Original Article

Beach volleyball set and technical performance indicators for elite women's teams

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ABSTRACT

This study aimed to investigate the beach volleyball set and technical performance indicators that best discriminate between winning and losing elite women's teams in set according to the final score differences of the set. The data have been collected from all sets played (N = 236) in the women's beach volleyball 2022 World Championship. Cluster analysis established two types of 21 points sets (S-21): balanced (S-21B) with a difference from 2-5 points and unbalanced (S-21U) with a difference >5 points. A discriminant function analysis indicated which skill(s) significantly contribute to winning in each type of set. The results of this study revealed that the teams that won S-21B, S-21U and S-15 had better performance than their opponents in set indicators (attack, block, serve, opponent errors) and technical indicators (attack kill percent, attack efficiency, and serve efficiency). Attack points and attack kill percent were the most important predictors of a team's success in terms of set and technical indicators, respectively. In summary, the attack kill percent is the most important indicator in elite women's beach volleyball in every type of set. However, serve aces per set point significantly increases the probability of winning a set in every type of 21-point set, while block per set points contributes equally significantly in 15-point sets. Despite the high level of blocking, women's teams must avoid attack errors to improve their chances of winning a set. The study's findings highlight the importance of the offensive ability to win a set, in women's elite beach volleyball.

Keywords: Performance analysis of sport, Benchmarks, Elite level, Discriminant analysis, Coaching, FIVB.

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INTRODUCTION

The first women's FIVB Beach Volleyball tournament took place in 1992. Along with the Olympic Games, the beach volleyball World Championships, which has been held every two years since 1997, is the most significant international women's event (Couvillon, 2004). In the World Championship, 48 teams from all continents participated in the tournament's final phase (Volleyball World, 2022).

The quantification of competitive abilities is crucial in team sports because it allows teams and athletes to assess and identify the factors that affect game results (Carling et al., 2009; Drikos and Vagenas, 2011; Garca-de-Alcaraz et al., 2016). Performance indicators are crucial for coaches to manage the characteristics of practice and competition (Drikos et al., 2018; Drikos et al., 2021). Performance in team sports is the result of a dynamic and interactive process between two competing teams (Garca-de-Alcaraz and Marcelino, 2017). The high level of competition increases the requirement for performance factor knowledge, therefore, to succeed, one must develop their potential to a high level (Griego-Cairo et al., 2016). To play at one's best, it is important to learn each technique in beach volleyball (López-Martnez et al., 2018; Valladares et al., 2016).

Because of this, using technology, match data are captured in software programs by skilled observers (Data Project, 2017), so coaches and athletes can use this information to improve their preparation. However, because so much data are gathered, interpretation is more difficult, and the usage of the data may be shared or kept secret between the competing teams. But simple data are easy to use in court training sessions (Mackenzie and Cushion, 2013). Numerous studies in sports other than volleyball, utilizing match report data have shown that it is possible to identify the performance indicators that distinguish winners from losers in the matches even using reduced statistics (Giatsis et al., 2022; Giatsis, 2022b). However, utilizing software to provide more thorough match reports could give a better overview of the game, and analysing individual sets would also provide a clearer picture of how efficiently teams and players performed.

Match reports have been used in important competitions in volleyball (Fernández-Echeverria et al., 2017; Oliveira et al., 2016) and beach volleyball (Link and Wenninger, 2019). These statistics, which quantify the frequency of various skills and how points are gained, include team and player statistics. The points a team can score from serve, attack, block, and an opponent's errors, such serve, attack, or other errors are all listed in the beach volleyball match report. With this information, coaches and athletes may assess their performance in games and training sessions using frequencies, percentages, efficiency, coefficients, and performance indicators (Griego-Cairo et al., 2016). Additionally, by including these stats in television broadcasts, beach volleyball matches can provide spectators with a more thorough understanding of the sport.

The International Volleyball Federation (FIVB) states that beach volleyball is played two versus two, and a team must win two sets to win the match. While the first two sets of the match are played to 21 points, the third one is played to 15 points in case teams are tied at one each (FIVB, 2022). Serve, serve reception, setting, attack, block, and dig are the order of actions (Giatsis and Zahariadis, 2008). Also, in many cases the players perform the attack without using a set but directly after the reception (Giatsis and Tzetzis, 2003; Giatsis et al., 2015). The side-out and counter-attack phases, which have different functions but are related, are also separated in beach volleyball. Serve, serve reception, set, and attack are all part of the side-out phase (Complex I), while block, dig, set, and attack are all part of the counter-attack phase (Complex II) (Perez-Turpin et al., 2019). With this differentiation, coaches and players may more easily evaluate how their teams perform in the two different game complexes.

The best performance in beach volleyball can be achieved thanks to studies of each technical action (Alvarado-Ruano and López-Martinez, 2022; Giatsis and Zahariadis, 2008; Giatsis et al., 2015; López-Martinez et al., 2018; Medeiros et al., 2014; Michalopoulou et al., 2005). Considering these findings, other researchers (Giatsis and Zahariadis, 2008) analysed the numerous technical actions and found that in F.I.V.B. games with a 2-0 score, winners performed better in practically every game action and that the opponents' offensive errors were the most crucial element in winning a match. However, in 2-1 matches winners performed better only in the total of win points. According to a recent study by Kumar et al. (2021), winning in top beach volleyball matches was associated with the opponents' errors. In another study, Palao and Ortega (2015) found that winning teams had higher side-out efficacy, more points, and fewer attack errors. Furthermore, several researchers reported that the kill attack percent for the teams in elite beach volleyball is roughly 55-60%. (Koch and Tilp, 2009; Papadopoulou et al., 2020; Roglan and Grydeland, 2006). Also, losing teams displayed more attack errors than winning teams. However, the top three teams in the Athens 2004 Olympic Games had an attack percent of over 60%.

Several researchers (Jiménez-Olmedo et al., 2012; Kumar et al., 2021; Medeiros et al., 2014; Palao and Ortega, 2015; Tilp et al., 2006) approved the value of the serve skill. The winning teams served more effectively, scoring more points, and making fewer serve errors than the losing ones. In this instance, no variations in the efficacy of the various serve types in women were discovered (Turpin et al., 2019). Additionally, at the Olympic level, 8.3% of serves were errors and 2.9% of serves were aces (Papadopoulou et al., 2020). According to earlier research, the winning teams typically had fewer serve errors than the losers (Simac et al., 2017, Turpin et al., 2019).

In men's F.I.V.B. matches, the block skill was crucial (Jimenez-Olmedo and Penichet-Tomas, 2017; Pena et al., 2013) and attacks were carried out against a block in place in 84–90% of games (Laios, 2008; Mesquita and Teixeira, 2004), and 91% of side-out phases (Giatsis et al., 2015). Additionally, successful teams in beach volleyball matches won more blocking points than losing teams (Grgantov et al., 2005; Medeiros et al., 2014; Medeiros et al., 2017). However, women perform blocking skills at 69.5% and had 4.9% block points per match (Laios, 2008).

The literature research indicates that there is no evidence of single set data for beach volleyball at the greatest rank of women's competition. We think that this difference is necessary to properly evaluate the performance of the winners in each set, since the standards may be lower when the final match score of 2-1, owing to the winning team dropping a set. Additionally, we anticipate that the performance indicators will be differentiated into groups of 21 points and 15 points. However, among the many sets being completed in a beach volleyball tournament, several of them have clear differences in scoring between competing teams. These sets may lead to a bias of the analysis's trends and increase the significance of several key performance indicators.

This study's objective was to investigate performance indicators that best discriminate between winning and losing a set, and according to the set final points difference, utilizing the data from women's match reports from the Beach Volleyball World Championship 2022. The goal of this study was to identify the best predictor variable(s) for winning a set across scoring skills and to explore the effect of skill parameters on the set outcome.

