Game-Related Performance Factors in four European Men's Professional Volleyball Championships

by
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The present study was designed to assess the relevance of game-related performance factors as outcome predictors in high-level volleyball. To carry out the analysis, the official box scores of 399 matches played by 47 different teams in four different European male professional volleyball leagues (Italy, Poland, Germany and Turkey) during the 2013-14 regular season were analyzed. A logistic mixed model was performed to determine the effects of different variables in matches' outcomes. According to the multivariate analysis the following factors were significantly associated with winning matches: the number of scorers (OR = 1.32; CI: 1.09 – 1.59), service errors (OR = 0.91; CI: 0.87 – 0.95), service points (OR = 1.25; CI: 1.15 – 1.36), reception errors (OR = 0.79; CI: 0.74 – 0.84), the percentage of positive receptions (OR = 1.02; CI: 1.00 – 1.04) and blocked balls (OR = 1.17; CI: 1.11 – 1.26). Team category 2 (OR = 0.39; CI: 0.24 – 0.63) and team category 3 (OR = 0.15; CI: 0.09 – 0.25) were significantly associated with losing matches. These findings can contribute to a better understanding of performance indicators in professional volleyball, helping coaches and decision makers to better determine the importance of particular game factors.

Key words: performance analysis, volleyball, logistic mixed models, official box scores, team sports.

Introduction

Today, understanding performance is a major issue within the field of performance analysis. Contemporary performance analysis studies play an important role in advancing scientific understanding, providing coaches with a more ecological knowledge and analyzing the game from a more complex point of view (Drust, 2010).

Performance factors and their relation with games' outcomes have been objects of research in volleyball since the 1990s. Early examples of research into performance factors include the study of Eom and Schutz (1992) analyzing matches from the third Federation of International Volleyball Cup men's competition. In recent years, an increasing number of performance analysis studies focused on

volleyball has been observed, aiming at finding correlations between different elements of the game and an increased chance of winning matches (Campos et al., 2014; Kountouris et al., 2015; Monteiro et al., 2009; Rodríguez-Ruiz et al., 2011; Silva et al., 2014). Similarly, some of them tried to predict the outcome of a game using some key variables and tailored mathematical and statistical formulas (Marcelino et al., 2011; Miskin et al., 2010; Peña et al., 2013). Zetou et al. (2006, 2007) assessed the effectiveness of different skills grouped in tactical complexes with interesting findings for each of them. According to their research, the most determinant factor to score points playing in Complex I (attack phase) was a direct point from the first attack after reception, while during Complex II (counterattack phase)

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the best predictors were direct points coming from a service (aces) and direct points coming from attack actions. However, no categories of blocking or defense seemed relevant to predicting the final outcomes of matches. Palao et al. (2004) in an earlier study reported that blocking was the most important skill for high-ranked male and female teams in the 2000 Olympic Games, observing a significant reduction in block errors and better reception, attack, block and defense effectiveness in teams with a higher final ranking. Patsiaouras et al. (2011) supported this view, stating that blocking was a significant factor in game outcomes of the 2006 men's World Championship. Additionally, their findings revealed that reception errors and service points were of similar significance to blocking for winning or losing a match. Rodríguez-Ruiz et al. (2011) in an analysis of the 2009 men's European Championship, observed that the attack was the highest point-scoring game action, but in even matches (with sets ending in more than 25 points or tie break sets), the points scored by blocking became crucial for obtaining a positive final outcome. More recent studies carrying out volleyball game-analysis revealed interesting new facts deserving to be brought to light. Peña et al. (2013) in a research study analyzing 125 matches of the Spanish men's volleyball professional championship observed that the category of the team, the number of points obtained in Complex II, the number of reception errors and the number of blocked attacks by the opponent were significant statistical predictors of winning or losing the match. Similarly, Silva et al. (2014) studying 24 games from the men's 2010 World Championship found that service points, reception errors and blocking errors were the variables with a higher discriminatory power to predict the outcome of the match, while service points were the variable with a stronger association with match success. Campos et al. (2014) in an interesting study comparing the outcomes of Brazilian and Italian women's volleyball leagues, reported that in these professional leagues a home advantage effect was observed, and that the performance indicator most highly correlated with winning was the attack. A longitudinal study by Kountouris et al. (2015) comparing the effectiveness of the five volleyball major skills (service, reception, attack,

block and dig) during the last four editions of the Olympic Games, reported interesting differences between male and female teams. The authors' analyses showed that service faults, successful attacks and faulty blocks prevailed in the game of men when compared with women.

The aim of our study was to identify game-related performance factors of four high-level European male volleyball professional leagues, to determine which of them were more relevant, setting some new variables and applying this knowledge to the practical field.

