

Relationship between spike speed and selected strength parameters in top-level female volleyball players

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Abstract

This study aimed to determine the relationships between spike speed and selected strength parameters of female players in top-level volleyball. The research group consisted of 19 female volleyball players aged 17.77 ± 2.17 years; with a body height of 181.16 ± 3.59 cm and sport experience length of 7.52 ± 2.68 . The spike speed was measured with the Bushnell radar gun providing immediate output data in speed measurements with an absolute measurement error of ± 0.27 m.s-1. The reliability of the spike speed measurement in individual trials was expressed by the intraclass correlation coefficient (ICC) and the standard error of measurement (SEM). For the measurement of the ball flight speed after the spike we found these values: ICC = 0.91 and SEM = 0.99 m.s-1. Strength parameters were evaluated by the test of throwing a 1 kg ball in the kneeling position with the spiking hand, the spike reach height and the sit-up test of 30 seconds. Statistical data were evaluated by Pearson's (r) and Spearman's (R) correlation coefficient, coefficient of determination (R²) and regression equation formulas. We demonstrated significant relationships between spike speed and 1 kg ball throw ($p < 0.05$; $r = 0.663$) and spike reach ($p < 0.05$; $r = 0.463$). We did not find any significant relationships between the spike speed and the sit-up test ($p > 0.05$; $r = 0.134$). The results show the most important finding about the presumable changes in final spike speed depending on the changes in performances in the implemented tests, in which a significant relationship was demonstrated.

Key words: volleyball, women, spike speed, motor tests, performance analysis

Introduction

Modern volleyball is one of the most popular mass sports in the world. One of the reasons for the current attractiveness of volleyball is its high dynamics, which reflects in a significant acceleration of the individual phases of movement execution in the game skills. The reason for these changes is mainly the carefully thought-out strength training of players based on the knowledge of limiting fitness parameters and game movements that players apply in the execution of individual game activities (Kraemer et al. 2000, Marques et al. 2006, 2008, Bompá and Buzzichelli, (2015). When speaking about strength training, one of the main areas is the development of explosive power, which is one of the prerequisites for a player's ability to attack from a greater height or to develop a higher ball flight speed when spiking or spike serving (Forthomme et al. 2005, Baena-Raya et al. 2021). The game activity whose success rate has the most significant impact on a team's victory in a match is the offensive stroke (Palao et al. 2004, Marcelino et al. 2010, Silva et al. 2014, Přidal and Přikrelova (2018), Drikos et al. 2019, Shukla et al 2020, Přidal et al. 2021, Giatsis et al. 2022).

There are several studies that have researched the relationship between spike speed and kinematic parameters of motion. Ying-cheng and Chen-fu (2008) analysed the movement and speed of core of female volleyball players when spiking from the front and back rows. It was shown that the initial ball flight speed and the angular velocities of the shoulder, elbow and wrist were greater for spikes performed from the front zones than for spikes performed from the back zones. Plawinsky's (2008) study shows that different swing techniques in top-level university players during the offensive stroke can affect the resulting maximal ball flight speed from different zones when the strokes hit in different directions. The authors see the reason for the difference in ball flight speed in the more noticeable wrist flexion during the swing when stroking across the body. Li-Fang et al. (2008) dealt with the range of motion of the shoulder joint, timing and coordination of the individual body segments during the execution of an offensive stroke. The authors conclude that the maximum speed a spiker can impart to the ball after a stroke is related to the magnitude of produced force, which showed a dependence with the range of motion during the arm swing. In this study was confirmed that there is a difference in shoulder joint range of motion between the top-level volleyball players and the other performance categories, with the top-level players having a greater range of motion. This greater range then allows the players to achieve greater acceleration of the individual body segments and thus produces a greater moment of force when stroking the ball. Fewer studies have dealt with the relationship between ball flight speed and motor factors limiting performance in volleyball. Cloes et al. (2004) identified a dependence between selected variables and ball flight speed during a stroke between two groups of players of different performance. It shows a positive correlation

between the ball flight speed and the height of the spike reach, the result when throwing the 800g ball, jump with hands counter movement, body weight, body mass index and strength training in hours per week for both groups. Forthomme et al. (2005) found a relationship between ball flight speed and muscle force during shoulder internal rotation in the concentric phase of the movement, concentric contraction of the elbow joint flexors and extensors in the male category. Valades and Palao (2015) researched, among other parameters, also the relationship between spike speed and in-season power level in professional female volleyball players. The results showed that the players' training increased their upper body strength and power, but these improvements did not transmit to the players' ability in stroke speed.