MATERIALS AND METHODS

Participants

48 teams from 29 countries participated in the 2022 beach volleyball World Championships, which took place in Rome, Italy. Expert Data Volley software observers assigned by the tournament organizers, recorded, and uploaded match reports to the official website throughout the 2022 beach volleyball World Championships (Data Project, 2017). The report included match and setup data, player information, scores, and statistics on how the players performed regarding their beach volleyball skills. The Volleyball Information System (F.I.V.B. V.I.S., 2015), which was created from official statistics and made available on the F.I.V.B. website, was used to record and evaluate.

For the 2022 World Championship data sample, 108 official match reports in total were collected. Three games were not included since a player was injured. In this tournament, 236 sets of 8318 points were played. From the total number of sets, 208 were at 21 points (S-21) and 28 were at 15 points (S-15). The distribution for the two types of sets is shown in Figure 1 according to the amount of points difference in each set. The main parameters that were recorded and analysed were: 9,907 attacks, 5,108 attack points, 468 blocks, 910 attack errors, 8,318 serves, 617 serve points (aces), 910 serve errors, and 191 other points (setting and blocking errors). The rally scoring system was used in all matches, with one point awarded per rally (FIVB, 2022).

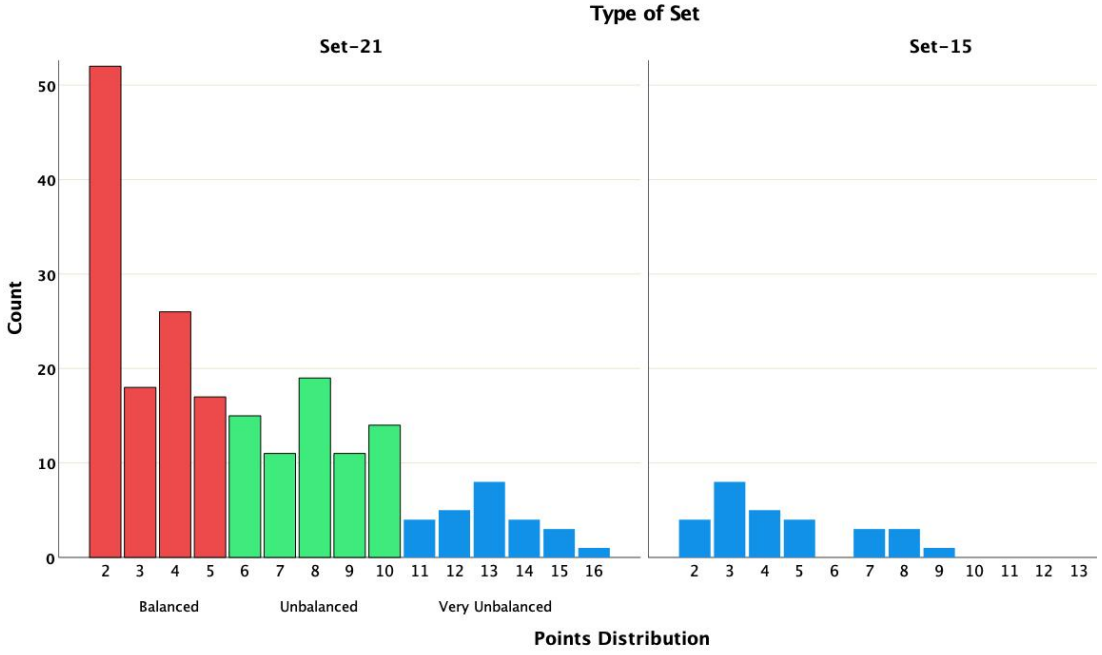

Figure 1. Distribution of sets according to the points difference in Set-21 (N = 208) and Set-15 (N = 28).

Measures and procedures

All serve and attack attempts were analysed. Total points and breakpoints (points scored when a team serves) are also analysed. All ways the team scores were examined: attack, block and serve scoring skills. Also, the opponent's error points (OpErr) team earned, were analysed (attack, block, serve, and setting errors). According to the FIVB official rules, overhand setting and blocking errors were respectively the illegal handling of the ball and the touch of the net.

The set and technical indicators were analysed in this study (Hughes and Bartlett, 2002). The set indicators were defined as the points won by attack, block, serve, and opponents' errors (attack, serve and other errors), while technical indicators were defined as the attack kill percent, attack efficiency, block per set points, attack opponents' errors per set points and serve aces per set points. The attack kill percent was determined by dividing the total number of successful attempts by the attack sum. The block, attack opponents' errors and serve aces, were calculated as the fraction of the points earned by the team divided by the total sum of both teams' set points. The attack efficiency was determined by the sum of successful attempts minus the lost attacks (blocked attempts and attack errors) divided by the total number of attacks. The serve efficiency was determined as the number of serve aces, minus the sum of serve errors, divided by the total number of serves.

Categorization was accomplished for the 21 points sets using k-means clustering (Norusis, 2005) and three distinct clusters were generated based on the final points set difference, with the greatest possible distinction: (a) balanced, (b) unbalanced, and (c) very unbalanced sets.

In each set, the teams' performance was classified according to the set result (win-loss) and type of set (21 and 15 points). The first author of the study as a beach volleyball expert (GG) collected 15% (N = 16 matches) of the total sample (Tabachnick and Fidell, 2007) from the FIVB official channel (http://www.volleyballworldtv.com) and recorded data in a Microsoft Excel special spreadsheet data. For attack, block, serve and opponents' errors, the reliability of data recording revealed perfect intra-ratter Cohen Kappa values (κ= 1.000, p < .001). In addition, an inter-rater reliability analysis using Cohen's Kappa statistic was performed between the author (G.G.) observations and the Data Volley statisticians, to determine the degree of consistency of data recording and presented almost perfect agreement across attack, block, serve, and opponent's errors (κ= .994, p < .001).

Analysis

Descriptive statistics were used to determine the winning and losing teams and the means and standard deviations of the two types of sets for each independent variable. In addition, for the set and technical indicators, an ANOVA was performed to evaluate the differences in the selected variables between winners and losers in all set types. The effect sizes (ES) were estimated using partial eta squared (η_p^2) to report the magnitude of the effect of the performance effectiveness for every beach volleyball skill, using the following interpretation criteria: 001 - .05 = small, .06 - .13 = medium, and ≥ .14 = large effect (Cohen, 1988).

Additionally, two stepwise discriminant analyses (DA) were used to find the set's and technical indicators' contributions to winning in every type of set. The DA aimed to determine three elements within each type of set: a) which variables were the best predictors for a team to win, b) the discriminant function that best differentiated a beach volleyball set from winning or losing, and c) the accuracy of the equation that best-discriminated success in a beach volleyball set. Structural coefficient (SC) loadings of magnitude greater than 0.30 are meaningful, indicating that the respective independent variable contributes significantly to the separation of different levels of the dependent variable (Pedhazur, 1997). The absolute loadings were: > .32 poor, > .45 fair, > .55 good, > .63 very good, and > .71 excellent (Comrey and Lee, 1992). To reduce classification bias, the validation of discriminant models was conducted using the "*leave one out*" classification, like jack - knifing (Norusis, 2005), with each case being classified by applying the classification function to all the data except in the particular case. An eigenvalue > 1 indicates a good model, e.g., a high value for canonical correlation implies a high degree of association between the dependent variable and the groups in the discriminant function. Using a Scatterplot, the accuracy of the discriminant function

regarding the key variables was shown to graphically represent the significance of the key performance indicators. The SPSS (version 27) was used to run the statistical analyses at a = .05 significance level.

The absence of multicollinearity has previously been detected using tolerance levels and variance inflation factors (VIF). Because the tolerance values were greater than .01 and the VIF values were lower than 10 there weren't any multicollinearity issues, and the data are appropriate to proceed with multivariate analysis.

RESULTS

Cluster analysis was performed on a total sample of 208 sets to generate a 21-point classification of three types of sets. From the total of sets, 113 sets (54.3%) were classified as balanced (S-21B) with a difference of two to five points, 70 sets (33.7%) were classified as unbalanced with a difference from six to ten points, and 25 sets (12.0%) were classified as very unbalanced with points difference equal or above 11 points. Due to a large number of balanced sets and the small number of very unbalanced sets it was deemed necessary to merge the sets from unbalanced and very unbalanced groups (S-21U).