Material and Methods

The study sample consisted of 399 matches played by 47 teams during the 2013-14 regular season in four different European male professional volleyball leagues: Italy (n = 130), Poland (n = 90), Germany (n = 100) and Turkey (n = 80). All the data were retrieved from the official box scores published on the official websites of each professional league. The official box scores provided information on the game statistics analyzing teams' collective behavior. These game-related statistics are of general use among volleyball coaches, managers and other decision makers, and had been used in the past in several studies (Silva et al., 2014; Campos et al., 2014).

No informed consent was necessary as the used information is public and available on the different leagues official websites.

Measures

The following variables were analyzed: (a) result of the game using a binary variable (1, won match; 0, lost match), (b) a home/away court factor, (c) the team category according to the final ranking of the teams at the end of the regular season (category 1 for the teams ranked 1–4, category 2 for the teams ranked 5–8, and category 3 for the teams ranked 9–12), (d) the number of scorers (considering a scorer a player with a total contribution of at least 10 points), (e) points obtained in Complex II, (f) service errors, (g) service direct points, (h) the number of reception errors, (i) the number of positive receptions, (j) the number of perfect receptions, (k) the percentage of positive receptions, (l) the percentage of perfect receptions, (m) attack errors, (n) blocked attacks, (o) attack points, and (p) block performances of both teams.

Most of the above-mentioned variables

are well known by volleyball researchers and practitioners despite being of different nature (binary, modifiable by training and uncontrollable); however, in the present study we tried to understand variations in team performances using the game-by-game context of four elite European volleyball leagues. In addition, we introduced a new variable i.e. the number of scorers, considering a player highlighted in scoring when his overall contribution to the team was equal or greater than 10 points.

Statistical analysis

A descriptive study was carried out on qualitative and quantitative variables to characterize the study population by frequency distribution for qualitative variables as well as by a central tendency and precision measurement for quantitative variables.

To study the factors considered as predictors of winning matches we used a logistic mixed model assuming a binomial error distribution and the logit link function. The logistic mixed model is also known in the literature as a generalized linear mixed model (GLMM), a hierarchical generalized linear model (HGLMs) and a multilevel generalized linear model (MGLMs) depending on the field (Christensen et al., 2014; Garson et al., 2012; Lee et al., 2006).

On the basis of the works of Bolker (2009), Thiele (2012) and Casals (2014), a list of relevant information and basic characteristics of the logistic mixed model was reported. The model expression for team i in its jth games is the following: logit $(\pi_{ij})= \log(\pi_{ij}/1- \pi_{ij})= X_{ij} \beta+ u_i$ where π_i is the probability of winning a match and X includes all independent variables of interest. The vector β contains the fixed effects, whereas u_i is the random effect corresponding to team i. The random effects are assumed to be independent and normally distributed: $u_i \sim N(0;\sigma^2)$, where σ_u^2 is the variance of random effect. The model accounted for repeated measures and the fact that the values of X could change from one game to the next.

As suggested by Crawley (2007), model simplification was performed by backward selection of variables from the full model, and models were compared using the likelihood ratio test (LRT) until a minimal adequate model was obtained. Model selection was based on the Akaike Information Criterion (AIC). To estimate the model parameters we used the Gauss-Hermite quadrature (GHQ) with 10 points (Bolker, 2009). The statistical significance of the fixed effects associated with the covariates included in the model was assessed using the Wald test. We checked the correlation and the main possible interactions among the covariates in the final model. Possible over-dispersion in the model was studied using a Pearson's dispersion parameter, applying values above 1.5 as the criterion for over-dispersion (Bolker, 2009). Finally, in order to assess the predictive or discriminatory ability of the model we performed the area under the curve (AUC) (Lopez-Raton et al., 2014).

All statistical analyses were performed using the statistical package R (The R Foundation for Statistical Computing, Vienna, Austria), version 3.1.1. We used the main package for mixed models called *lme4* (Bates et al., 2014). The relationships were determined by the *odds ratio* (OR) and their 95% confidence intervals (CI). Statistical significance was set at alpha <0.05.

Results

Table 1 summarizes all of the variables employed in this study for game-related statistics. Moreover, this table shows the descriptive results for all stratified performance factors in the European leagues studied.

Table 2 shows the logistic mixed model for all European leagues assessed, including all the variables of interest. According to the multivariate analysis, the following variables were significantly associated with winning matches: the number of scorers, a team category, service errors, service points, reception errors, the percentage of positive receptions and blocked balls.

A positive, but non-significant relationship between the court and game outcome in the model was also observed. However, it must be acknowledged that there was weak evidence of the importance of this variable, as the AIC of the model was better than the simpler model without the home court variable. The team-level variance was 0.05. The AUC value of the model showed an appropriate performance (AUC: 0.86; 95%CI: 0.84 – 0.89).

