Rankings and Benchmarks of Volleyball Performance Indicators in High-Intensity Volleyball Games

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Abstract

Purpose: This study aimed to investigate the rankings and benchmarks of performance indicators in high-intensity volleyball games. **Methods:** Data were collected through the Volleyball Information System (VIS)for the Top Volleyball League (TVL) seasons in Taiwan from 2017 to 2021. We adopted regression analysis and conditional probability to identify rankings and benchmarks of performance indicators. **Results:** Results revealed that there were no major differences between the sexes. Dig fault and spike point ranked men's top 2 indicators while spike point possessed women's highest rank followed by dig fault. The rankings for the remaining eight indicators were consistent across both sexes. In order to reach over 50% of the winning probability for a set (benchmark), more than half of the points must come from spiking. Achieving the benchmark could be accomplished with just 2 to 3 blocks, and a few service faults were not detrimental. In addition, 1 to 2 service aces was essential to meet the benchmark. Non-scoring indicators such as reception fault and set fault were not common but crucial for overall performance. **Conclusion:** Conditional probability could sufficiently present benchmarks of overall volleyball team performance indicators. This study offers statistical evidence for roster construction, training plans, and tactic applications.

Keywords: Volleyball Benchmark, Conditional Probability, Volleyball Information System

Introduction

Volleyball is considered one of the most popular sports in the world as it has been part of the Olympic Games for decades and becomes more competitive. Several researchers had investigated ways to maximize team performance and winning percentage (WP). From improving individual player's ability (Fuchs et al., 2019; García-De-Alcaraz et al., 2020; Ramirez-Campillo et al., 2021) to developing new tactics (Budak et al., 2017; Costa et al., 2017; Martins et al., 2021; Yang, 2022;

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Yang et al., 2021), coaches incorporated cutting edge technology to reach the best training outcomes. In addition, researchers and coaches analyzed related data to identify the decisive skills for victory or defeat (Valladares et al., 2016). However, the determinants of the match result such as individual ability/skill and team tactics remain uncertain. To bridge this gap in the literature, this study analyzed the national volleyball game data to identify the significance of benchmarks by skill to enhance the WP.

The attributes of volleyball skills include scoring skills (spike, block, and serve) and non-scoring skills (set, reception, and dig) (Oliveira et al., 2018). Researchers had identified these skills as the determinants of a victory or defeat. For example, spiking acted as the leading skill to win a set for both male and female teams (Drikos et al., 2020). Moreover, a high spike rate could increase the chance of winning in elite youth men's volleyball matches (Costa et al., 2017; Drikos et al., 2021). Blocking is another scoring skill that is critical for wining high-intensity men's volleyball matches (Drikos & Tsoukos, 2018). Besides, non-scoring skills such as serving and reception can profoundly influence team performance and overall results (Valladares et al., 2016). How the key skills impact on the result of a match remained inconclusive in the literature. Therefore, this research focused on weighting the importance of volleyball skills in winning a set.

Several studies across different sports and geographical regions adopted conditional probability to assess their dependent variables, such as baseball WP, batting average, and volleyball passing rate (Chu & Wang, 2019; Drikos, 2018; Kim et al., 2013). In addition, Chance (2020) attempted to determine WP in the best-of-seven championship series in World series, NBA finals, and Stanley Cup by incorporating conditional probability. Moreover, Drikos and Tsoukos (2018) benchmarked volleyball skills as the ratio of successful to unsuccessful attempts for different ranked teams, which can differentiate the components of team ranking. However, the results might not be enough to provide a solid prediction of winning a match. The purpose of this study adopted conditional probability to investigate the impact of volleyball skills on probability of winning a set and the benchmark of each skill. Results of this study could provide scientific foundation for prioritizing the skills in planning training schedule, tactical principle, and decision making during a match. By implementing a task-oriented training on different player positions, coaches could deliver a more effective training and more precise tactical decisions during a match to achieve a higher WP.