Table 1 displays descriptive statistics of the attack attempts, serve attempts, total points, and breakpoints of every type of set for the factor set result, results of the ANOVA (F-value), significance value (*p*-value), and effect size.

Table 1. Means (M) and standard deviations (SD) of attack and serve attempts, break, and total points for the factor set result. Results of ANOVA (F-value), significance value (*p*-value) and effect size.

		Winners		**Losers**				
	N	M	SD	M	SD	Sig.	F	ES (η_p^2)
Attack attempts								
S-21	208	21.3	4.9	21.8	4.7	.265	1.25	.003
S-21B	113	23.8	4.4	23.3	4.5	.413	0.67	.003
S-21U	95	18.3	3.9	20.0	3.9	**< .01**	9.09	.046
S-15	28	16.5	3.8	17.5	3.1	.278	1.20	.022
Serve attempts								
S-21	208	20.6	.88	15.9	3.9	**< .001**	286.91	.409
S-21B	113	20.8	1.1	18.9	1.8	**< .001**	104.23	.318
S-21U	95	20.3	0.5	12.4	2.6	**< .001**	840.27	.817
S-15	28	14.9	0.9	11.1	2.7	**< .001**	48.54	.473
Total points								
S-21	208	21.2	.70	15.3	4.0	**< .001**	453.20	.523
S-21B	113	21.4	0.9	18.3	1.7	**< .001**	284.04	.559
S-21U	95	21.0	0.0	11.7	2.6	**< .001**	1187.36	.863
S-15	28	15.3	0.8	10.8	2.5	**< .001**	80.36	.598
Break points								
S-21	208	6.1	2.3	2.5	1.8	**< .001**	325.04	.440
S-21B	113	5.2	1.7	3.5	1.5	**< .001**	65.31	.226
S-21U	95	7.1	2.5	1.3	1.2	**< .001**	431.62	.697
S-15	28	4.7	1.6	1.6	1.3	**< .001**	58.78	.521

Note. Effect size: .001 - .05 = small effect, .06 - .13 = medium effect, ≥ .14 = large effect.

Set indicators

Table 2 presents the descriptive statistics of the factor set results, ANOVA results (F-value), significance value (*p*-value) and the effect size of set indicators. Attack points were significantly different ($p < .001$) across all types of sets, and serve points were significantly different ($p < .01$) for S-21, S-21U, and S-21B, as set winners gained more points. In addition, there were significant differences ($p < .001$) in the block, attacking opponent errors, other points, and total opponent errors set metrics between S-21 and S-21U, as winners earned more points than losers. However, block, attack opponent errors, other points, and total opponent errors were not significantly different ($p > .05$) for S-21B. The serve opponent errors points indicator was not significantly different ($p > .05$) for every type of set.

Figure 2 shows a visual summary of the set indicators (including outliers).

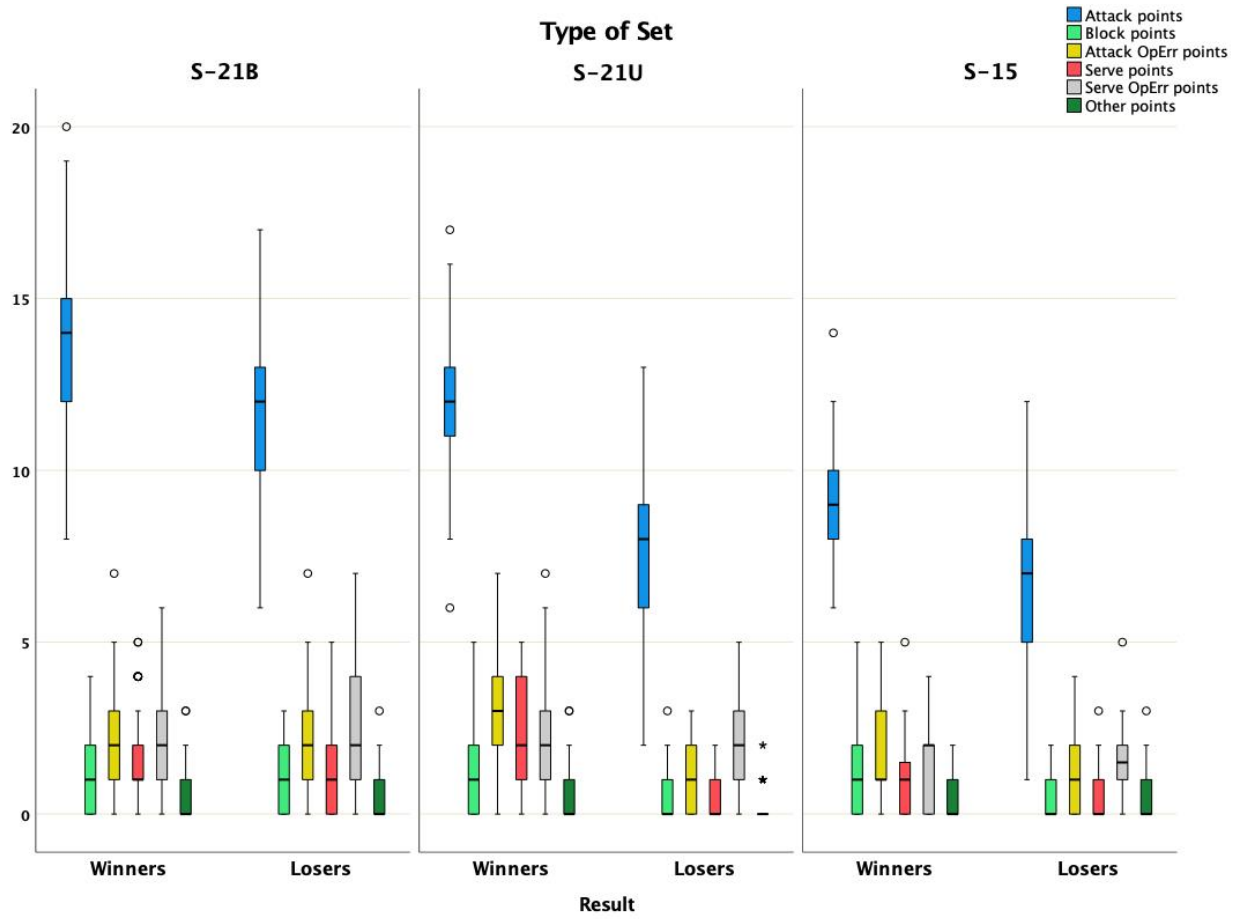

Figure 2. Boxplot of set indicators for all types of sets for the factor set result.

The eigenvalues, chi-square values, canonical correlations, respective significances, and correct classifications of the discriminant functions are presented in Table 3. For all types of sets, the discriminant function was significant ($p < .001$), and the canonical correlation values and corresponding classifications between a set of wins and losses were S-21 = .713, 87.5%, S-21B = .621, 77.4%, S-21U = .916, 99.5% and S-15 = .723, 85.7%.

Table 2. Means (M) and standard deviations (SD) of set indicators for the factor set result. Results of ANOVA (F-value), significance value (*p*-value) and effect size.

