RESEARCH ARTICLE

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Analysis of Critical Determinant Factors for Beach Volleyball Winning in Elite Men and Women Teams

Yi-Kun Peng and Shih-Chung Cheng

ABSTRACT

Purpose: was to explore critical determinant factors for beach volleyball winning in elite men's and women's teams. Methods: Python web crawler were implemented to collect attack & defense records of the world beach volleyball world championships for elite men & women beach volleyball games during 2015~2022, including 839 sets from 366 men's matches as well as 840 sets from 367 women's matches. By using classification and regression tree referring to decision tree, binary logistic regression, characteristics of the scoring effectiveness and model of critical determinant winning skills were built accordingly. Findings: (1) attack points, opponent errors and breakpoints were ranked the top 3 determinant skills for winning; (2) breakpoints, attack errors and opponent errors were identified as top 3 crucial factors affecting winning of the games; and (3) results of the decision tree showed that the most critical game winning skills was breakpoints which cover connecting actions of service and block as well as back defense, set and counter attack followed which were collectively called "counter attack". It is implied that the higher successful rate of counter attacks was secured, the more likely the winning rate to be improved.

Keywords: Data Analysis, Match Analysis, Prediction, Sport Performance, Web Crawler Skill.

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I. Introduction

Ball games are fast-paced and unpredictable in nature. Therefore, identifying sequences and patterns in ball games has been of interest to coaching staff and researchers in the field of sports science. The quantification of sports performance allows for objective assessments of athletes' competitive performance. Moreover, performance statistics enable coaches to evaluate the implementation efficiency of training programs accurately, assess the conditions of athletes, properly execute training programs, and produce professional knowledge of competitive sports (Chen & Liu, 2010). Accordingly, video recordings of matches and statistics of players' skills have garnered the attention of sports scientists because they play crucial roles in the technical and strategic research of ball games and opponent analyses (Liu, 2007). The collection and extraction of sports data, establishment of databases, and data analytics have influenced various aspects of competitive sports, increased the knowledge of sports science, assisted athletes with training, and improved real-time decision-making during competitions (Passfield & Hopker, 2017; Rein & Memmert, 2016). Big data and data science in sports have gradually garnered attention in various fields of research. Additionally, researchers have paid great attention to the application of data-science concepts into sports training and development. The most renowned example was showcased in the film *Moneyball*, which was based on the 2002 Oakland Athletics, a Major League Baseball team. In the film, the team used data analysis and scientific statistical methods based on Sabermetrics to select players to reconstruct their team. The team's methods achieved outstanding results, and the team won the season championship under heavy budget constraints (Lin *et al.*, 2017). Data analysis has played a key role in competitive sports, specifically in understanding and grasping the progression of games. Bai and Bai (2021) and Lee *et al.* (2018) applied big data analysis and artificial intelligence technology to assist athletes and coaching teams in understanding athletes' performance during regular training and games. The authors were able to adjust training activities according to athletes' movements and physical conditions and analyze the strengths and weaknesses of competitors in large games to increase the athletes' chances of winning. For example, the German national football team collaborated with the SAP Software Company by using the SAP HANA platform to assist the coaching team with identifying the strengths and weaknesses of the team and their opponents through big data on training. The coaching team devised tactics and strategies for the team by employing technology to assist the German national football team with winning the 2014 FIFA World

Championships (Tai, 2014). In *VolleyMetrics: The Moneyball of Volleyball*, current USA and UCLA men's volleyball head coach John Speraw indicated that statistics tell you what skills correlate most with winning, how your players execute those skills, and finally, indicate what areas demand your focus in training. They also add a level of objectivity. The numbers can help you evaluate players more accurately in what can be an emotional environment (Pham, 2014).

In a study on the use of big data for designing a volleyball game analysis decision-support tool, Sarah *et al.* (2013) analyzed historical data on George Mason University (GMU)'s Division I men's and women's volleyball teams, both of which were outplayed by their top competitors within their respective conferences from 2006 to 2012. Their results revealed that the GMU men's and women's volleyball teams had a lower probability of scoring points by an average of 0.21 and 0.05, respectively. The win–loss outcome was determined using a function that represented the combinations of sequences of events attributable to the team's actions and coach's tactics. In their study, a computer-aided analysis tool was employed to analyze the trends that underlay the teams' wins and losses because the historical data were too complex for anyone to analyze comprehensively; they provided suggestions for improving the overall team performance of a volleyball team. Similarly, Sebastian *et al.* (2020) employed a market basket analysis, a big data mining technique, to evaluate technical and tactical models in top-level beach volleyball games. The study used sequential rule mining and clustering to mine for performance data collected from over 400 games held at Fédération Internationale de Volleyball between 2013 and 2016 to reveal the underlying connotations behind the big data. For sports teams, identifying changes and patterns or anticipating how opponents will apply and change their own tactics can effectively increase their chance of winning. Currently, several countries have adopted advanced technology (e.g., high-magnification video cameras, sensor devices, wearable technology, artificial intelligence image recognition technology, and machine learning) to collect vast amounts of sports data from games; the collected data contained abundant referential resources and value. Through big data analyses, coaching teams can perform a real-time analysis to evaluate the present conditions of their team and their opponents. Moreover, the coaching team can predict the changes and development of the game, anticipate the opponent's tactics, and ensure that their team has the advantage, all of which increases the team's win rate.