Methods

This study analyzed the 2017 - 2021 Volleyball Information System (VIS) data from Top Volleyball League (TVL), which is the highest level of men's and women's professional volleyball league organized by Chinese Taipei Volleyball Association (CTVBA) in Taiwan. VIS has been widely

adopted by International Volleyball Federation (FIVB), Volleyball Nations League (VNL), and CTVBA to record and calculate points scored for individual skills of volleyball players. A total of 3,086 sets have been played during these four seasons for both men's and women's sub-leagues. To normalize the statistics, we chose sets that played to 25 points to provide a consistent per set rate for each skill as suggested by Mashima (2017). Sets played over 25 points and the 15-point tie-breakers were excluded from the analysis. This process resulted 1,352 men's and 1,168 women's sets. Data was authorized by CTVBA to ensure the validity. All data passed the consistency test using the formula of $\frac{A\ team\ total\ scoring\ points}{B\ team\ total\ losing\ points} = 1$. We also tested the Intra-class Correlation Coefficient (ICC) for the interrater reliability by reviewing 420 (33%) sets each for men's and women's matches which were broadcasted. The ICCs were between .92 to 1. Followed by ICC tests, we constructed the indicators then computed the weightings of each indicator.

We also performed regression analysis to assess the impact of indicators on WP. Based on the attribute, all indicators were separated into scoring and error indicators. The scoring indicators included serve aces, spike points, kill blocks, and opponent's errors. On the other hand, the error indicators included serve faults, spike faults, block faults, dig faults, reception faults, and set faults. In order to assess the impact holistically, the opponent's errors, which included the opponent's faults not caused by serving, spiking, and blocking that resulted a point gain, such as rotation fault, offside, net fault, holding, and double contact, were also included in the model. The formula of dependent variable (WP) was $WP_{set} = \frac{points\ scored\ (set)}{points\ played\ (set)}$. The next step was to conduct the regression model to obtain the standardized β for each indicator. Then we used the following formula to assess the weightings for each indicator. $W_{x1} = \frac{|\beta_{x1}|}{|\beta_{x1}|+|\beta_{x2}|+|\beta_{x3}|+\cdots+|\beta_{xn}|}$. After confirming the ranking of each indicator, we used conditional probability analysis to evaluate the probability of winning a set (Pwin) under every circumstance for each indicator. The formula was $P_{win}(B|A) = \frac{p(A \cap B)}{p(A)} = \frac{probability\ of\ A\ occuring\ when\ B(win)\ had\ happened}{probability\ of\ condition\ A}$. Pwin is between 0 and 1. The higher the value means the higher the chance to win a set under A circumstance. The benchmark was identified when Pwin exceeded or dropped below 50%. All the analyses were separated by sex.

Results

We analyzed VIS data from 2017-2021 TVL seasons. Based on all the scorings and errors played within the 2,520 sets, the regression analysis showed 10 statistically significant indicators on WP. The adjusted R^2 reached higher than .99, suggesting the combination of these 10 indicators explained more than 99 percent of the variance of winning a set in both men and women. The scoring and error indicators' weightings were 43% and 57% for men, and 45% and 55% for women, suggesting that the error indicators had a higher impact on WP than scoring indicators. Additional results of conditional probability analysis were presented in 2 figures grouped by sex.

The standardized regression coefficients of the top 2 indicators in men's and women's indicators were similar. They were dig faults (.17) and spike points (.16) for men and spike points (.18) and dig faults (.17) for women. No major difference was detected for the other 8 indicators between men's and women's teams. In addition, the weighting ranking positively related to the number of points of each indicator for both men and women. VIF scores were below 2 for all indicators, suggesting no multicollinearity concern.

Mathematically speaking, Pwin increases when the scoring indicator's point increases. On the contrary, Pwin decreases when the error indicator's point increases. Our results confirmed this mathematic assumption for scoring indicators. However, Pwin started to increase when service error increased at the beginning and then dropped rapidly at the end for both men's and women's matches. This result suggested both men's and women's teams to adopt power serve as the priority attacking strategy to restrict opponent's offense.

Figure 1 showed Pwins for men's indicators. The benchmark of dig fault was spotted at the point 9 where Pwin dropped significantly from 62% to below 50%. Although Pwin fluctuated at some points, the overall trend was ascended when spike points and opponent's errors increased. To be specific, Pwin started to raise after 7 spike points, but decrease a little at the 8th point. The biggest jump was spotted at the points 10 to 11 and 13 to 14, where Pwin exceeded 50%. In regards to the opponent's errors, the ascending trend was relatively steady until the points 7 to 8 where Pwin jumped from 50% to 62%.