	Winners			Losers				
	N	M	SD	M	SD	Sig.	F	ES (η_p^2)
Attack points								
S-21	208	12.8	2.4	9.6	3.0	**< .001**	142.48	.256
S-21B	113	13.6	2.4	11.4	2.2	**< .001**	55.53	.199
S-21U	95	11.8	2.0	7.5	2.5	**< .001**	167.89	.472
S-15	28	9.3	1.8	6.9	2.4	**< .001**	17.99	.250
Block points								
S-21	208	1.3	1.2	0.7	0.8	**< .001**	39.91	.088
S-21B	113	1.2	1.0	1.0	0.9	.091	2.89	.013
S-21U	95	1.5	1.3	0.4	0.6	**< .001**	56.39	.231
S-15	28	1.3	1.4	0.4	0.7	**< .01**	8.74	.139
Attack Opponent Errors points								
S-21	208	2.4	1.4	1.6	1.3	**< .001**	39.87	.088
S-21B	113	2.1	1.3	2.0	1.4	.424	0.64	.003
S-21U	95	2.8	1.5	1.1	1.0	**< .001**	83.92	.309
S-15	28	1.7	1.3	1.0	1.1	**< .05**	4.48	.076
Serve points								
S-21	208	1.9	1.4	0.8	1.0	**< .001**	88.03	.175
S-21B	113	1.6	1.2	1.1	1.2	**< .01**	10.32	.044
S-21U	95	2.3	1.5	0.5	0.6	**< .001**	120.40	.390
S-15	28	1.0	1.2	0.5	0.8	.064	3.57	.062
Serve Opponent Errors points								
S-21	208	2.2	1.3	2.3	1.4	.541	0.29	.001
S-21B	113	2.3	1.3	2.5	1.5	.311	1.03	.005
S-21U	95	2.1	1.4	2.0	1.3	.743	0.11	.001
S-15	28	1.5	1.2	1.5	1.1	.907	0.014	.000
Other Opponent Errors points								
S-21	208	0.5	0.8	0.3	0.6	**< .001**	14.77	.034
S-21B	113	0.5	0.7	0.3	0.6	.051	3.84	.017
S-21U	95	0.5	0.7	0.2	0.5	**< .001**	13.32	.066
S-15	28	0.5	0.6	0.4	0.7	.689	0.162	.003
Total Opponent Errors points								
S-21	208	5.2	2.0	4.2	2.0	**< .001**	26.05	.059
S-21B	113	5.0	1.8	4.8	2.0	.675	0.176	.001
S-21U	95	5.4	2.2	3.4	1.7	**< .001**	54.08	.223
S-15	28	3.7	1.8	3.0	1.6	.116	2.55	.045

Note. Effect size: .001 - .05 = small effect, .06 - .13 = medium effect, ≥ .14 = large effect.

To maximize the multivariate difference for the type of result (winners or losers), the discriminant function coefficients and the relative contribution of each set indicator were analysed (Table 4). The attack possessed a meaningful SC for all types of sets. Additionally, the block, serve and attack OpErr indicators had a meaningful SC for the S-21, while the serve points indicator had a meaningful SC for S-21U and block points indicator for S-15. Therefore, the only indicator common to all set types was attack points, which also varies by set type The dominant SC value of the attack points indicator for the S-21 (.576), S-21B (.628), S-21U

(.414) and S-15 (.551) indicated that 33%, 39%, 17% and 30% (squared SC values) of the variance respectively is accounted for by each discriminant function.

Table 3. Eigenvalue, test of the significance and classification table of set indicators for the discriminant function.

Type of score	**S-21**	**S-21B**	**S-21U**	**S-15**
Eigenvalue	1.036	.629	5.220	1.096
Canonical Correlation	.713	.621	.916	.723
Wilks' Lambda	.491	.614	.161	.477
Chi-square	293.000	108.363	339.974	38.494
Df	4	4	4	4
$p \leq$	**< .001**	**< .001**	**< .001**	**< .001**
Correct Classification	87.5%	77.4%	99.5%	85.7%

Table 4. Test of significance (*p*-values, in bold) of set indicators for the equality of group means and structure coefficients (in bold > |.3|) for the type of result in all types of sets.

Set Indicators	**S-21**		**S-21B**		**S-21U**		**S-15**	
Attack points	**< .001**	***.576***	**< .001**	***.628***	**< .001**	***.414***	**< .001**	***.551***
Serve points	**< .001**	***.453***	**< .01**	*.271*	**< .001**	***.350***	.064	*.245*
Block points	**< .001**	***.305***	.091	*.143*	**< .001**	*.240*	**< .01**	***.384***
Attack OpErr points	**< .001**	***.305***	.424	*.067*	**< .001**	*.292*	**< .05**	*.274*

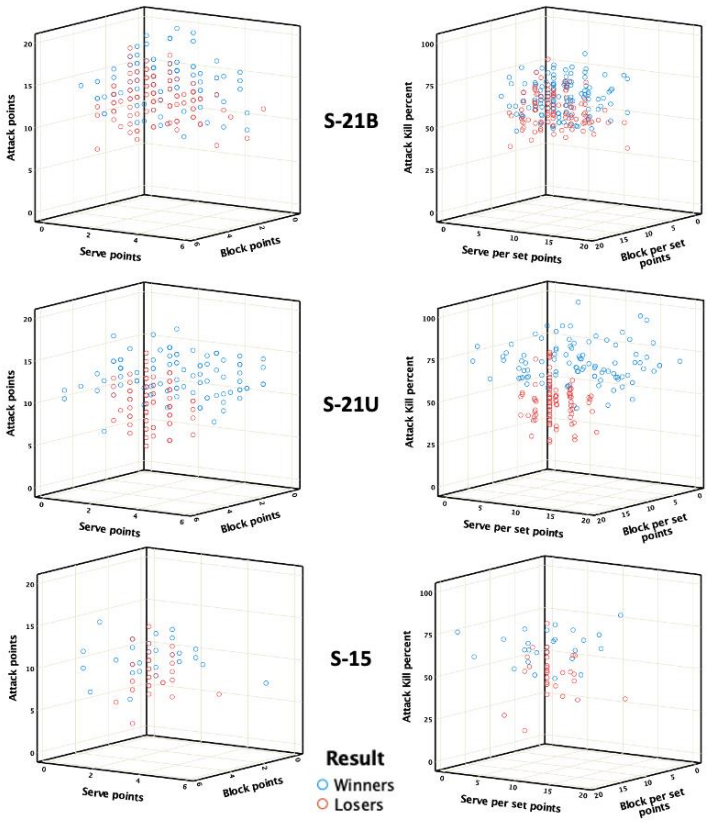

Figure 3. Scatter plot with values of the set point indicators (left column) and technical indicators (right column) and labels of the predicting group (blue for winners and red for losers) for all types of set.

The discriminant function's accuracy for the importance of attack, block, and serve points indicators is shown by scatter plots (Figure 3). The Y-axis displays attack points, the X-axis displays serve points, and the Z-axis displays block points. Additionally, the factor score results predicted, group labels are indicated.

Technical indicators

The descriptive statistics of the technical indicators of the factor set results are shown in Table 5. The ANOVA results (F-value), significance value (*p*-value), and effect size are also displayed. All technical indicators of S-21 and Set-21U were significantly different ($p < .001$), as the percentage values of winners were higher than losers. In S-21B, attack kill percent, attack efficiency, and serve aces per set points were significantly different ($p < .001$). Also, in S-15, attack kill percent, attack efficiency ($p < .001$), block ($p < .01$), attack OpErr per set points ($p < .05$) were significantly different, as winners had higher values percentages than losers. Figure 4 visually summarizes the technical indicators (including outliers).

Table 5. Means (M) and standard deviations (SD) of technical indicator percentages for the factor set result. Results of ANOVA (F-value), significance value (*p*-value) and effect size.