Table 1

Summary of game-related performance factors in four European volleyball leagues

	[ALL] N=798	Italy N=264	Germany N=195	Poland N=177	Turkey N=162
Winning matches					
No	397 (49.7%)	132 (50.0%)	96 (49.2%)	88 (49.7%)	81 (50.0%)
Yes	401 (50.3%)	132 (50.0%)	99 (50.8%)	89 (50.3%)	81 (50.0%)
Court					
Away	397 (49.7%)	132 (50.0%)	96 (49.2%)	88 (49.7%)	81 (50.0%)
Home	401 (50.3%)	132 (50.0%)	99 (50.8%)	89 (50.3%)	81 (50.0%)
Team Category					
Team category 1	265 (33.2%)	88 (33.3%)	53 (27.2%)	54 (30.5%)	70 (43.2%)
Team category 2	278 (34.8%)	87 (33.0%)	70 (35.9%)	71 (40.1%)	50 (30.9%)
Team category 3	255 (32.0%)	89 (33.7%)	72 (36.9%)	52 (29.4%)	42 (25.9%)
NScorers	2.61 (1.17)	2.54 (1.15)	2.67 (1.24)	2.68 (1.20)	2.56 (1.09)
NScorers categorical					
<3 scorers	348 (43.6%)	124 (47.0%)	81 (41.5%)	73 (41.2%)	70 (43.2%)
>=3 scorers	450 (56.4%)	140 (53.0%)	114 (58.5%)	104 (58.8%)	92 (56.8%)
Break points					
Median (IQR)	23 (16-27)	21 (15-26)	24 (17-27)	23 (17- 27)	23 (17-27)
Service errors					
Median (IQR)	14 (11-17)	15 (12-17)	13 (10-16)	13 (11-17.5)	13.5 (11-16)
Service points					
Median (IQR)	4 (3-6)	4 (3-6)	4 (3-6)	4 (3-6)	4 (2-6)
Total reception errors					
Median (IQR)	5 (3-8)	6(4-9)	4 (2-5)	4 (3-6)	8 (5-10)
Percentage positive receptions					
Median (IQR)	54 (47-60.25)	56 (49-61)	56 (48-63)	48 (41-55)	57 (51-62)
Percentage perfect receptions					
Median (IQR)	31 (24-39)	30.5 (25-38)	28 (22-36)	27 (20-33)	43 (35-47)
Attack errors					
Median (IQR)	8 (5.75-10)	7 (5-9)	9 (7-12)	7 (5-9)	8 (6-11)
Opponent Blocks					
Median (IQR)	10 (7-12)	9 (6-11)	10 (7-13)	11 (8-13)	9 (7-12)
Attack points					
Median (IQR)	45 (37-53.25)	44 (36-51)	46 (37-56)	46 (38-52.5)	47.5 (38-54)
Blocked balls					
Median (IQR)	10 (7-12)	9 (6-11)	10 (7-13)	11 (8-13)	9 (7-12)

IQR: interquartile range

Estimates for the logistic mixed model parameters in the won matches

Variables	Estimate	SE	OR (95% CI)	*p*
Intercept	-1.332	0.735	0.263 (0.062 - 1.115)	0.070
Home court	0.293	0.184	1.341 (0.933 - 1.926)	0.112
Number of scorers	0.278	0.096	1.321 (1.092 - 1.598)	0.004
Team category 2	-0.921	0.237	0.397 (0.249 - 0.633)	<0.001
Team category 3	-1.868	0.257	0.154 (0.093 - 0.255)	<0.001
Service errors	-0.085	0.022	0.918 (0.878 - 0.959)	<0.001
Service points	0.229	0.041	1.257 (1.158 - 1.365)	<0.001
Reception errors	-0.227	0.032	0.796 (0.746 - 0.849)	<0.001
% Positive receptions	0.022	0.096	1.022 (1.003 - 1.042)	0.020
Blocked balls	0.165	0.029	1.179 (1.112 - 1.264)	<0.001

SE: standard error

Discussion

The number of scorers, the team category, service errors, service points, reception errors, the percentage of positive receptions and blocked balls were found as volleyball performance factors in our study. Coaches and practitioners can use these findings to anticipate a positive or negative game outcome and to study in detail the most relevant factors to improve during practices to achieve a better technical outcome.