Next, men's top 4th to 6th indicators included spike faults, block faults, and kill blocks. Pwin decreased gradually when the spike faults increased within the point 8. Although Pwin fluctuated from the point 8 to 12, it did not fall below point 7's Pwin. The benchmark for spike fault was located at the point 5 where Pwin dropped from 58% at the point 4 to 41%. Similarly, the trend of block faults was bounced at the point 11 then dropped again. It was noteworthy that men's teams only obtained 67% Pwin with no block fault. In addition, Pwin was almost identical at the points 1- 3 with 55% and 4-6 with 50% before dropping to 45% at the point 7. Lastly, Pwin was raised when kill block was

increased. Even without successful kill blocks, men's team still reached the Pwin of about 20%. The benchmark was observed at the point 3 where Pwin jumped from 46% at the point 2 to 62%. With 7 and more kill blocks in a set, Pwin reached 100%.

Bottom of Figure 1 presented Pwin for men's last 4 indicators, ie. serve faults, serve aces, reception faults, and set faults. All the Pwins did not start from either 100% for error indicators or 0% for scoring indicators. Pwin for serve faults fluctuated around 50% from the points 1 to 7 and suddenly dropped to 0 at point 8. This trend was difficult to identify the benchmark, yet we observed, even with 7 serve faults, Pwin remained above 50%. On the other hand, the overall Pwin was raised when serve aces increased. With only 1 serve aces, Pwin reached 55%. Based on our analysis, the reception faults and set faults were relatively rare, which explained why they were ranked the last. However, it was worth noting that Pwin dropped to less than 50% with only 1 reception fault or set fault.

Figure 2 displayed Pwin for women's indicators. First, Pwin steadily ascended when spike points increased. The benchmark was observed at the point 14 as Pwin was raised from 49% at the point 13 to 63%. This result suggested that women's teams need to obtain more than half points by spike to achieve 50% chance to win a set. Second, Pwin gradually dropped as dig faults increased. The benchmark was located at the point 12 when Pwin dropped from 52% at the point 11 to 35%. Similar to other scoring indicators, Pwin ascended as opponent's error increased. Yet, two big drops were also observed at the points 9 and 13.   The benchmark was observed at the point 6 where Pwin increased from 48% to 52%.

The next three indicators for women's Pwin included spike faults, block faults, and kill blocks. All three indicators started from neither 0% nor 100% at point 0. Pwin gradually dropped below 50% while committed 5 spike faults. Similar to men's trend, Pwin fluctuated around 50% with 1 to 5 block faults and dropped to 40% at the point 6. In regards to kill blocks, Pwin steadily increased by more kill blocks and reached 53% with as few as 2 blocks.