A literature review revealed two main conventional methods for collecting data on beach volleyball techniques and tactics: the notation analysis and observation method. The observation method consists of the manual recording of data followed by the use of statistical methods to explore the team's performance in offensive, defensive, and counterattacking skills (e.g., serve, attack, block, back defense, reception, and set) and an analysis of the characteristic differences between the winning and losing teams. A model is then established to determine the technical indicators for predicting the winning team and is provided to the beach volleyball team for training and competition applications (Tian, 2016; Bai, 2010; Xu, 2019; Peng, 2007; 2020; Liao, 2003; Alexandre & Rui, 2017; Giatsis & Zahariadis, 2008; Mikko & Kostas, 2012; Palo & Ortega, 2015; Papadopoulou *et al.*, 2020). In both methods, data are collected and obtained by reviewing video recordings and manual recording data of games. Such methods produce little data, consume considerable labor and time, and may incur human errors because they rely on people to make judgements and complete data entry manually. Therefore, the present study conducted a data-science analysis to compile large amounts of technical and tactical data (e.g., attacking and defending skills, scoring skills, and key skills to winning) collected from world-class men's and women's beach volleyball games. Python web crawling technology was used to collect research data rapidly and accurately, and the decision tree, a big data statistical method, was used for clustering and determine the nodes. Data on serving techniques as well as offensive, defensive, counterattacking, and scoring skills were analyzed to explore the technical characteristics of each beach volleyball player, determine key factors for winning, and establish skill combinations for scoring in beach volleyball. By using evidence based on data science, this study identified key factors for winning and proposed a result prediction model, which can assist coaching teams with devising plans for training and competitions. The main motivation for this study was to provide a reference for Taiwanese volleyball players and coaching teams when devising plans for training and competitions. Overall, this study developed a model based on the skills recorded in world-class men's and women's volleyball games, compared the performance of both male and female players, and explored factors influencing the results of volleyball games.

II. Research Methods

A. Research Participants and Methods

Volleyball as a sport game started in the 1920s. In 1997, the first Beach Volleyball World Championships were held in 1997 in Los Angeles, United States. The championships are held biannually and are the largest in terms of scale, level, prize money, and ranking among all competitions organized by the *Fédération International de Volleyball* (FIVB).The study analyses were based on match reports collected from FIVB's

Volleyball Information System (VIS) for all games played during the Beach Volleyball World Championships held between 2015–2022 for both male and female players. The match reports were commissioned by the FIVB and produced by Data Project through the Click & Scout software. The reports are publicly available on FIVB's official website.

This study conducted a secondary data analysis, which involves collecting existing data and using the raw data to explore a new research topic (Stewart & Kamins, 1993; 2000). The advantage of secondary data analysis is the public availability of match records on the Internet, which allows for quick investigation, reduced data collection time, and lower human errors in data entry. Additionally, secondary data analysis does not require verification on the research design or sampling, which can save time and research costs. This study employed a data mining approach; a Python web crawler was used to mine for data on all games played during the 2015, 2017, 2019, and 2022 Beach Volleyball World Championships. Data on 839 sets from 366 men's games, which consisted of 48,378 records of skills, and 840 sets from 367 women's games, which consisted of 47,550 records of skills, were collected. These skill data on the player's performance in offense and defense were used for the subsequent analyses. The VIS selects and defines skills as (a) skills leading to winning a point (e.g., breakpoints, service points, attack points, and block points) and (b) skills (errors) leading to losing a point (e.g., service errors, reception errors, attack errors, attack blocked, and opponent errors). These skills were used as the research variables. A cross analysis was first conducted on the collected data to evaluate the model structure of skills used in men's and women's beach volleyball games, compare the differences in offensive and defensive performance between players of both sexes, and explore factors influencing the game's outcomes.

B. Data Collection Technology and Validity

Python web crawling technology is a mainstream technique for data collection; it uses a program to automatically extract data from websites. In data science, "without big data, there is no artificial intelligence." Web crawling is a key data collection technique in the field of big data.

This study commissioned a professional to code a web crawler algorithm and in Python. The web crawler was then used to extract relevant data from the Internet. Subsequently, the database management tool, MySQL, was used to manage the collected data. The web crawler collected statistical data from FIVB's VIS on the offensive and defensive performance of male and female players in all games played during four editions of the Beach Volleyball World Championships from 2015 to 2022. The data were downloaded and converted into an Excel file to obtain performance data on the players' offensive and defensive skills. Data comparison, testing, and debugging were subsequently conducted using a program. A 1-week web crawling teat session was conducted once in July and once in August 2022 for data collection. The data were then converted into Excel files for statistical analysis, and the data downloaded in September 2022 were used as the final version. The author randomly sampled match reports of 20 men's matches and women's matches each from different years for a validity test to ensure consistency between the web crawling data and VIS database records.

C. Data Processing and Statistics

A decision tree analysis is the most common data mining technique. Decision trees are a supervised-learning classification method in which tree analysis concepts are applied as the decision-making model. The tree model is constructed through data preparation, tree growth and pruning, and rule extraction (Kung, 2021). This study adopted the SPSS 22.0 software to construct a classification model with the classification and regression tree (CART) algorithm. The aim was to identify factors influencing the results of men's plays and women's plays in the Beach Volleyball World Championships and determine the win–loss ratio for each skill combination. Similar to Chen and Liao (2018), who analyzed key factors for men's double badminton matches by using a decision tree algorithm, this study also employed the decision tree algorithm for identifying classification characteristics and key factors influencing decision-making. Accordingly, a tree model was established based on the outcomes of games, with the decision tree grown according to the win–loss ratio of games and the patterns and trends of the variables (i.e., skills leading to winning or losing a point). The decision tree was subsequently used for sample prediction.

The classification criterion is to maximize (1).

$$\Delta i(s,t) = i(t) - pLi(tL) - pRi(tR) \quad (1)$$

where $\Delta i(s,t)$ is the impurity of node t before splitting by variable s minus its impurity after splitting; $i(t)$ is the impurity of node t before splitting; and $pLi(tL)$ and $pRi(tR)$ are the impurities of the left and right nodes, respectively.

During the model construction process, the node classification accuracy of the growth model was evaluated. The criterion variables were set as categorical, and the Gini index and the Twoing criterion were used for impurity measurements.

This study employed the Gini index and a classification model based on the overall sample to construct the largest possible decision tree structure and limit noise interference (Chiang & Lin, 2014; Tsai, 2018; Breiman *et al.*, 1984; Witten & Frank, 2005). The minimum sample size for parent nodes was 100; the minimum sample size for child nodes was 50.