Statistical methods commonly used in sport sciences focus on generalized linear models (GLMs) such as counts or proportions (Poisson or logistic regressions). Only a small number of studies consider the correlation structure of repeated measures or recurrent events. Future studies should consider repeated measures and apply the appropriate model. Ignoring the correlation of observations between teams may, for example, lead to underestimation of the standard error. For this reason, sports researchers have started to use statistical models such as logistic mixed models that take into account heterogeneity between teams (Bullock et al., 2009; Casals et al., 2013; Gomez et al., 2014; Sampaio et al., 2010).

To our knowledge, the number of scorers is a variable never used before in research about performance analysis in volleyball. In a sport with the main characteristics of volleyball, it seems quite logical that dividing the total attack load among several players may lead to opponents' block impairment. Nevertheless, frequently in men's volleyball we observe a single player bearing this scoring responsibility. From our findings we can understand that sharing the score contribution between 3 or more players is significantly more effective for a positive team performance, increasing the likelihood of winning a match by 1.32 times for each additional player scoring 10 points or more at the end of it.

Belonging to the group of teams ranked from 1 to 4 (category 1) seems to be a significant factor in increasing the probability of winning more matches in all the analyzed leagues, although the teams' final rankings are a direct product of the number of games won. Besides questions concerning budgets and quality of players in the higher category teams, volleyball is one of the team sports with a lower degree of uncertainty in the game outcomes owing to its structure. This differs from some other sports of the same family with opponent direct

interference. These findings are consistent with those of Peña et al. (2013) who found a similar effect for team categories in the Spanish men's professional volleyball league.

The importance of the service skill in volleyball has been shown in several reports before (Hughes and Daniel, 2003; Patsiaouras et al., 2011; Silva et al., 2014; Zetou et al., 2006). Since the introduction of the rally point system by the F.I.V.B. in 1999, production of Complex-I has balanced the competitive performance of top teams. Thus, the ability of the service to impair directly or indirectly the development of this game phase on the opposing team is clearly related to the final outcome in the competition. The results of our analysis show that the odds of winning a volleyball match increase 1.2 times with every additional service direct point. In contrast, chances of obtaining a positive game outcome decrease by 8.2% for each additional service error. These findings are also consistent with previous research on the matter (Kountouris et al., 2015) showing that error management can be even more important than achieving direct points when using the service skill.

Along the same lines, the management of reception is also paramount in volleyball, as the ability of the players to reduce direct errors has been revealed in our research as a relevant performance factor. These results match those observed in previous studies (Peña et al., 2013; Silva et al., 2014) and show that reducing errors in this skill can be of outmost importance as it has a direct negative impact on the number of points obtained in Complex II skills by the opposing team. This study also demonstrated that improving the team percentage of positive receptions can unbalance the final outcome. Although some research had stated otherwise (Peña et al., 2013), our findings display increased odds of winning a match when increasing this value. Increasing the number of positive receptions by 1% will give a team 1.02 more odds of winning when compared to a team with 1% fewer positive receptions. On the question of blocked balls, this research found that the team's capacity to neutralize the opponents' attacks with the first line of defense can be linked to obtaining a victory, with several studies agreeing with our findings (Palao et al., 2004; Rodriguez-Ruiz et al., 2011). It seems that when matches become tied,

the ability to block comes to be decisive in obtaining the victory in volleyball. In contrast to previous findings (Campos et al., 2015; Eom and Schutz, 1992; Rodriguez-Ruiz et al., 2011; Zetou et al., 2006, 2007), no evidence of any of the attack categories becoming a performance predictor was found in our analyses. In today's volleyball, with an increased frequency of high attacks, the importance of this technical skill seems to be decreasing, matching the competitive opportunities of teams with lower attack potential.

Previous studies evaluating the home-court advantage effect provided inconsistent results on whether playing in a specific venue might be an asset for volleyball teams. Some of them have observed no effects in some leagues (Peña et al., 2013), while others found this factor important exclusively during the initial set of the match (Marcelino et al., 2009). Contrary to expectations, our study found increased odds of winning for the teams playing at home (1.34 times).

Conclusions

The main goal of the current study was to determine which performance factors influenced most the outcome of high-level volleyball games. Logistic mixed models appear to be a powerful statistical approach to identify key performance indicators in volleyball. We can conclude that the number of team scorers, the team category, the number of service errors, service points, reception errors, blocked balls, the percentage of positive receptions and the venue are game-related performance factors. Several of these variables can be clearly modified and improved by training, thus, coaches should reconsider their importance in the game and the amount of practice necessary to improve the technical, tactical and physical fitness aspects of each of them. To diversify the number of team main scorers, improving error management and making the right managerial and organizational decisions seems crucial in order to improve performance at the top level, with some skills and factors showing more predictive power than others. At present, winning a volleyball game is becoming increasingly complex and factors at different levels can affect positively and negatively the final outcome.

Acknowledgements

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