		Winners		**Losers**				
	N	M	SD	M	SD	Sig.	F	ES (η_p^2)
Attack Kill percent								
S-21	208	61.7	11.1	44.1	11.7	**< .001**	246.54	.373
S-21B	113	58.2	9.6	49.6	9.1	**< .001**	47.91	.176
S-21U	95	65.9	11.4	37.6	11.2	**< .001**	297.17	.613
S-15	28	57.5	10.5	39.2	12.3	**< .001**	35.88	.399
Attack Efficiency								
S-21	208	51.3	14.9	26.6	17.0	**< .001**	247.93	.375
S-21B	113	45.6	12.7	35.3	12.5	**< .001**	38.02	.145
S-21U	95	58.1	14.5	16.4	16.0	**< .001**	356.04	.654
S-15	28	48.6	12.4	21.7	18.4	**< .001**	40.87	.431
Block per set points								
S-21	208	3.7	3.4	1.8	2.1	**< .001**	45.35	.099
S-21B	113	3.0	2.5	2.5	2.2	.086	2.97	.013
S-21U	95	4.5	4.1	1.1	1.8	**< .001**	57.26	.233
S-15	28	5.2	6.2	1.7	2.7	**< 0.01**	7.84	.127
Attack Opponent Errors per set points								
S-21	208	6.8	4.3	4.2	3.2	**< .001**	49.25	.106
S-21B	113	5.4	3.2	5.0	3.3	.340	0.91	.004
S-21U	95	8.5	4.7	3.4	2.8	**< .001**	84.97	.311
S-15	28	6.5	5.2	3.8	4.1	**< 0.05**	4.91	.169
Serve Aces per set points								
S-21	208	5.5	4.3	2.1	2.5	**< .001**	95.52	.187
S-21B	113	4.1	3.1	2.8	2.8	**< .001**	11.45	.049
S-21U	95	7.3	4.9	1.4	1.9	**< .001**	116.61	.383
S-15	28	4.0	4.9	1.9	3.0	.057	3.78	.065
Serve Efficiency								
S-21	208	-1.7	9.4	-9.9	12.2	**< .001**	59.61	.126
S-21B	113	-4.3	8.7	-6.8	10.3	.052	3.81	.017
S-21U	95	1.5	9.2	-13.6	13.2	**< .001**	83.19	.307
S-15	28	-3.5	10.8	-9.1	12.2	.077	3.26	.057

Note. Values are percentages. Effect size: .001-.05 = small effect, .06-.13 = medium effect, ≥.14 = large effect.

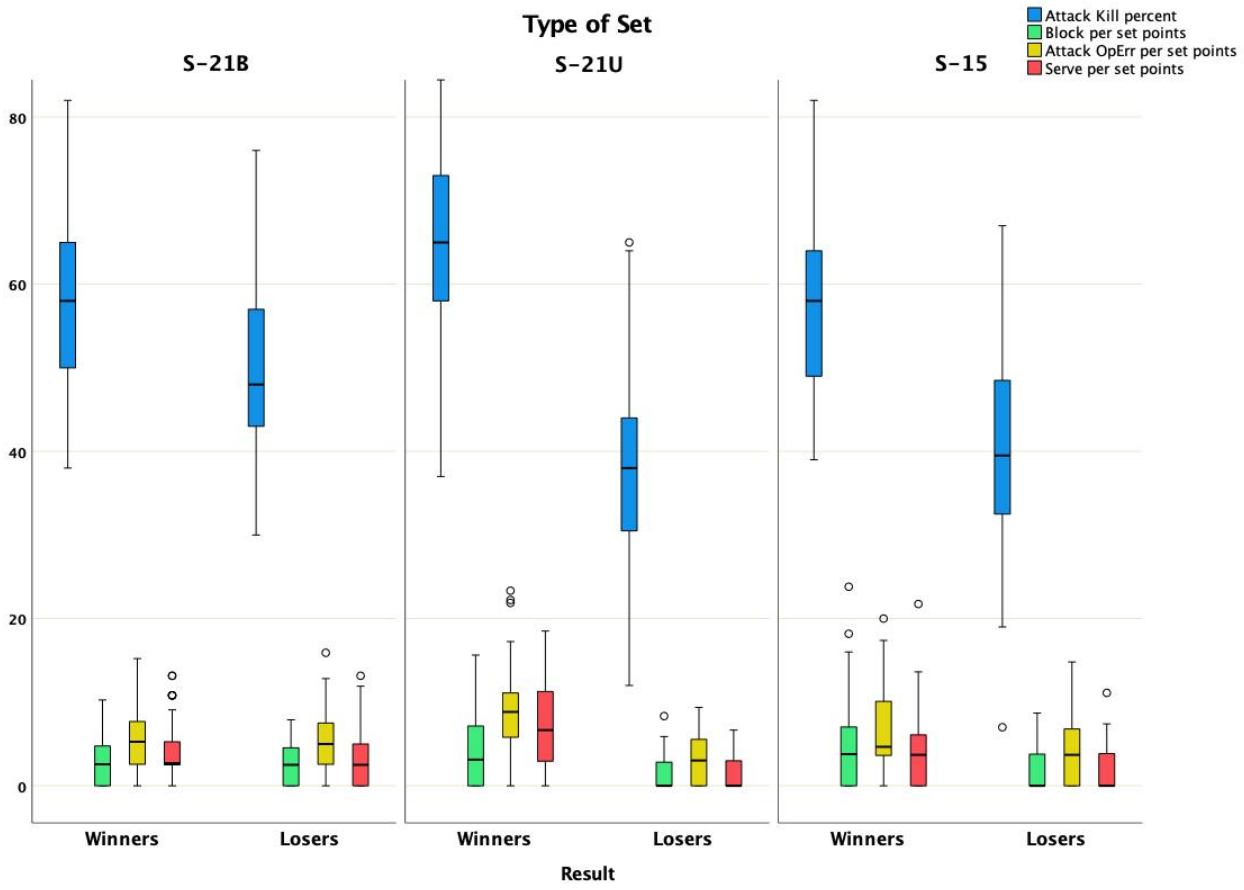

Figure 4. Boxplot of technical indicators for all types of the set for the factor set result.

Table 6 presents the eigenvalues, canonical correlations, chi-square values, relative significance, and correct classification of the discriminant functions. The discriminant functions were all statistically significant (p < .001). Canonical correlation ranged from .591 to .895 and the corresponding classifications between winning or losing sets were 86.1% for S-21, 74.3% for S-21B, 98.9% for S-21U and 87.5% for Set-15.

Table 6. Eigenvalue, test of significance and classification table of technical indicators for the discriminant function.

Type of score	**S-21**	**S-21B**	**S-21U**	**S-15**
Eigenvalue	1.068	.536	4.024	1.274
Canonical Correlation	.719	.591	.895	.748
Wilks' Lambda	.484	.651	.199	.440
Chi-square	299.332	95.299	300.243	42.718
Df	4	4	4	4
$p \leq$	**< .001**	**< .001**	**< .001**	**< .001**
Correct Classification	86.1%	74.3%	98.9%	87.5%

Table 7 shows the relative contribution of each set indicator in maximizing the multivariate difference for the type of result (winners or losers) and the coefficients of the discriminant functions. The attack kill percent indicator possessed a meaningful SC for all types of sets. Also, for all types of the set except S-15, serve

aces per set points possessed a meaningful SC. However, the block per set points indicator possessed a meaningful SC only in S-21 and S-15. The attack OpErr per set points was meaningful only for S-21 and S-21U. Therefore, attack kill percent, was the only common indicator across all set types and varies according to the type of final score. The dominant SC value was the attack kill percent indicator for the S-21 (.747), S-21B (.632), S-21U (.627) and S-15 (.722), indicating that 56%, 40%, 39 and 52% (squared SC values) of the variance respectively is accounted for by each discriminant function.

Figure 3's scatter plots illustrate the impact of the attack kill percent, block per set points, and serve aces per set point for the discriminant function's accuracy. The attack efficiency' values are presented on the Y-axis, serve per set points on the X-axis, and block per set points on the Z-axis. Additionally, the factor result's predicted group labels are shown.

Table 7. Test of significance (*p*-values, in bold < .05) of technical indicators for the equality of group means and structure coefficients (in bold > |.3|) for the type of result in all types of sets.