III. Results

A. Ranking of Determinant Skills for Winning or Losing a Point in Beach Volleyball World Championships Games

Data collected on men's plays revealed that attack points (mean: 25.19 points/game), opponent errors (mean: 10.82 points/game), and breakpoints (mean: 8.89 points/game) were the top three determinant skills for winning or losing a point. Reception errors was associated with the least winning and losing points (mean: 1.37 points/game), preceded by service points (mean: 2.09 points/game) (Table I).

TABLE I: Descriptive of Skill used in the Men's Play (366 Games)

Skill	Winner			Loser			Total		
	Sum	Mean	SD	Sum	Mean	SD	Sum	Mean	SD
Break Points	4164	11.38	3.14	2344	6.40	3.38	6508	8.89	4.10
Service Errors	1839	5.02	2.63	1875	5.12	2.67	3714	5.07	2.65
Service Points	972	2.66	2.88	555	1.52	1.45	1527	2.09	2.35
Reception Errors	377	1.03	1.30	623	1.70	1.83	1000	1.37	1.63
Attack Errors	1555	4.25	2.78	2228	6.09	2.59	3783	5.17	2.84
Attack Block	1096	2.99	2.02	1624	4.44	2.33	2720	3.72	2.30
Attack Points	9960	27.21	6.12	8482	23.17	7.27	18442	25.19	7.01
Block Points	1654	4.52	2.30	1109	3.03	2.00	2763	3.77	2.28
Opponent Errors	4347	11.88	3.89	3574	9.77	4.01	7921	10.82	4.09

TABLE II: Descriptive of Skill used in the Women's Play (367 Games)

Skill	Winner			Loser			Total		
	Sum	Mean	SD	Sum	Mean	SD	Sum	Mean	SD
Break Points	4698	12.80	3.98	2349	6.40	3.92	7047	9.60	5.08
Service Errors	1810	4.93	2.48	1763	4.80	2.45	3573	4.87	2.47
Service Points	1420	3.87	2.26	799	2.18	1.83	2219	3.02	2.22
Reception Errors	557	1.52	1.73	966	2.63	2.29	1523	2.07	2.10
Attack Errors	1560	4.25	2.82	2330	6.35	2.90	3890	5.30	3.05
Attack Blocked	649	1.77	1.72	1092	2.98	1.99	1741	2.37	1.95
Attack Points	9869	26.89	5.81	7865	21.43	7.61	17734	24.16	7.30
Block Points	1125	3.07	1.96	658	1.79	1.71	1783	2.43	1.95
Opponent Errors	4443	12.11	4.40	3597	9.80	4.09	8040	10.95	4.40

Table II presents data collected from women's plays. Attack points (mean: 24.16 points/game), opponent errors (mean: 10.95 points/game), and breakpoints (mean: 9.60 points/game) were the top three determinant skills for winning or losing a point. Reception errors (mean: 2.07 points/game) was ranked last for winning or losing a point—identical to men's plays—and preceded by attack blocked (mean: 2.37 points/game). These results indicated that the rankings of the skills determinant for winning or losing a point were similar between men's and women's plays. The top three skills and the last skill were the same between men's and women's plays. However, the rankings of the other five determinant skills for winning or losing a point differed.

B. Ranking of Crucial Factors Affecting the Results of the Beach Volleyball World Championships Games

This section comprehensively explores the factors influencing the results of match outcomes. The CART algorithm was used to construct a model on the characteristics of the scoring effectiveness and a model of critical winning skills that influence the outcomes for world-class men's and women's beach volleyball games. The purpose of model construction was to avoid the use of a conventional single-factor analysis of the skill performance of beach volleyball games, which may overlook the key factors influencing the game outcomes.

In the decision tree analysis, the skills and game outcomes were employed as the predictors and the target variables, respectively. The tree established with data on men's plays had a depth of 3 and 7 terminal leaf nodes, and the tree constructed using data on women's plays had a depth of 3 and 6 terminal leaf nodes (Table III). The overall analysis results revealed breakpoints, attack errors, and opponent errors to be the top three crucial factors affecting the results of men's plays. For women's plays, breakpoints, attack points, and attack errors were the top three crucial factors affecting the game results.

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TABLE III: MODEL SUMMARY

Growing Method	Men (366 games)	Women (367 games)
	CART	
Dependent Variable	Result (win or lose)	
Independent Variables	Break Points, Attack Points, Block Points, Service Points, Reception Errors, Attack Errors, Opponent errors, Attack Block, Service Errors	
Validation	None	
Maximum Tree Depth	5	
Minimum Cases in Parent Node	100	
Minimum Cases in Child Node	50	
Independent Variables Included	Same above	
Number of Nodes	13	11
Number of Terminal Nodes	7	6
Depth	3	3

Note: CART; Classification and Regression Tree

Most factor rankings were consistent between men's plays and women's plays, which indicated that most skills had the same importance levels in the two groups. However, differences existed in the top rankings of men's and women's plays; the ranking of attack points was higher in women's plays, whereas the ranking of opponent errors was higher in men's plays (Table IV, Fig. 1, and Fig. 2).