The authors see the cause of this in the lack of specificity of the applied exercises. Baena-Raya et al. (2021) studied the connection between spike and serve speed and between mechanical variables derived from force and speed in top-level volleyball players. According to the authors, maximum vertical jump power, sprint speed, and bench press in ascending order were strongly associated with spike and serve speed, while it had a greater impact on serve speed. Terol-Sanchiz et al. (2021) analysed the relationship between the isometric force produced in different joints and its effects on the spiked serve speed as a predictive aspect to improve sports performance in beach volleyball. Our results showed a relationship between the isometric force developed in the shoulder's internal rotation and the speed of the ball. In other isometric exercises, we found positive low to moderate correlations in the spine and knee extension and elbow flexion.

Our study aimed to clarify the relationship between the maximum ball flight speed after stroking the ball at the spike speed (SS) and selected strength parameters of female players in women's top-level volleyball. We assumed to demonstrate the dependence of spike speed on the performance in implemented strength tests in top-level female volleyball players. We will point out the importance of specific strength training for female players and how it reflects in the qualitative characteristics of the spike, which is, among other factors, the ball flight speed.

Material & methods

Participants

The research group consisted of 19 top-level slovak female volleyball players, whose game function is called passing spiker (calendar age 17.77 ± 2.17 , sport age 7.52 ± 2.68 , body weight 72.14 ± 6.27 , body height 181.16 ± 3.59 , arm span length 181.89 ± 3.27 , and spike reach height 236.11 ± 5.97). It is a player's function for which it is characteristic to attack from the net edges from zone 4 in the offensive game phase.

All participants were informed of the procedures and the main purpose of the study. The presented procedures followed the ethical standards of human experimentation as stated in the Helsinki Declaration.

Procedures

Among the selected and diagnosed parameters, we included the following tests: a 1 kg ball throw in the kneeling position with a spiking hand (BTT - Ball Throw Test), the height of the spike reach after a three-step run-up to the stroke (SR - spike reach). Spike speed [m.s⁻¹], sit-ups (SU- sit-ups) lasting 30 seconds . The measurement took place in the 2018/19 competition season, where we assumed the highest connection between strength parameters and game skills.

Prior to the testing, we shortly presented to all female players the objectives of this research, the testing process and were given instructions on how to perform the tests correctly. Subsequently, they were asked to perform their subjectively maximal performances. The players did not have information about their performance, nor about the performance of the other examined players. After the players warmed up, we proceeded to measure the spike speed [m.s⁻¹] in our simulated test situation. After the measurement of the individual trials of the stroke speed, we proceeded to the diagnosis of the strength abilities, in the following order of tests: a 1 kg ball throw in the kneeling position with a spiking hand, the spike reach height after a three-step run-up to the stroke, sit-ups for 30 seconds. To obtain the results, we prepared detailed descriptions for specific tests depending on the principle of the measuring instruments.

The ball flight speed after the spike was measured with the Bushnell radar gun providing immediate output data in speed measurements with an absolute measurement error of ± 0.27 m.s⁻¹. The reliability of the spike speed measurement in individual trials was expressed by the intraclass correlation coefficient (ICC) and the standard error of measurement (SEM). For the measurement of the ball flight speed after the spike we found these values: ICC = 0.91 and SEM = 0.99 m.s⁻¹. The measurement of the spike speed was performed after the spike run following a pass from a stable passer from zone 4 to the defined area of zone 5. The passer passed the ball after his own toss, thus ensuring optimal conditions for the realization of an accurate pass (Fig. 1). We used the Mikasa Prestige MVA200 balls for our testing. The internal air pressure in the ball was 32.5 kPa. Measurement of the pressure in the ball was carried out using a Mikasa digital pressure gauge AG500. The net height was 224 cm, which is in accordance with the current international volleyball rules for the women's category. Each player made twelve valid attempts. The rest interval between repetitions was 60 seconds. A valid attempt was considered to be an offensive stroke after a spike run in that direction into the defined area of zone 5 with the player's best effort to achieve the highest possible speed. The test criterion was the average value of the five valid trials in which we achieved the highest spike speed.

