. To address one of the main objectives of the study, i.e., to investigate whether the records of consecutive winning and losing points in real games are different from those generated by Monte-Carlo simulation, a χ^2 test with a significance level of $\alpha = 0.05$ was conducted. The test was performed on the difference in proportions to determine any difference in the total frequency between the real and simulated data and was calculated as follows:

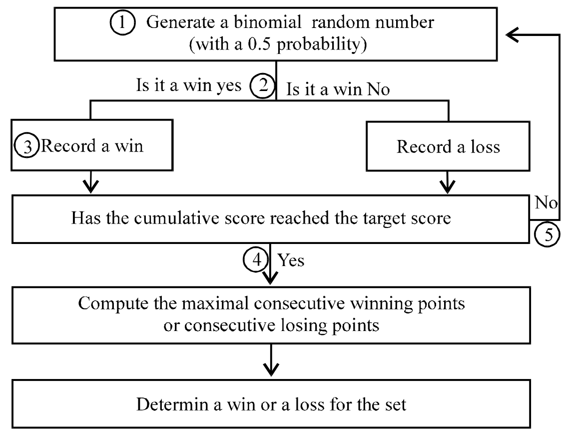

Fig. 1: 1 Generation of pseudo data generate a random number with a 0.5 probability for winning/losing a point, 2 if the random number corresponds to winning a point, record a win if it corresponds to losing a point, record a loss, 3 Determine whether the cumulative points reached the predetermined cumulative score (21 points for badminton and 11 points for table tennis). 4 If the cumulative points reached the predetermined target score, terminate the iteration. 5 Otherwise, return to the beginning and reiterate. A total of 1 million simulated games were performed for badminton and table tennis, respectively. A deuce scoring system was not assumed

$$x^2 = \sum \frac{(\text{Observed proportion-Expected proportion})^2}{\text{Expected proportion}}$$

RESULTS AND DISCUSSION

Test for homogeneity in the real and pseudo data: Figure 2 compares the difference in the proportions of consecutive winning and losing points in the real and simulated badminton data. With regard to consecutive winning points, the difference between the real and simulated data was not statistically significant $\chi^2 = 6.366$, $p = 0.703$) and in both types of data, the probability of consecutively winning 4 points was the highest (27% in the real data and 28% in the simulated data). With regard to consecutive losing points, again, the difference between the real and simulated data was not statistically significant ($\chi = 1.037$, $p = 0.999$). In both types of data, the probability of consecutively losing 4 points was the highest (27% in the real data and 28% in the simulated data).

Figure 3 compares the difference in the proportions of consecutive winning and losing points in the real and simulated table tennis data. With regard to consecutive winning points, the difference between the real and

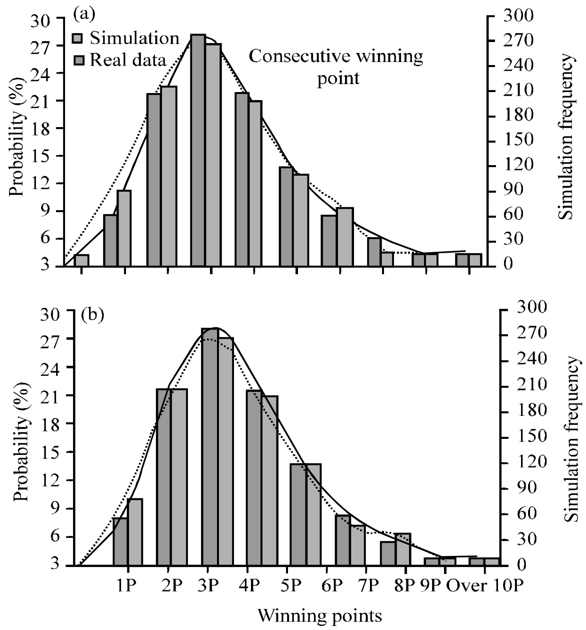

Fig. 2: Probability distributions of consecutive winning and losing points in the real data and the simulated data from badminton games; a) Difference in probabilities of consecutive winning points χ^2 = 6.366, df = 9, p = 0.703 and b) Difference in the probabilities of consecutive losing points χ^2 = 1.037, df = 9 p = 0.999