TABLE IV: INDEPENDENT VARIABLE IMPORTANCE

Key factors of win	Men		Women	
	Normalized Importance	Rank	Normalized Importance	Rank
Break Points	100.0%	1	100.0%	1
Service Errors	0.7%	9	2.1%	9
Service Points	15.7%	7	27.5%	5
Reception Errors	14.3%	8	24.8%	6
Attack Errors	40.0%	2	42.9%	3
Attack Blocked	31.6%	4	30.5%	4
Attack Points	30.2%	5	52.1%	2
Block Points	24.0%	6	20.7%	8
Opponent Errors	33.6%	3	21.6%	7

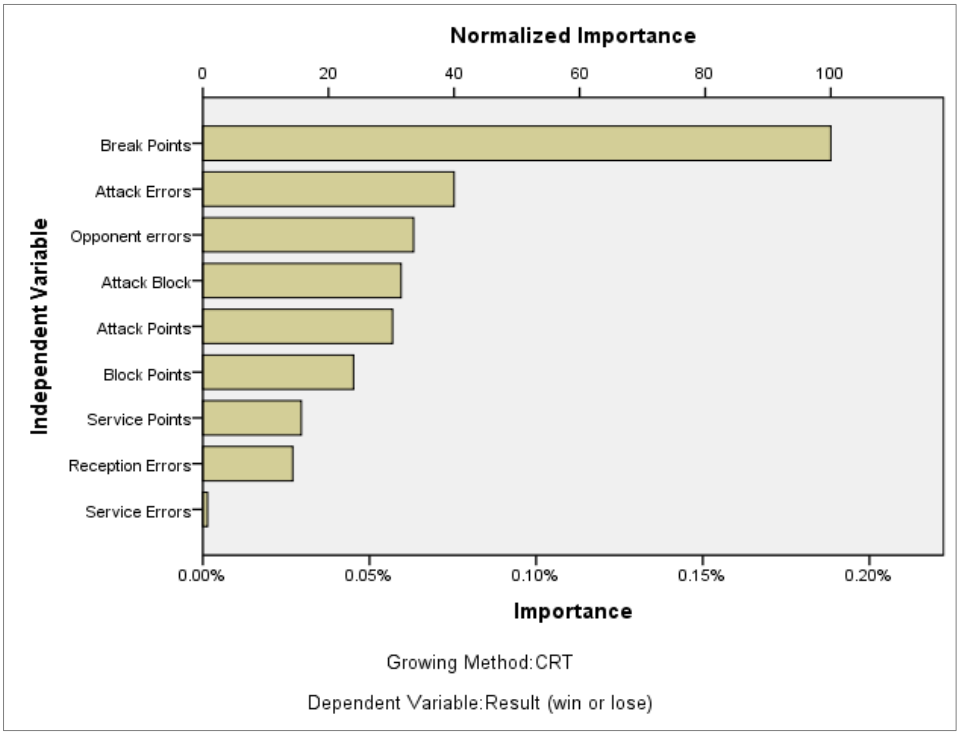

Fig. 1. The importance of factors influencing the result of the men's play.

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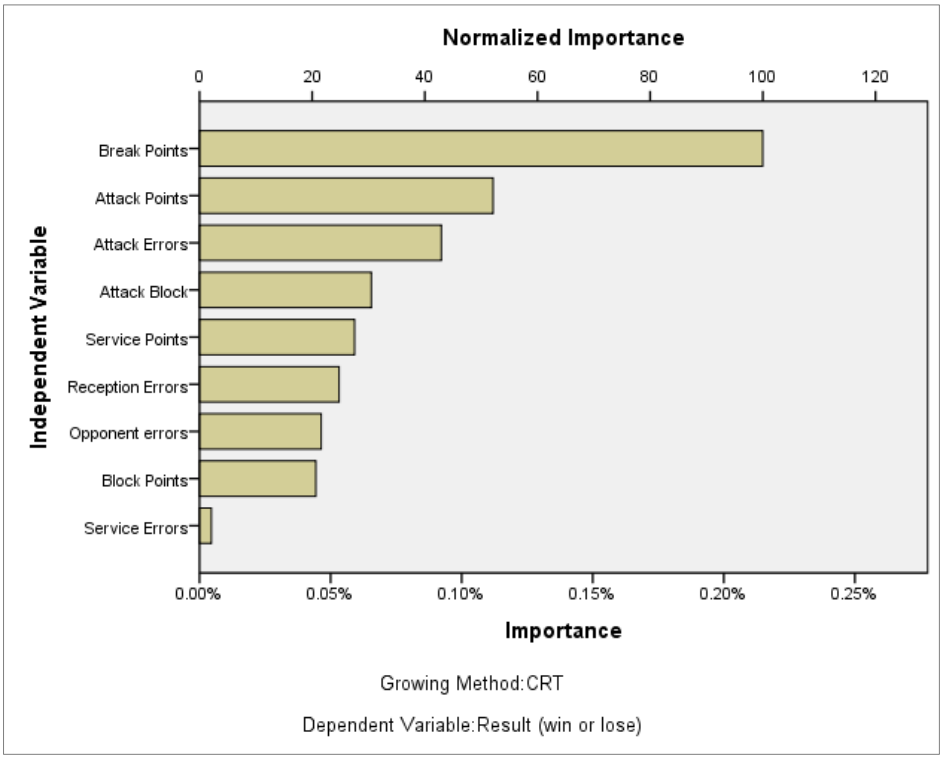

Fig. 2. The importance of factors influencing the result of the women's play.

C. Decision Tree Analysis of Most Critical Game-Winning Skills

1) Men's plays

A comparison between Nodes 1 and 2 of the decision tree models for men's plays with respect to the win–loss ratio revealed that breakpoints had the greatest contribution to winning. Teams with high breakpoints (>8.5) had a win rate of 76.3%, and those with low breakpoints (≤8.5) had a win rate of 20.3%. Node 5 indicated that teams with high breakpoints and few attacks blocked (≤3.5) had a win rate of 91.0%. Node 9 revealed that teams with high breakpoints, few attacks blocked, and few attack errors (≤4.5) had a win rate of 98.5%.

In Table V, Node 10 demonstrated that men's plays with high attack errors, but few attacks blocked had a win rate of 79.0%. Node 12 indicated that teams with many attacks blocked, and high breakpoints had a win rate of 77.8%. Node 4 indicated that for teams with low breakpoints, pressuring the opponent to increase opponent errors (>12.5) could increase their win rate (51.6%).