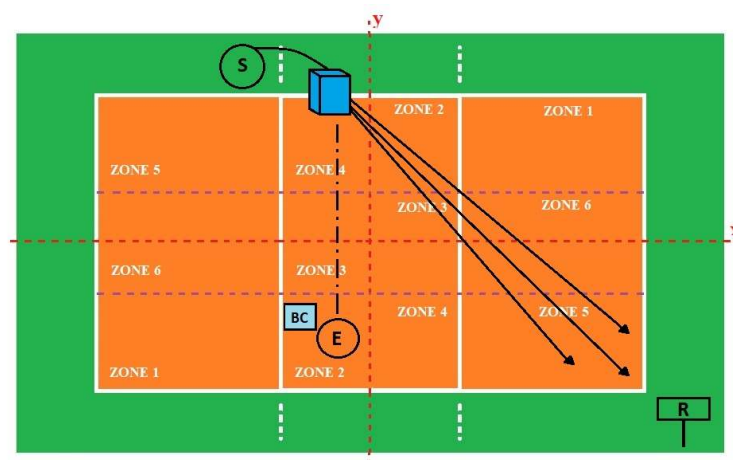


Figure 1 Spatial organisation and implementation of the spike speed measurement

Legend: S – spiker (attacking player); E – examiner; BC – ball cart; BRG – Bushnell Radar Gun

When measuring the throw of a 1 kg ball from the kneeling position with the spiking hand, the player knelt on her knees (having knees at the same level) on the mat just behind the throwing line. With a ball in his preferred hand, he makes a backswing and tries to throw it as far as possible along the outstretched area. After the throw, the player can fall forward behind the line. Each player has four attempts, which she performs consecutively. There is a 30-second rest interval between each one. We evaluated it with an accuracy of 0,1 m. The performance criterion in the test is the best attempt measured in meters.

The spike reach height after the three-step run was measured using a jump meter. The player bounced around after the three-step run and tried to reach as high as she could on the jump meter. Each player had four trials, which she performed consecutively. The rest interval between each trial was 60 seconds. It was measured with an accuracy of 0.01 m. The performance criterion in the test is the highest reached height in metres on the jump meter.

When measuring the parameters of dynamic and endurance strength of the abdominal, lumbar and thigh muscles by the sit-up test of 30 seconds, the players were asked to perform the maximum number of repetitions (one repetition is the transition from lying to sitting and back to lying). The examiner knelt facing the tested player, fixed her feet on the ground, and checked that the prescribed 90-degree knee flexion was maintained. After we explained to them the measurement and positioning, the players had the opportunity to try out the correct execution of the exercise. During the measurement we corrected our subjects and if they did not touch the pad with their arms or elbows, the cycle was not counted. The criterion in the test was the number of correctly performed repetitions during 30 seconds.

Statistical analysis

The empirical data obtained research were subjected to mathematical and statistical processing using Microsoft Office Excel 2007 and IBM SPSS Statistics 19 software. These statistical methods were used to process the empirical data: intra-class correlation coefficient R (ICC correlation) - verification of the relative reliability of measurement methods, standard error of measurement (SEM) - absolute reliability index expressed in units of the measured variable, Kolmogorov-Smirnov Test for normality of data distribution, Pearson's linear correlation coefficient (r), Spearman's coefficient of rank-order correlation (R), coefficient of determination (R square; R²). The significance of the relationships between the variables was assessed at the 5% level of statistical significance.

Results

The average maximal spike speed of each tested player is expressed by the average of the best five out of twelve valid attempts. The highest average maximal speed of the spike was 23.61 m.s⁻¹ and the lowest was 20.17 m.s⁻¹. The difference between the highest and lowest measured average maximal speed is 3.44 m.s⁻¹. The average maximal speed was 21.79 ± 0.96 m.s⁻¹. The reliability of the measurement of maximal spike speed within the individual measured trials, expressed by the intraclass correlation coefficient (ICC), was 0.89. The standard error of measurement (SEM) was 1.18 m.s⁻¹. The Shapiro-Wilk test ($W = 0.969$) did not reject the normality of the distribution of measured ball flight speeds after the spike ($p = 0.747$).

When solving the relationships between the studied variables, we found in the relationship between the average maximal spike speed and the length of the throw in the test of throwing a 1 kg ball from the kneeling position with the spiking hand values of 16.02 ± 2.06 m. The maximal measured value was 19.60 m, and the minimal measured value was 12.70 m. The variation range between the measured values was 6.9 m. The Shapiro-Wilk test ($W = 0.963$) did not reject the normality of the distribution of the measured performances in the test of throwing a 1 kg ball from the kneeling position with the spiking hand ($p = 0.632$). A graphical

illustration of the linear dependence between the observed variables is shown in Figure 2. The relationship between the average maximal spike speed and the throw in the test of throwing a 1 kg ball from the kneeling position with the spiking hand, evaluated by Pearson's linear correlation coefficient (r), reached the value of 0.663. Between the observed variables was demonstrated no statistically significant relationship ($p < 0.05$). The determination coefficient (R^2) was 0.439. The regression coefficient (R square) explains our regression model at 43.9%. The standard error of estimate (SEE) was 0.74 m.s⁻¹. The unstandardized B coefficient with a value of 0.308 indicates a directly proportional change in the ball flight speed after the spike, which is related to the change in performance in the 1 kg ball throw test. The overall model of the regression equation took the form of: spike speed [m.s⁻¹] = 0.308 x result in throwing 1 kg ball (m) + 16.86.