Technical Indicators	**S-21**		**S-21B**		**S-21U**		**S-15**	
Attack Kill percent	**< .001**	***.747***	**< .001**	***.632***	**< .001**	***.627***	**< .001**	***.722***
Serve Aces per set points	**< .001**	***.465***	**< .001**	***.309***	**< .001**	***.393***	.057	*.234*
Block per set points	**< .001**	***.334***	.086	*.157*	**< .001**	*.275*	**< .01**	***.338***
Attack OpErr per set points	**< .001**	***.320***	.341	*.087*	**< .001**	***.335***	**< .05**	*.267*

Figure 5's scatter plot represents the attack efficiency and serve efficiency for the factor result. The Y-axis shows the attack efficiency, and the X-axis shows the serve efficiency value.

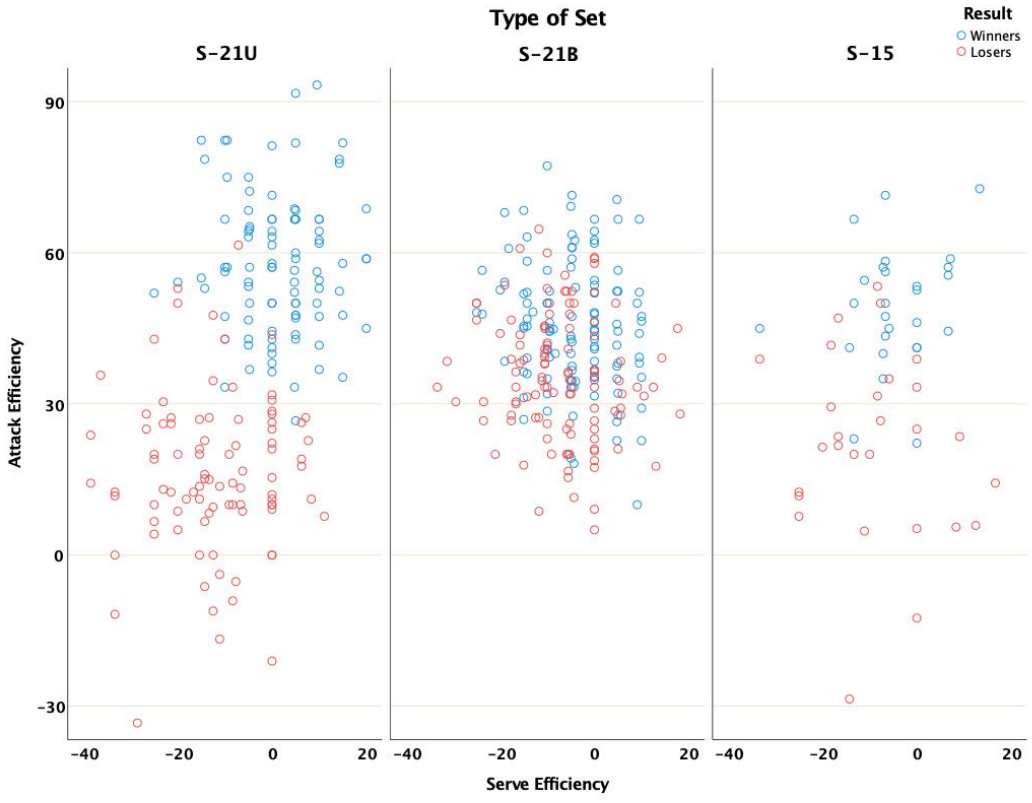

Figure 5. Scatter plot with values (percent) of the attack and serve efficiency and labels of the predicted group (blue for winners and red for losers) for all types of set.

DISCUSSION

This study used the data of match reports from the women's beach volleyball World Championship 2022 to examine which performance indicators resulted in a set win with S-21, S-21B, S-21U, and S-15 points. The set and technical performance indicators were analysed, to explore which were the best predictors to win a set and which classified the cases more accurately. The performance indicators, set points and technical revealed high correct classification in S-21 (87.5% and 86.1%), S-21B (77.4% and 74.3%), S-21U (99.5% and 98.9%) and S-15 (85.7.3% and 87.5%) respectively. In elite women's beach volleyball, the results revealed that winners had higher set and technical indicators values in every type of set, and in all ways to score a point except serve opponent errors.

The significance of women's beach volleyball serve has been noted by several studies (Kumar et al., 2021; Lopez-Martinez et al., 2020; Medeiros et al., 2014). The indicators of serve efficiency and serve points were higher for winners, which agrees with the findings of the previous studies. This might have occurred because winners served more effectively, as the average aces were 1.1 and 0.5 more points for winners in S-21 and S-15 respectively. Furthermore, in S-21B winners had 0.5 points more with a significant difference ($p < .01$). However, despite the larger number of serve attempts from winners, no difference was found between the winning' and losing' teams in serve opponents' error points in all types of sets. As a result, serve efficiency was higher at 7.2% and 5.6% in S-21 and S-15 for winners. This is in accordance with Busca et al. (2012) who found that serve with higher velocity was mostly used by higher-ranking players in the FIVB. This suggests that significant importance should be given to the serve training (Zetou et al., 2005) so that the number of serve points can be increased while maintaining a low level of serve errors.

A lot of studies highlighted the importance of block in beach volleyball (Giatsis and Zahariadis, 2008; Jiménez-Olmedo and Penichet-Tomas, 2017; Medeiros et al., 2017; Mesquita and Teixeira, 2004; Peña et al., 2013) and these results are similar with those of the present study. Like serve, winners' better performance of 0.6 and 0.7 points in block or a +1.9% and +3.5% higher block per set point percentage, raises the probability of winning a set in S-21 and S-15 respectively.

The block performance indicators had a meaningful SC for S-21 and S-15 with winning teams differing significantly from losing ones. These results could be attributed to the fact that elite women's teams were more experienced and may have a better "*reading*" of the game. Montoro and Hernández (2014) found that the greater the experience or level of performance, there is less reaction time, more power in the legs and higher jumping ability. Another reason could be the body height of the blockers (Giatsis et al., 2011).

The most important predictors of winning every type of set were the attack points and attack kill percent. Winners had 3.2 and 2.4 more points per set and 17.6% and 18.3% higher attack kill percent in S-21 and S-15 respectively. Attacking performance, which is derived from points of the attack, block, and errors, is important. At the top level of women's beach volleyball, the SC of the attack, block, and attack opponent errors were significant indicators in S-21, accounting for 87.5% of the variance explained by the discriminant function in S-21. Additionally, this probability in S-15 was 85.7 of the variance, showing that the only two skills that had a meaningful SC were attack and block. Furthermore, in both types of sets, attack kill percent was the dominant indication, highlighting the significance of players' attacking skills in beach volleyball. However, S-21B and S-21U lacked meaningful SC for both block set and technical indicators. In addition, looking at the S-21B scatter plot (Figure 3) a team that achieves over 50% kill percent and has 5% per set points in the block and serve wins the set. As far as the points are concerned, this is explained by 10 points in attack, and by 2 points in serve and block.

A visual inspection of the efficiency factors for attack and serve highlights a novel finding for the dominance of attack skill in women's beach volleyball. As presented in Figure 5 for a simultaneous performance of serve efficiency of 0% (no aces-no errors) combined with a greater than 30% attack efficiency for balanced and unbalanced 21 points sets, there was a significant probability of a team's success in a set, as compared to when ceteris paribus the serve efficiency (0%) the simultaneous value in attack efficiency performance was below 30%.

Previous studies related to men and women's volleyball (Giatsis et al., 2022; Giatsis, 2022b) and beach volleyball (Giatsis, 2022a) proposed that match reports should include attack efficiency. Attack opponent errors, serve errors, and other faults are included in the data displayed in the current match report. These statistics show that in S-21, the factor of attack opponent errors was a meaningful set indicator. This could be highlighted by the fact that blockers' body height and skill may cause players to avoid blocks, which could result in attack errors that affect the set's outcome. (Giatsis and Tili, 2011). This disparity in attack errors is crucial since, in the current study, serve opponent error points were not significantly different, and other error differences between winners and losers were only 0.2 points more. Additionally, by calculating attack and serve efficiency using these multiple error types, additional performance indicators could be revealed. Winners attack efficiency was 24.7% and 18.3% more than losers and 8.2% and 5.6% in serve efficiency in S-21 and S-15 respectively.