TABLE V: GAINS FOR NODES OF MEN'S PLAY

Node	N	Win/lose ratio	Classification rule
7	172	win：1.2% lose：98.8%	(BreakPoints) <= 8.5 AND (Opponenterrors) <= 12.5 AND (BreakPoints) <= 6.5
8	79	win：25.3% lose：74.7%	(BreakPoints) <= 8.5 AND (Opponenterrors) <= 12.5 AND (BreakPoints) > 6.5
4	93	win：51.6% lose：48.4%	(BreakPoints) <= 8.5 AND (Opponenterrors) > 12.5
9	131	win：98.5% lose：1.5%	(BreakPoints) > 8.5 AND (AttackBlocked) <= 3.5 AND (AttackErrors) <= 4.5
10	81	win：79.0% lose：21.0%	(BreakPoints) > 8.5 AND (AttackBlocked) <= 3.5 AND (AttackErrors) > 4.5
11	95	win：42.1% lose：57.9%	(BreakPoints) > 8.5 AND (AttackBlocked) > 3.5 AND (BreakPoints) <= 11.5
12	81	win：77.8% lose：22.2%	(BreakPoints) > 8.5 AND (AttackBlocked) > 3.5 AND (BreakPoints) > 11.5

Holding an advantage in breakpoints, increasing attack points (i.e., reducing attacks blocked and errors), and increasing opponent errors can considerably increase the win rate of men's teams (Fig. 3).

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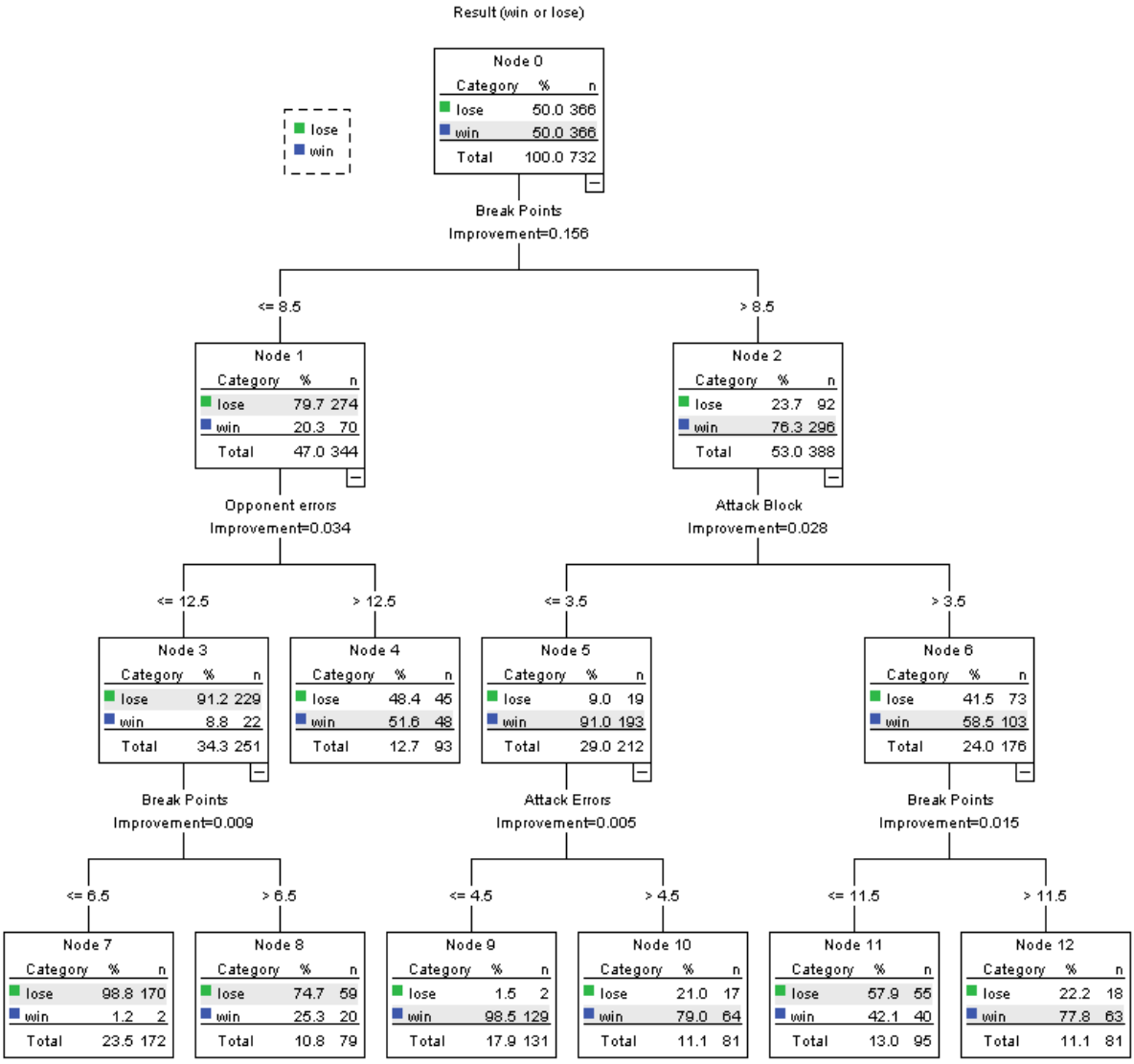

Fig. 3. Decision tree model for the result of the men's play.

2) Women's plays

Nodes 1 and 2 of the decision tree models for women's plays revealed similar results to those of men's plays. Specifically, teams with high breakpoints (>8.5) had a 77.3%-win rate, and those with low breakpoints (≤8.5) had a 13.9%-win rate. Node 5 revealed that teams with high breakpoints and few attack errors (≤4.5) had a win rate of 89.7%. Node 7 showed that teams with high breakpoints, few attack errors, and few attacks blocked (≤2.5) had a 99.6%-win rate.

In Table VI, Node 8 demonstrated that teams with high breakpoints, few attack errors, and many attacks blocked had a 68.4%-win rate. Node 9 revealed that teams with high breakpoints, many attack errors, and few reception errors had a win rate of 70.3%.