Bottom of Figure 2 presented Pwins for women's last 4 ranked indicators. Despite as an error indicator, serve fault exhibited an ascending curve from 0 to 6 points with the apex at 67% Pwin. However, Pwin dropped sharply from 50% at the point 7 to 0% at the point 8. On the other hand, Pwin reached 51% with only 1 service ace and 72% at 2 aces. Similar to men's results, Pwins started from around 60% with 0 reception faults and set faults then dropped rapidly. Specifically, Pwind dropped from 60% with only 1 reception fault to 26% at 2 reception faults. Lastly, set fault was identified as crucial as reception fault because, by having 3 set faults, Pwin would be as low as 23%.
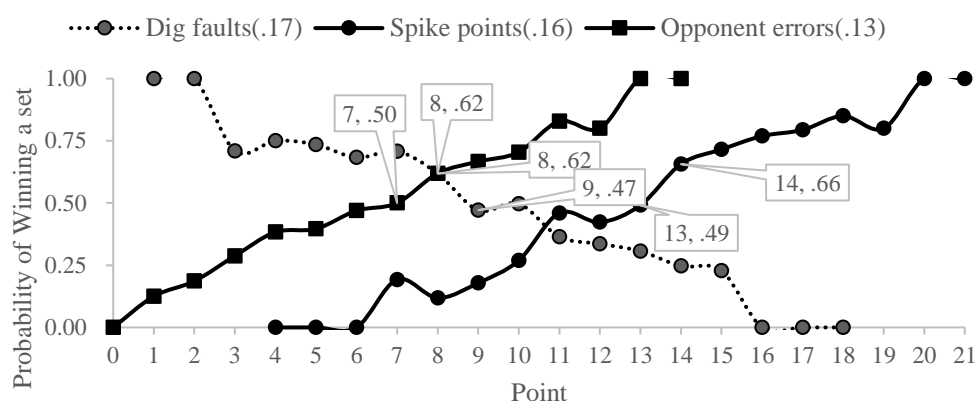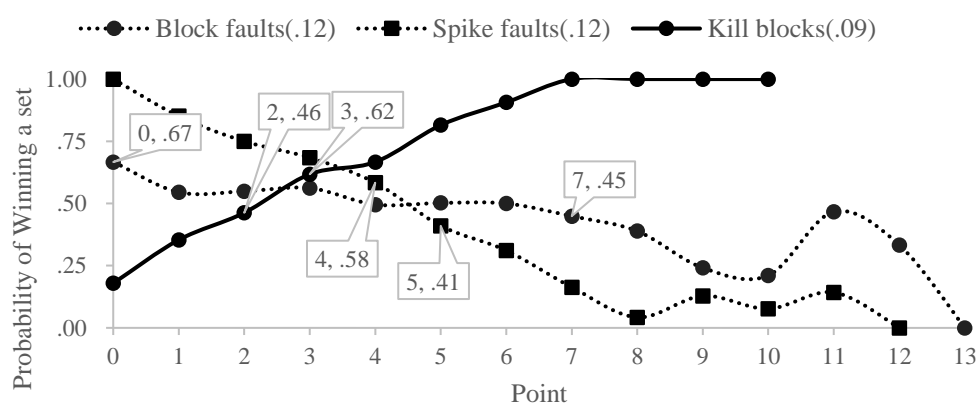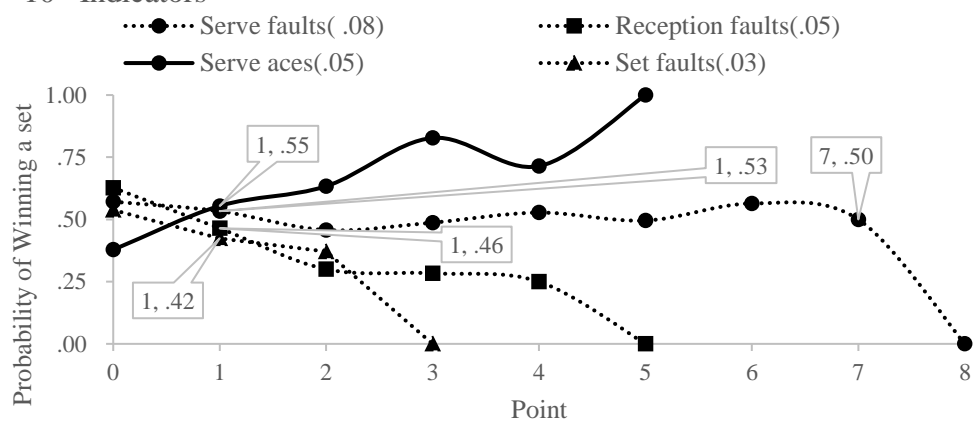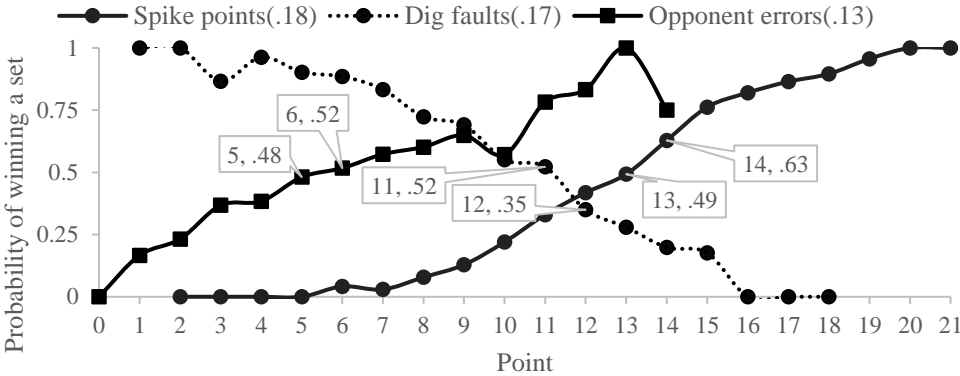
Top 3 Indicators