According to Kumar et al. (2021), the breakpoints scored when a team is serving were the major contributing factor to the outcome of high-level men's beach volleyball matches. It seems that this has happened in women's elite beach volleyball, as winning teams scored 3.6 in S-21 and 3.1 points in S-15 more than losing teams. Furthermore, winners won 1.7 more points in balanced sets which agrees with the total points difference.

All major tournaments must use statistical software since it gives statistics for the competition website and data volley usage (Data Project, 2017). In the women's beach volleyball World Championship 2022, the match report was adjusted by adding more data and indicating new performance indicators, such as attack efficiency and serve efficiency. These indicators evaluated how effectively a player, or a team, attack or serve to determine the ratio between points earned minus errors (and block in attack), divided by the total number of attempts. But the match report can continue to necessitate additional performance indicators. The attack efficiency in the two phases, after the reception (side-out) and after the defence (counter-attack) could provide useful information to players, coaches, media, and sports aficionados. Since the performance indicators reflect how each team performed during the two-game phases, the specific point indicators after receiving and counter-attack to total number of serves would be helpful. Coaches and players can use game statistics more creatively with the use of these data in match reports, from the most important beach volleyball competitions like the Olympics and the World Championships.

In the women's beach volleyball World Championships 2022, besides the elite teams' level, 56.8% of sets had differences of 5 points, indicating that the majority of the sets' results were uncertain (Figure 1). In addition, the minimum difference of 2 points in sets (23.7%) had the highest frequency. Because of this, the reference values shown in this research are very important for the performance analysis of the women's elite beach volleyball teams. Specifically, in Set-21, winners need to score 12.8 points from attack, 1.3 block points, and 1.9 serve points. Additionally, a team should have a 61.7% attack kill percent, 51.3% attack efficiency and 3.7% block rate per set points. As for Set-15, the winning team need to score 9.3 points on offence, 1.3 points from blocking, and 1.0 points from serve. Also, the attack kill rate should be increased to 57.5% and the attack efficiency to 48.6%. As for the balanced set to 21 points, the attack kill percent should

be 58.2% and the attack efficiency 45.6%. These benchmarks can help researchers, coaches, athletes, and media (Fernandez-Echverria et al., 2017; Laporta et al., 2019). Finally, the improved match report enabled to present performance benchmarks for each type of set, according to the main findings of the current study.

CONCLUSION

In conclusion, the attack kill percent is the most important indicator in elite women's beach volleyball in every type of set. However, serve aces per set point significantly raises the probability of a set win in every type of 21-point set, while block per set points contribute equally significantly in 15-point sets. Despite the high level of blocking, women's teams must avoid errors in attack to improve their chances of winning a set. The results of the study, highlight the importance of the offensive ability to win a set in women's elite beach volleyball.

AUTHOR CONTRIBUTIONS

George Giatsis: preparation and research design, data collection, statistical analysis, result interpretation, manuscript writing, supervised the study, reviewed the final version. Afroditi Lola: data collection, manuscript writing (introduction). Sotirios Drikos, manuscript writing, result interpretation, reviewed the manuscript. Ana Belen Lopez-Martinez: manuscript writing (introduction). Turpin Perez José A.: reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

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REFERENCES

Alvarado-Ruano, R. & López-Martínez, A. B. (2022). Analysis of technical-tactical factors in beach volleyball: a systematic review. Cultura, Ciencia y Deporte, 17(52), 15-35. https://doi.org/10.12800/ccd.v17i52.1839

Buscà, B., Moras, G., Peña, J., & Rodríguez-Jiménez, S. (2012). The influence of serve characteristics on performance in men's and women's high-standard beach volleyball. Journal of Sports Sciences, 30(3), 269-276. https://doi.org/10.1080/02640414.2011.635309

Carling, C., Reilly, T., & Williams, A.M. (2008). Performance Assessment for Field Sports (1st ed.). Routledge. https://doi.org/10.4324/9780203890691

Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Comrey, A.L., & Lee, H.B. (1992). A First Course in Factor Analysis (2nd ed.). Psychology Press. https://doi.org/10.4324/9781315827506

Couvillon, A. (2004). Sands of Time. The History of Beach Volleyball. VO:3. Hermosa Beach: Information Guides.

Data Project. (2017). Data volley (Release 3.8.6). Sarerno, Italy.

Drikos, S., & Vagenas, G. (2011). Multivariate assessment of selected performance indicators in relation to the type and result of a typical set in men's elite volleyball. International Journal of Performance Analysis in Sport, 11(1), 85-95. https://doi.org/10.1080/24748668.2011.11868531

Drikos, S., Angelonidis, Y., & Sobonis, G. (2018). The role of skills in winning in different types of set in women's volleyball. International Journal of Performance Analysis in Sport, 18(6), 950-960. https://doi.org/10.1080/24748668.2018.1528714

Drikos, S., Barzouka, K., Nikolaidou, M. E., & Sotiropoulos, K. (2021). Game variables that predict success and performance level in elite men's volleyball. International Journal of Performance Analysis in Sport, 21(5), 767-779. https://doi.org/10.1080/24748668.2021.1945879

F.I.V.B. (2022). Official Beach Volleyball Rules 2021-2024. Lausanne, Switzerland. Retrieved from: https://www.fivb.com/en/beachvolleyball/thegame_bvb_glossary/officialrulesofthegames

F.I.V.B. VIS (Volleyball Information System). (2015). Guide Manual VIS. Retrieved from: https://cevadmin.cev.eu/Administration/BeachVolley/EditorImages/547/fivb_vis_user_manual.pdf

Fernández-Echeverria C., Mesquita I., González-Silva J., Claver F., & Moreno M. P. (2017). Match analysis within the coaching process: a critical tool to improve coach efficacy. International Journal of Performance Analysis in Sport, 17(1-2), 149-163. https://doi.org/10.1080/24748668.2017.1304073

García-de-Alcaraz, A. G., Valadés, D., & Palao, J. M. (2016). Evolution of game demands from young to elite players in men's volleyball. International Journal of Sports Physiology and Performance, 12(6), 788-795. https://doi.org/10.1123/ijspp.2016-0027

Giatsis, G. (2022a). Beach volleyball performance benchmarks in men's high level. Journal of Human Sport and Exercise, in press. https://doi.org/10.14198/jhse.2023.182.15

Giatsis, G. (2022b). Performance indicators in women's volleyball Olympics and World Championships (2014-2021). International Journal of Sports Science & Coaching. https://doi.org/10.1177/17479541221106378

Giatsis, G., & Tzetzis, G. (2003). Comparison of performance for winning and losing beach volleyball teams on different court dimensions. International Journal of Performance Analysis in Sport, 3(1), 65-74. https://doi.org/10.1080/24748668.2003.11868276

Giatsis, G., & Zahariadis, P. (2008). Statistical Analysis of Men's FIVB Beach Volleyball Team Performance. International Journal of Performance Analysis in Sport, 8(1), 31-43. https://doi.org/10.1080/24748668.2008.118 68420

Giatsis, G., Drikos, S., & Lola, A. (2022). Analysis of match report indicators in men's volleyball olympics and world championships (2014-2021) depending on the type of final score. International Journal of Sports Science & Coaching. https://doi.org/10.1177/17479541221086779

Giatsis, G., Lopez Martinez, A. B., & García, G. M. G. (2015). The efficacy of the attack and block in game phases on male FIVB and CEV beach volleyball. Journal of Human Sport and Exercise, 10(2), 537-549. https://doi.org/10.14198/jhse.2015.102.01

Grgantov, Z., Katic, R., & Marelic, N. (2005). Effect of new rules on the correlation between situation parameters and performance in beach volleyball. Collegium Antropologicum, 29(2), 717-722.

Griego-Cairo, O., Navelo-Cabello, R., Lanza-Bravo, A., & Griego-Cairo, E. (2016). Prueba para controlar el desarrollo técnico-táctico del saque en el voleibol de playa de iniciación. Arrancada, 16(29), 118-128.