TABLE VI: GAINS FOR NODES OF WOMEN'S PLAY

Node	N	Win/lose ratio	Classification rule
3	211	win：3.8% lose：96.2%	(BreakPoints) <= 8.5 AND (AttackPoints) <= 22.5
4	105	win：34.3% lose：65.7%	(BreakPoints) <= 8.5 AND (AttackPoints) > 22.5
7	175	win：96.6% lose：3.4%	(BreakPoints) > 8.5 AND (AttackErrors) <= 4.5 AND (AttackBlocked) <= 2.5
8	57	win：68.4% lose：31.6%	(BreakPoints) > 8.5 AND (AttackErrors) <= 4.5 AND (AttackBlocked) > 2.5
9	128	win：79.3% lose：29.7%	(BreakPoints) > 8.5 AND (AttackErrors) > 4.5 AND (ReceptionErrors) <= 2.5
10	58	win：43.1% lose：56.9%	(BreakPoints) > 8.5 AND (AttackErrors) > 4.5 AND (ReceptionErrors) > 2.5

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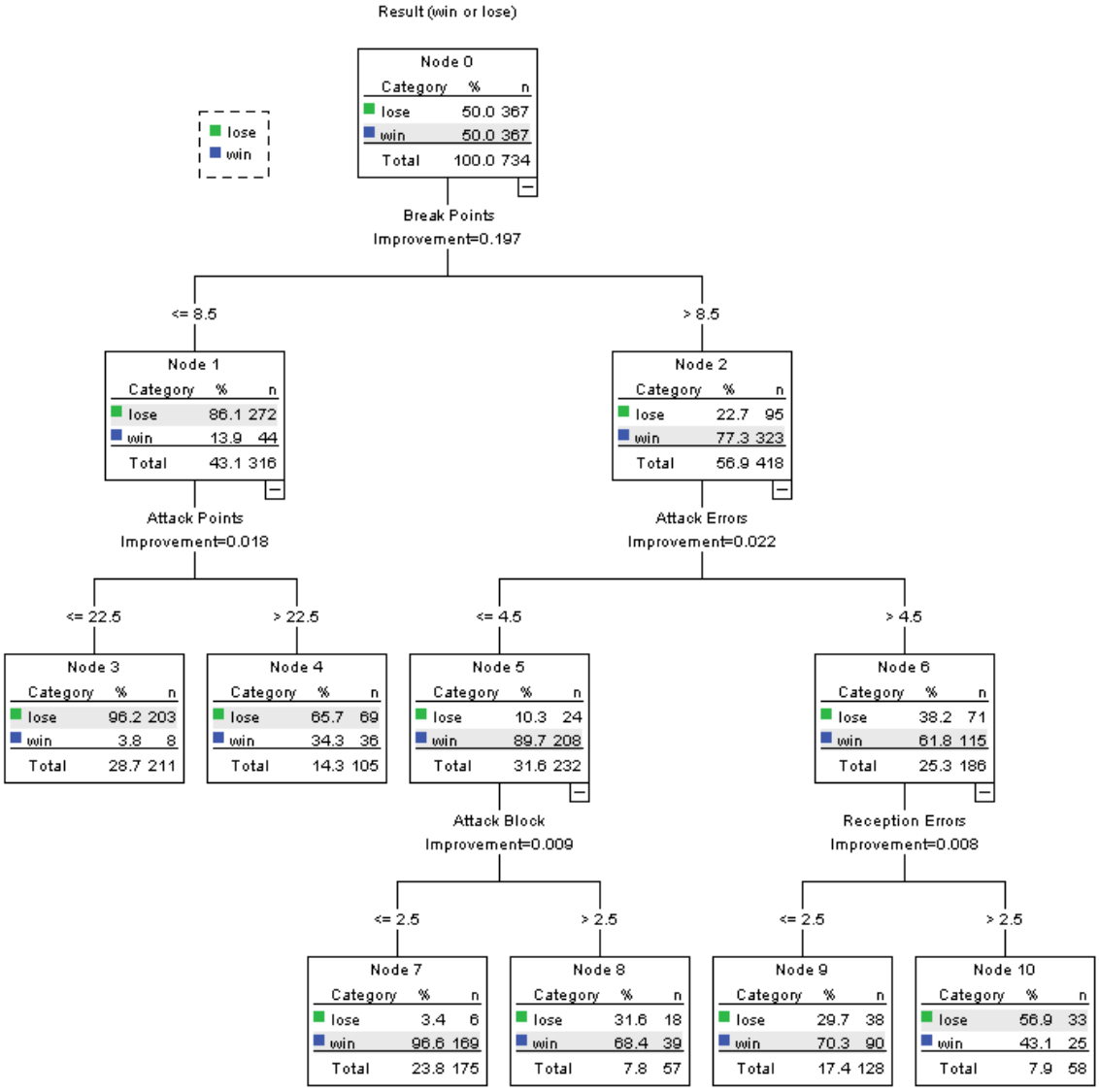

Fig. 4. Decision tree model for the result of the women's play.

Additionally, Node 4 indicated that teams with low breakpoints (≤8.5) and high attack points (>22.5) had a 34.3%-win rate. Overall, to increase the chance of winning, women's teams should maximize high breakpoints and minimize reception errors, attack errors, and the number of attacks blocked. This skill combination and winning model were similar to those of the men's plays, but the skills had different importance levels (Fig. 4).

D. Binary Logistic Regression Analysis of Characteristics of Skills and Win Rate

This study employed binary logistic regression; a statistical model used to determine the probability that an event occurs. The binary logistic regression model presents the relationships between characteristics and calculates the possibility of each result happening, such as a team's win rate in a game. A regression analysis was conducted on the influences of the nine crucial skills (i.e., the independent variables) on the results of the men's and women's plays of the Beach Volleyball World Championships and the level of these influences. Forward conditional selection was used with Wald statistical testing to select independent variables with significant effects on the dependent variable for further discussion.