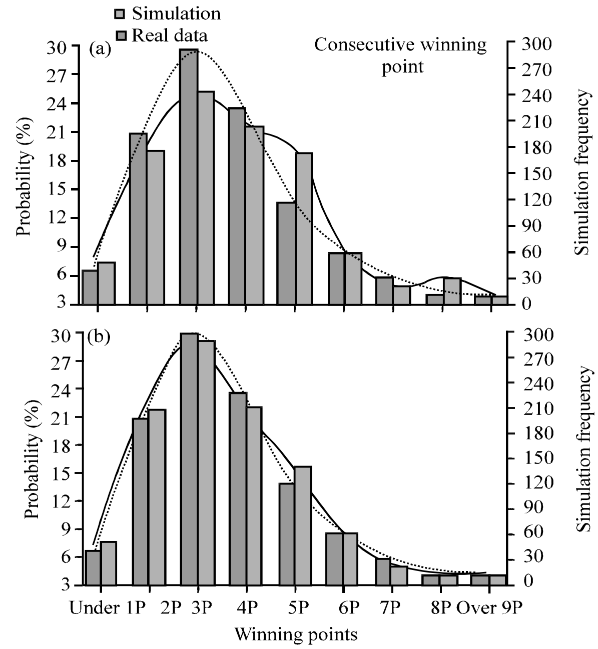

Fig. 3: Probability distributions of consecutive winning and losing points in the real data and the simulated data from table tennis games; a) Difference in the probabilities of consecutive winning points χ^2 = 5.44, df = 8, p = 0.709 and b) Difference in the probabilities of consecutive losing points χ^2 = 1.258, df = 8, p = 0.996

simulated data was not statistically significant χ^2 = 1.037, p = 0.709) and in both types of data, the probability of consecutively winning 4 points was the highest (25% in the real data and 30% in the simulated data).

With regard to consecutive losing points in table tennis games, the difference between the real and simulated data was also not statistically significant (χ^2 = 1.258, p = 0.996) and in both types of data, the probability of consecutively losing 4 points was the highest (29% in the real data and 30% in the simulated data). Therefore, the distributions of consecutive winning and losing points in the real games of badminton and table tennis followed the naturally occurring probability distributions of random numbers generated by chance. This finding suggests that the effect of intrinsic or extrinsic factors such as player's psychological state or game situation is relatively small on consecutive winning and losing points and that additionally, the algorithm used in the present study is a valid way to calculate winning conditions in badminton and table tennis games.

Winning condition with PCPS: To determine conditions under which winning is likely based on consecutive winning and losing points in PCPS sports competitions, the probabilities of winning were computed and arranged in a matrix. Table 1 shows the winning probabilities in badminton and Table 2 shows winning probabilities in table tennis.

Based on the results shown in Table 1, the winning conditions in a badminton game are as follows. The first condition is to obtain more consecutive winning points than consecutive losing points. Specifically, if there is one more consecutive winning point than consecutive losing points, the probability of winning is more than 55% in all cases if there are two additional consecutive winning points, the probability is more than 65% in all cases. A second condition is to consecutively win five or more points. The probability of winning was 48% (also 48% in the real data) when 4 points were consecutively won and 64% (72% in the real data) when 5 points were consecutively won. That is after consecutively winning five or more points, the probability of winning was higher than the probability of losing. A third condition is to consecutively lose <5 points. The probability of winning was 52% (and 55% in the real data) when 4 points were consecutively lost and 36% (and 28% in the real data) when 5 points were consecutively lost, suggesting that the probability of winning is higher than that of losing if <5 points are consecutively lost.

Table 1: The probabilities of winning based on consecutive winning and losing points in the simulated data (badminton) (N = 1,000,000 set)

Consecutive winning points/ Consecutive losing points	1P (%)	2P (%)	3P (%)	4P (%)	5P (%)	6P (%)	7P (%)	8P (%)	9P (%)	Over10P (%)	Total (%)
1P	-	100	100	100	100	100	100	100	100	100	100
2P	-	**48**	93	99	100	100	100	100	100	100	99
3P	0	7	**50**	78	89	95	97	99	99	100	79
4P	0	1	22	**50**	68	78	85	90	94	97	**52**
5P	0	0	10	32	**50**	61	71	78	84	92	36
6P	0	0	6	22	38	**49**	59	66	75	84	26
7P	0	0	3	16	29	41	**50**	58	67	79	20
8P	0	0	2	11	22	33	41	**51**	58	68	15
9P	0	0	1	6	16	27	37	41	**50**	66	11
Over 10P	0	0	0	3	8	17	22	31	29	**50**	7
Total	0	2	21	48	**64**	73	80	85	89	92	**50**

Table 2: The probabilities of winning based on consecutive winning and losing points in the simulated data (table tennis) (N = 1,000,000 set)