Hughes, M., & Bartlett, R. M. (2002) The use of performance indicators in performance analysis, Journal of Sports Sciences, 20(10), 739-754. https://doi.org/10.1080/026404102320675602

Jiménez-Olmedo, J. M., & Penichet-Tomas, A. (2017). Blocker's activity at men's European beach volleyball university championship. Retos. Nuevas Tendencias En Educación Física, Deporte y Recreación, (32), 252-255. https://doi.org/10.47197/retos.v0i32.56076

Jimenez-Olmedo, J. M., Penichet-Tomas, A., Saiz-Colomina, S., Martinez-Carbonell, J., & Jove-Tossi, M. (2012). Serve analysis of professional players in beach volleyball. Journal of Human Sport and Exercise, 7(3), 706-713. https://doi.org/10.4100/jhse.2012.73.10

Koch, C., & Tilp, M. (2009). Beach volleyball techniques and tactics: a comparison of male and female playing characteristics. Kinesiology, 41(1), 52-59. Retrieved from: https://hrcak.srce.hr/file/60567

Kumar, G., Shukla, A., Chhoker, A., & Thapa, R. K. (2021). Identification of Factors Determining Winning in Men's and Women's Beach Volleyball: a Logistical Regression Approach. Teorìâ ta Metodika Fìzičnogo Vihovannâ, 21(1), 26-35. https://doi.org/10.17309/tmfv.2021.1.04

Laios, Y. (2008). Comparison of the basic characteristics of men's and women's beach volley from the Athens 2004 Olympics. International Journal of Performance Analysis in Sport, 8(3), 130-137. https://doi.org/10.1080/24748668.2008.11868454

Laporta, L., Afonso, A., Valongo, B., & Mesquita, I. (2019) Using social network analysis to assess play efficacy according to game patterns: a game-centred approach in high-level men's volleyball, International Journal of Performance Analysis in Sport, 19(5), 866-877. https://doi.org/10.1080/24748668.2019.1669007

Link, D., & Wenninger, S. (2019). Performance Streaks in Elite Beach Volleyball - Does Failure in One Sideout Affect Attacking in the Next? Frontiers in Psychology, 10, 919. https://doi.org/10.3389/fpsyg.2019.00919

López-Martínez, A.B, Palao, J.M., Ortega, E., & Garcia de Alcaraz, A. (2020). Efficacy and manner of execution of the serve in top-level women's beach volleyball players. Revista da Educação Física, 31(1), e3142. https://doi.org/10.4025/jphyseduc.v31i1.3142

López-Martínez, A.B. & Palao, J. (2009). Effect of serve execution on serve efficacy in men's and women's beach volleyball. International Journal of Applied Sport Sciences, 21, 1-16.

López-Martínez, A.B., Palao, J. M., Ortega, E., & García-de- Alcaraz, A. (2018). Forma de ejecución y eficacia de la defensa en jugadoras de élite de voley playa femenino. Actividad Física y Deporte: Ciencia y Profesión, 29, 75-87.

Mackenzie, R., & Cushion, C. (2013) Performance analysis in football: A critical review and implications for future research. Journal of Sports Sciences, 31(6), 639-676. https://doi.org/10.1080/02640414.2012.746720

Medeiros, A. I., & Palao, J., Marcelino, R., & Mesquita, I. (2014). Systematic review on sports performance in beach volleyball from match analysis. Revista Brasileira de Cineantropometria e Desempenho Humano. 16(6), 698-708. https://doi.org/10.5007/1980-0037.2014v16n6p698

Medeiros, A. I., Marcelino, R., Mesquita, I. M., & Palao, J. M. (2017). Performance differences between winning and losing under-19, under-21 and senior teams in men's beach volleyball. International Journal of Performance Analysis in Sport, 17(1-2), 96-108. https://doi.org/10.1080/24748668.2017.1304029

Medeiros, A. I., Mesquita, I. M., Marcelino, R., & Palao, J. M. (2014). Effects of technique, age and player's role serve and attack efficacy in high level beach volleyball players. International Journal of Performance Analysis in Sport, 14(3), 680-691. https://doi.org/10.1080/24748668.2014.11868751

Mesquita, I., & Teixeira, J. (2004). Caracterização do processo ofensivo no voleibol de praia masculino de elite Mundial, de acordo com o tipo de ataque, a eficácia e o momento do jogo. Revista Brasileira de Ciencias do Esporte, 26(1), 33-49.

Michalopoulou, M., Papadimitriou, K., Lignos, N., Taxildaris, K., & Antoniou, P. (2005). Computer analysis of the technical and tactical effectiveness in Greek Beach Volleyball. International Journal of Performance Analysis in Sport, 5(1), 41-50. https://doi.org/10.1080/24748668.2005.11868314

Montoro-Escaño, J., & Hernández-Mendo, A. (2014). Incidencia del nivel de competición en el rendimiento del bloqueo en voleibol femenino [Impact on competition level performance block female

volleyball]. RICYDE, Revista Internacional de Ciencias del Deporte 36, 144-155. https://doi.org/10.5232/ricyde2014.03605

Oliveira, A., Valladares, N., Vaz, L., & João, P. (2016). Evaluation of Scoring Skills and Non Scoring Skills in the Brazilian SuperLeague Women's Volleyball. Montenegrin Journal of Sports Science and Medicine, 5(2), 25-31.

Palao, J. M., & Ortega, E. (2015). Skill efficacy in men's beach volleyball. International Journal of Performance Analysis in Sport, 15(1), 125-134. https://doi.org/10.1080/24748668.2015.11868781

Papadopoulou, S. D., Giatsis, G., Billis, E., Giannako, A., & Bakirtzoglou, P. (2020). Comparative analysis of the techical-tactical skills of elite male beach volleyball teams. Sport Science, 13(1), 59-66.

Pedhazur, E.J. (1997) Multiple Regression in Behavioral Research: An Explanation and Prediction. Holt, Rinehart & Winston, New York.

Peña, J., Rodríguez-Guerra, J., Buscà, B., & Serra, N. (2013). Which skills and factors better predict winning and losing in high-level men's volleyball? Journal of Strength and Conditioning Research, 27(9), 2487-2493. https://doi.org/10.1519/JSC.0b013e31827f4dbe

Pérez-Turpin, J., Campos-Gutiérrez, L. M., Elvira-Aranda, C., Gomis-Gomis, M. J., Suárez-Llorca, C., & Andreu- Cabrera, E. (2019). Performance Indicators in Young Elite Beach Volleyball Players. Frontiers in Psychology, 10(2712). https://doi.org/10.3389/fpsyg.2019.02712

Ronglan, L. T., & Grydeland, J. (2006). The effects of changing the rules and reducing the court dimension on the relative strengths between game actions in top international beach volleyball. International Journal of Performance Analysis in Sport, 6(1), 1-12. https://doi.org/10.1080/24748668.2006.11868351

Tabachnick, B. G., & Fidell, L. S. (2007). Using Multivariate Statistics (5th ed.). pp. 980. New York: Allyn and Bacon.

Tili, M., & Giatsis, G. (2011). The height of the men's winners FIVB Beach Volleyball in relation to specialization and court dimensions. Journal of Human Sport & Exercise, 6(3), 504-510. https://doi.org/10.4100/jhse.2011.63.04

Tilp, M., Koch, C., Stifter, S., & Ruppert, S. G. (2006). Digital game analysis in beach volleyball. International Journal of Performance Analysis in Sport, 6(1), 140-148. https://doi.org/10.1080/24748668.2006.11868362

Volleyballworld. Beach Volleyball World Championship Rome (2022). Retrieved from: https://en.volleyballworld.com/beachvolleyball/competitions/beach-volleyball-world-championships-rome-2022/competition/history

Zetou, E., Tzetzis, G., & Giatsis, G. (2005). Validation and reliability of beach volleyball skill test instruments. Journal of Human Movement Studies, 49 (3), 215-230.