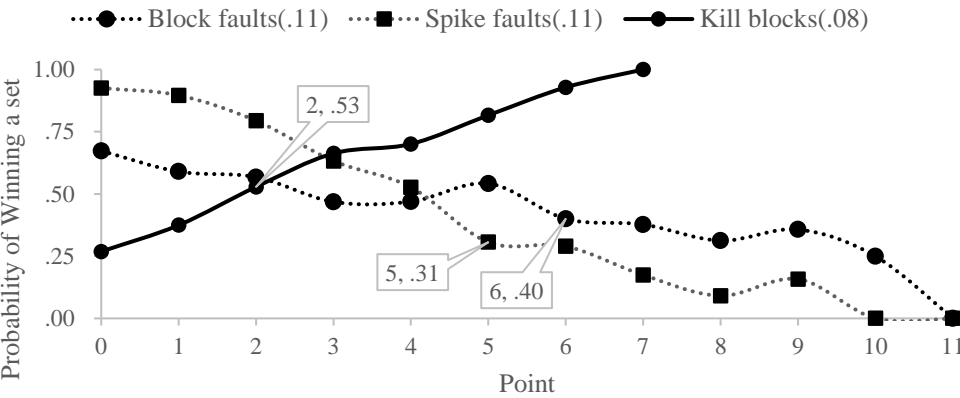4th-6th Indicators

7th-10th Indicators

Figure 1. Benchmarks for Men's Indicators

Note: the statistic inside each pair of parentheses indicates the standardized weighting of each indicator

Top 3 Indicators

Spike points(.18) ····•···· Dig faults(.17) ——■—— Opponent errors(.13)

4th-6th Indicators

····•···· Block faults(.11) ····■···· Spike faults(.11) ——•—— Kill blocks(.08)

7th-10th Indicators

····•···· Serve faults(.07) ····■···· Reception faults(.06)
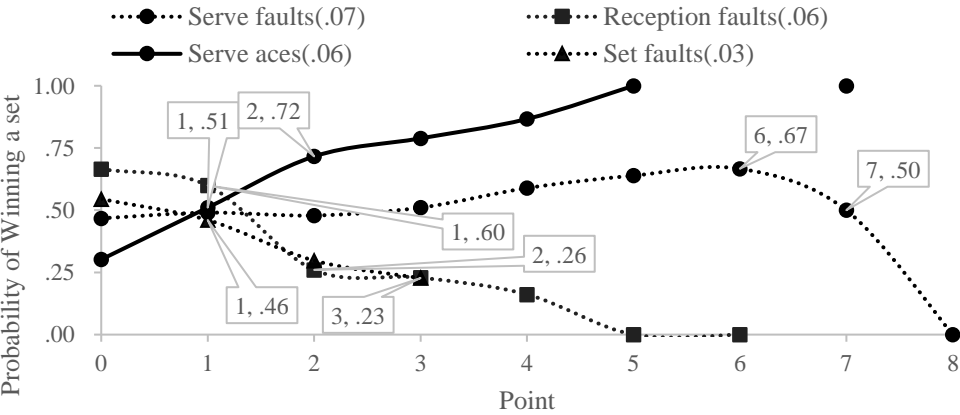——•—— Serve aces(.06) ····▲···· Set faults(.03)

Figure 2. Benchmarks for Women's Indicators

Note: the statistic inside each pair of parentheses indicates the standardized weighting of each indicator

Discussion

The purpose of this study was to determine the impact of volleyball skills on probability of winning a set and identifying the benchmark of each indicator. We assessed the weighting of volleyball skills and their benchmarks on the probability of winning a set. Our results revealed almost identical weightings for men's and women's games. This result implied no sex differences were found for the impact of scoring and error indicators on the probability of winning a set. Therefore, volleyball coaches can set similar goals and apply training principles when designing their training plan for high-intensity men's and women's teams.