Consecutive winning points/Consecustive losing points	Under 1P (%)	2P (%)	3P (%)	4P (%)	5P (%)	6P (%)	7P (%)	8P (%)	Over 9P (%)	Total (%)
Under 1P	**0**	100	100	100	100	100	100	100	100	100
2P	0	**50**	89	97	99	100	100	100	100	90
3P	0	11	**50**	74	87	95	98	100	100	**56**
4P	0	3	25	**50**	66	78	89	95	100	33
5P	0	1	13	34	**50**	64	76	87	97	21
6P	0	0	6	22	36	**50**	65	79	93	13
7P	0	0	2	11	24	36	**50**	60	82	7
8P	0	0	0	4	13	24	34	**54**	82	4
Over 9P	0	0	0	1	1	9	17	28	**48**	1
Total	0	10	44	**67**	79	87	93	96	99	**50**

Bold values are significant

Based on the results shown in Table 2, the winning conditions in a table tennis game are as follows. The first condition is again, obtaining more consecutive winning points than consecutive losing points. Specifically, if there is one consecutive winning point more than consecutive losing points, the probability of winning is more than 60% in all cases and if there are two more consecutive winning points, the probability of winning is more than 75% in all cases. A second condition is to consecutively win 4 points or more. The probability of winning was 44% (48% in the real data) when three points were consecutively won and 67% (73% in the real data) when 4 points were consecutively won. In other words, by consecutively winning 4 points or more, the probability of winning became higher for a player than the probability of losing. The third condition is to consecutively lose <4 points. The probability of winning was 56% (55% in the real data) when 3 points were consecutively lost and 33% (and 31% in the real data) when 4 points were consecutively lost. That is by consecutively losing <4 points, the probability a player will win is greater.

This study examined whether naturally occurring probability distributions of consecutive winning and losing points in PCPS sports competitions are the same as the empirical distributions obtained in real games of badminton and table tennis. It also suggested winning conditions based on consecutive winning and losing points in PCPS badminton and table tennis competitions. The study results show that the probability distributions of consecutive winning and losing points observed in real games of badminton and table tennis are not different from naturally occurring probability distributions. This finding suggests that the algorithm used in the study is a valid way to determine winning conditions in badminton and table tennis games. If the empirical distributions of consecutive winning and losing points observed in the real data were different from the naturally occurring probability distributions, this would infer that other mediating variables exist. For instance, if the probability of winning a point is higher for the player who hits a serve or the skill levels are different between players, the empirical distribution of consecutive winning and losing points would be notably different from the naturally occurring probability distributions. Therefore, we believe that the algorithm used in the study can be used in future research to test differences in player's skill levels or identify mediating variables that affect the results of a sports game.

There are three types of winning conditions in badminton and table tennis games. The first condition is to obtain more consecutive winning points than consecutive losing points. This point does not go beyond the common sense idea that the more consecutive winning points and fewer consecutive losing points he or she has increases his or her probability of winning. However, the winning probability matrices presented in the present study notable in that they provide researchers, players and sports leaders with scientific information based on objective data. A second condition is to consecutively win 5 points or more in a badminton game and 4 points or more in a table tennis game. When a player consecutively wins 5 points in a badminton game, the probability he or she will win is 64% when a player consecutively wins 4 points in a table tennis, the probability he or she will win is 67%. A third is to consecutively lose 4 points or fewer in a badminton game and three points or fewer in a table tennis game. A player who consecutively loses 4 points in a badminton game has a probability of winning of 52% and a player who consecutively loses three points in a table tennis game has a probability of winning of 56%. To put it differently, the momentum of consecutive winning and losing points which determines a win or a loss occurs at 4.5 points in a badminton game and at 3.5 points in a table tennis game. In the past, the importance of consecutive winning and losing points has been mentioned in studies but information with respect as to exactly how many points have to be won or lost has been lacking. Hence, we expect that the results of the present study will be utilized as basic data for establishing strategies and training plans regarding game management in the field of sports competition. Furthermore, the winning conditions involving consecutive losing points are expected to be strategically utilized to make use of momentum such as when using timeouts during a game in order to change the content or the flow of a game before it progresses beyond the point of the winning criteria presented in the study.

CONCLUSION

The conclusions are as follows. First, in a badminton game, it is best to consecutively win five or more points or consecutively lose <5 points because the momentum that determines a win or loss occurs at 4.5 points. Second, in a table tennis game, it is better to consecutively win four or more points or consecutively worse to lose <4 points because the momentum that determines a win or a loss occurs at 3.5 points. We believe these findings can be used as basic data to establish strategies and training plans for game management in badminton and table tennis competitions.

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