Table VII lists the results of the regression analysis. In men's plays, five variables, namely breakpoints, reception errors, attack errors, attacks blocked, and opponent errors, had significant effects on the dependent variable and were revealed as crucial factors that influenced the results of the games. The odds ratios (ORs) of breakpoints and opponent errors were 1.67 and 1.22, respectively. Both ORs were greater than 1, suggesting that breakpoints and opponent errors had a positive effect on winning. Specifically, the more frequently these skills were used, the higher the team's win rate was. The ORs of the other variables—service errors, attack errors, and attacks blocked —were less than 1, suggesting that they had a negative effect on winning. Therefore, less frequent use of these skills led to in higher win rates.

TABLE VII: SUMMARY OF LOGISTIC REGRESSION OF BEACH VOLLEYBALL WORLD CHAMPIONSHIPS

Independent Variables	Men			Women		
	B	OR	*p*	B	OR	*p*
Constant	-3.06	0.05	0.000	-4.06	0.02	0.00
Break Points	0.51	1.67	0.000	0.32	1.38	0.00
Service Errors	-	-	-	-0.15	0.86	0.01
Service Points	-	-	-	0.17	1.18	0.02
Reception Errors	-0.41	0.66	0.000	-0.44	0.65	0.00
Attack Errors	-0.36	0.70	0.000	-0.46	0.63	0.00
Attack Block	-0.35	0.70	0.000	-0.57	0.57	0.00
Attack Points	-	-	-	0.10	1.11	0.00
Block Points	-	-	-	0.22	1.24	0.01
Opponent errors	0.20	1.22	0.000	0.24	1.27	0.00

*p < 0.05, **p < 0.01, ***p < 0.001, Forward Selection (Conditional)，Wald test

In women's plays, all nine variables had significant effects on the dependent variable. The ORs of breakpoints, opponent errors, block points, service points, and attack points were 1.38, 1.27, 1.24, 1.18, and 1.11, respectively. The ORs of these five variables were greater than 1, suggesting that they all had a positive effect on winning. That is, the more frequently these skills were used, the more likely the team would win. The ORs of the other variables—service errors, reception errors, attack errors, and attacks block—were less than 1, suggesting that they had a negative effect on winning. Accordingly, less frequent use of these skills led to higher win rates.

The results of the logistic regression analysis revealed that breakpoints and opponent errors were factors with positive effects on winning in both men's and women's plays. The ORs of breakpoints and opponent errors in men's and women's plays ranged from 1.22 to 1.38. For each break point won by a men's team (OR = 1.38 > 1, $p < 0.001$), the team's win rate increased by 1.38 times. For each opponent error made by a women's team (OR = 1.27, $p < 0.001$), the team's win rate decreased by 1.27 times. Breakpoints can prevent the receiving team from organizing their first wave of attack for a side-out. The high ORs of breakpoints and opponent errors highlight the importance of defence, counterattacks, and increasing opponent errors; these two skills were both crucial skills with great influences on the results of men's and women's games. Additionally, women's teams should improve their serving, blocking, and counterattacking skills to further increase their win rate.

E. Comparison of Decision Tree Analysis Results and Binary Logistic Regression Analysis Results

For men's plays, the importance rankings of the skills in the logistic regression and the decision tree were similar. The top four skills in both analysis approaches were breakpoints, attack errors, attacks blocked, and opponent errors. Reception errors was assigned a low level of importance in the decision tree (ranked eighth) but was determined to have a significant effect on win rate in the logistic regression analysis, ranked fifth in importance (OR = 0.66 < 1, $p < 0.001$).

For women's plays, the importance rankings of the top three skills were similar to that of men's plays. However, the rankings of attack points and service points in the decision tree for women's plays (second and fifth, respectively) were higher than those determined in the logistic regression analysis (sixth and ninth, respectively). Opponent errors were ranked lower in the decision tree (seventh) than in the binary logistic regression model (fourth).

The results of the two methods revealed different results (Table VIII), which was mainly attributed to the different algorithms and equations used in each method. A comparison between the results of the two methods revealed that the top three skills for winning or losing in men's and women's plays were breakpoints, attack errors, and attacks blocked. Accordingly, earning the right to serve and scoring points were crucial skills for ensuring victory. Additionally, less frequent use of skills (errors) that led to losing a point, including attack errors and attacks blocked, was also part of the winning tactic.

TABLE VIII: COMPARISON OF DECISION TREE AND LOGISTIC REGRESSION

Skill	Men		Women	
	order of importance of DT	order of selection of LR	order of importance of DT	order of selection of LR
Break Points	1	1	1	1
Service Errors	9	-	9	7
Service Points	7	-	5	9
Reception Errors	8	5	6	5
Attack Errors	2	3	3	2
Attack Blocked	4	2	4	3
Attack Points	5	-	2	6
Block Points	6	-	8	8
Opponent Errors	3	4	7	4

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IV. Discussion

A. Importance of Break Points

The definition and connotation of breakpoints are identical to those of counterattack. Both of them require players to perform a series of skills to score. Break points are scored if a service team (a) scores a service point, (b) serves → scores block points, or (c) serves → blocks and performs back defense → sets → scores a counterattack point. The first two series of skills are included in the study's definition of breakpoints, whereas the third series is considered a counterattack composed of a specific skill combination. From the receiving team's perspective, a breakpoint is scored if (a) the opponent team incurs a reception error, (b) the opponent team incurs errors, or (c) the opponent team receives the serve → sets → incurs attack errors. Overall, breakpoints occur when the receiving team incurs errors in offensive or defensive skills, which result in the serving team scoring.