We assessed the team performance under actual skill circumstances instead of individual player's performance. Previous studies adopted bivariate analysis to investigate the relationship between scoring (or victory/defeat) and individual skills (Costa et al., 2017; Lima et al., 2019; Valladares et al., 2016). Our process could holistically evaluate the impact of skills on winning percentage and provide the benchmark of indicators for winning a set. As showed in some studies (Drikos et al., 2021; Drikos & Tsoukos, 2018), opponent's error was not included into analysis. We were able to take opponent's error into account and generated extremely high R^2. Our model can explain almost all the variance of winning a set and suggest a comprehensive model for future implementations. Skill weightings were positively correlated with the frequency of that specific indicator.

In order to enhance probability of winning a set to more than 50%, a team needs to generate at least half of the points from spike. This result suggested that offense remains the major skill in volleyball. Although kill block only ranked 6th on the weighting, the probability of winning a set reached 50% by having 2 blocks for women and 3 blocks for men.   Blocking is considered the first defense and the major skill to keep a team score up. This result confirmed Drikos (2018) that blocking was critical winning a high-level men's volleyball match. No faults on blocking, serving, reception, and set cannot guarantee a win. However, as the faults increased, probability of winning a set dropped rapidly. Specifically, reception and set faults pulled the winning percentage way below benchmark with only two faults. In regards to serve, serval service faults were not detrimental, while few service aces could push the winning percentage above benchmark.

Although our results may not be inferred to other level of competition, this model can be easily implemented to desired targets since VIS system is widely adopted in a variety of volleyball tournaments. Future studies are suggested to utilize this model and compare the benchmarks among different levels of competition. In addition, high impact indicators were proved crucial, however, the relationship between power serve and opponent's reception faults or the relationship between kill

block and spike fault and how these relationships impact on the result of a set need further investigation.

Conclusions

Conditional probability could provide a scientific assessment for volleyball performance indicators. Results of this study suggested spike point and dig fault ranked the most important indicators. The probability of winning a set remained steady with several service faults; however few service aces could achieve benchmark. Despite the low rank, few kill blocks could highly enhance the probability of winning a set. Non-scoring skill such as reception and set may not increase the probability of winning a set. Nevertheless, faults on reception and set could be fatal. All these results could infer to high-intensity male and female volleyball league.

Practical Applications

Our results could provide several practical applications for volleyball coaches. First, the scientific foundation for roster construction, especially for players with high impact skills such as serve and block. Previous study assessed player's skills by position (Wang et al., 2022). Current study suggested enlisting one or two specialty players on the roster. These specialty players could be a crucial position and important team asset to increase the kill block point and serve ace and further improve the chance of winning a set. Second, we suggested high weighting skills training during pre-season and should focus on high impact skill training in-season when scheduling the training plan. Third, tactic adjustment during the match. For example, substitute a blocker or server at critical timing in a set based on the on-court statistics. In addition, adjust the starting line-up for the next set during the interval to achieve more benchmarks. Finally, investigating opponent's performance indicators prior to the match and modify the team roster and tactics for restricting the opponent's probability of winning a set below benchmarks.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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高強度排球比賽中技術指標之排名及獲勝基準

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摘要

目的：本研究旨在探索高強度排球比賽中技術指標之排名與獲勝基準。**方法：**資料透過排球資訊系統 (Volleyball Information System, VIS) 收集 2017-2021 年台灣企業排球聯賽攻守數據。採用迴歸分析及條件機率鑑定各項技術指標之排名及獲勝基準。**結果：**結果顯示各項指標之排名及獲勝基準僅有些微地性別差異。首先，防守失誤及攻擊得分是男子組前兩名的指標，女子組則是攻擊得分為最重要之指標，防守失誤次之。其餘的八個指標排名男女組皆一致。 其次，若要將獲勝機率提升至 50%以上 (獲勝基準)，攻擊得分必須要超過每局一半的分數，但僅僅 2 到 3 個攔網得分便能達到獲勝基準。再者，少數的發球失誤並不嚴重拉低獲勝機率，但 1 到 2 顆的發球得分卻可以達到獲勝基準。雖然非得分的技術指標 (如接發球失誤及舉球失誤) 之數量不多，但卻顯得相當重要。**結論：**條件機率足以呈現排球各項技術指標中整體團隊之獲勝基準。本研究基於統計的佐證提出陣容組建、訓練計畫、以及戰術運用等實務建議。

關鍵詞：排球獲勝基準、條件機率、排球資訊系統