Decision tree and binary logistic regression tree analyses revealed that breakpoints were the main scoring skill used by world-class men's and women's volleyball teams and were the most crucial factor for winning. These results were consistent with the findings of Kumar *et al.* (2021), who explored a total of 212 and 214 games held in the men's and women's Beach Volleyball World Championships, respectively, in 2017 and 2019. They proposed counterattacks as the most crucial factor for winning. Peng (2007) reported that the numbers of attacks blocked ($t = 4.159$) and counterattacks ($t = 3.565$) had significant effects on the winning of games and significant correlations with the total points scored ($r = 0.670$ and counterattacks: $r = 0.550$, respectively; $p < 0.05$). These results indicated that training in counterattack skills (e.g., breakpoint skills) is the most effective for winning games.

B. Crucial Factors and Model for Winning

1. The rankings of determinant skills for winning or losing a point in men's and women's plays were similar. The top three determinant skills (i.e., attack points, opponent errors, and break points) and the bottom determinant skill (reception errors) for winning or losing a point were the same for men's and women's plays.
2. The decision tree CART algorithm was used to construct the characteristics of scoring effectiveness of the world-class men's and women's plays in beach volleyball. The top three crucial factors for winning in men's plays were break points, attack errors, and opponent errors in that order, whereas the top three in women's plays were break points, followed by attack points and then attack errors. Most rankings of the crucial factors for winning were the same for both men and women; thus, the importance levels of most skills did not differ between the two groups. Skills with distinctly different rankings were opponent errors, which ranked higher in men's plays (33.6%; third), and attack points, which ranked higher in women's plays (52.1%; second).
3. The decision tree results revealed break points as the most critical game-winning skill for both men's and women's plays. Break points were critical because teams that keep the serve can use the serve to prevent the opponent from organizing their first wave of attack and avoid a side-out through blocking, back defense, setting, and counterattacks. In this complex, the serving team performs a series of offensive and defensive skills, including serving, blocking, back defense, setting, and counterattacking. In other words, a higher success of counterattacks results in higher win rates, which was consistent with the findings of Peng (2020), who analyzed the skills used in the 2019 Beach Volleyball World Championships, and those of Alexandre *et al.* (2017), who researched the performance of U19, U21, and adult teams in men's plays at the 2010–2011 Beach Volleyball World Championships. Both studies reported increases in the success rate and efficiency of counterattacks to be a critical game-winning skill. This study verified that in beach volleyball, the "first wave of attack" (i.e., counterattacks, relative to break points) are fundamental and essential for victory. This finding was consistent with the results of Häyrinen and Tampouratzis (2012), who explored the differences between winning and losing teams in elite women's beach volleyball games. They analyzed games held during the 2010 Beach Volleyball World Tour and the 2011 Beach Volleyball European Championship and reported that the first wave of attack is a crucial skill that determines the game's results. This finding also echoed the results of Giatsis (2022), who analyzed the skill performance of top-level men's beach volleyball games.

C. Potential Influence of Service and Blocking Skills

Serving is both the start of the game and a form of attack. Excellent serving skills can disrupt the opponent from organizing an attack (i.e., reception → setting → attack), increase the serving team's success rate of defending against counterattacks, and thus affect the game's result (Koch & Tilp, 2009). Serves that are made with different techniques, are aimed toward the spot where the opponent may have a weak defense, have alternating levels of force, are difficult to receive, obstruct the opponent's attacks, and are made by a server with in-depth knowledge of serving can all directly or indirectly disrupt the opponent's rhythm and flow in their first wave of attack and thus reduce the possibility of successful counterattacks from them

(Sun & Yan, 2008; Kiraly & Shewman, 1999; Kumar *et al.*, 2021; Medeiros *et al.*, 2014; Tanner, 1998). Furthermore, in top-level men's volleyball games, blocking has a major effect on the game's results (Häyrinen & Tampouratzis, 2012; Jiménez & Penichet, 2017; Medeiros *et al.*, 2017), similar to serving. These two skills directly prevent the opponent from organizing an attack by forcing reception errors and attack errors, thereby causing the opponent to lose a point. Serving and blocking skills, although incapable of directly score points, may hinder the opponent, disrupt their attacks, and considerably undermine the opponent team's smoothness and rhythm when performing a series of skills. However, the statistical analysis revealed that both service points and block points ranked low in terms of their influence on and importance in winning a match. The results of this study indicated that breakpoints are the most critical game-winning skill. To win break points, the serving team needed to perform a series of skills including serving and blocking. The results of the present study were consistent with those of Kumar *et al.* (2021), who researched games in elite beach volleyball championships and reported significant correlations between several critical skills and winning.

V. Conclusion

To summarize the research and analysis results, this study proposed the following findings on effective skill combinations and models that are used in top-level men's and women's volleyball games. These skills and models are recommended for use in routine training and competitions: the winning continuous skill combination and victory model was identified when the server can defend well and continue to score by increasing attack points by reducing effective blocks performed by the opponent plus decreasing the team's attack errors and force the opponent to make more technical or skill errors.

The research variables of this study are based on skills leading to winning or losing points in beach volleyball, which were chosen and selected by the FIVB. Data on these skills were obtained from match reports produced by a data company through manual data entry under the commission of the FIVB. Such match reports may have limited the research scope of this study and influenced the direction of its discussion. Therefore, this study proposed the following suggestions:

1. Future studies can further expand on the research variables. For example, studies may explore how the efficiency of non-scoring-related skills, such as the efficiency of reception, setting, and serving, may affect a team's chance of winning to further the understanding of the offensive and defensive patterns of beach volleyball and the skill combinations and models that are most effective at scoring.
2. Future studies should increase the sample size. To reduce labor and time input and to ensure accuracy in data collection, future researchers are advised to employ artificial intelligence image recognition technology in place of traditional manual documentation, conversion, and collection of data. Consequently, researchers can collect large amounts of data on offensive and defensive skills used in volleyball games within a short time. After completing the analysis, researchers may subsequently classify the data and establish a database according to different categories, such as player age, sex, and bracket as well as the type of game, to produce more sophisticated predictions on the key skills and models for winning.

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