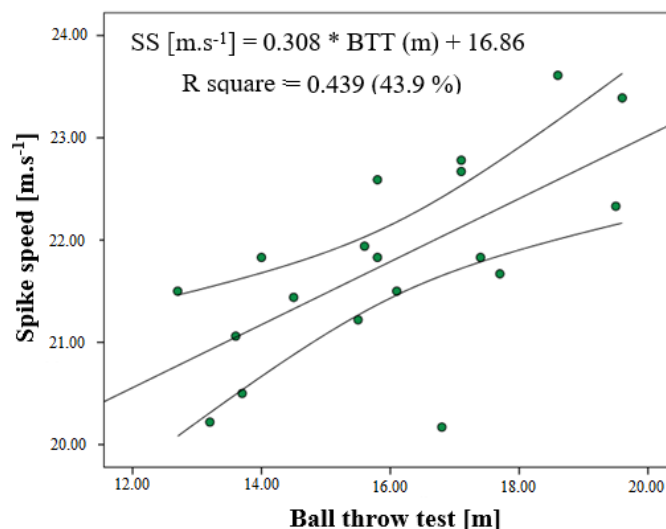


Figure 2 Dependence between the average maximal spike speed and the length of the 1 kg ball throw from the kneeling position with the spiking hand.

The average value of the spike reach height in the research group was 2.93 ± 0.06 m. The maximal measured value was 3.08 m and the minimum was 2.84 m. The variance range was 0.24 m. The Shapiro-Wilk test ($W = 0.965$) did not reject the normality of the distribution of measured reaches ($p = 0.667$). A graphical illustration of the linear dependence between the observed variables in the relationship between the average maximal spike speed and the spike reach height after a three-step run is shown in Figure 3. Pearson's linear correlation coefficient (r) was 0.463 ($p < 0.05$) and the determination coefficient (R^2) was 0.214. The regression coefficient (R square) explains our regression model at 21.4%. The standard error of estimate (SEE) was 0.874 m.s⁻¹. The unstandardized B coefficient with a value of 7.259 indicates a directly proportional change in spike speed related to the change in spike reach height after a three-step run-up. The overall model of the regression equation took the form: spike speed [m.s⁻¹] = 7.529 x spike reach performance (m) + 0.476.

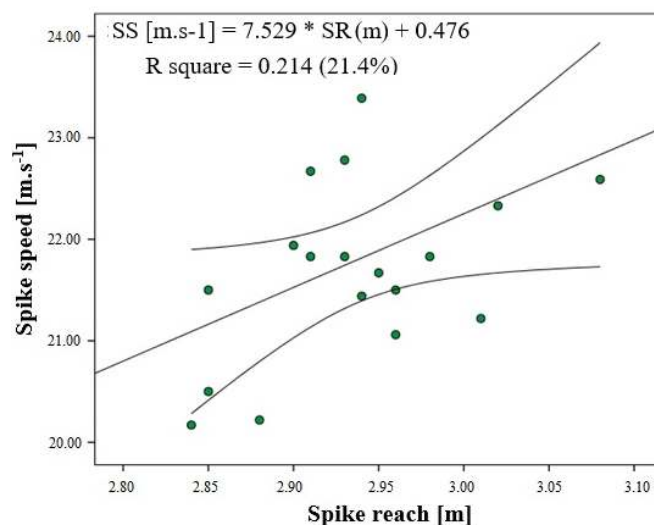


Figure 3 Dependence between average maximal spike speed and spike reach height after a three-step run-up to the stroke.

In the third performed 30-second sit-up test, the average value of repetitions was 25.63 ± 2.49 . The maximal number of repetitions was 30, and the minimum was 20 repetitions. The variance range represented a value of 10 repetitions. The Shapiro-Wilk test ($W = 0.966$) did not reject the normality of the distribution of the performance measurements ($p = 0.688$). A graphical illustration of the linear dependence between the observed variables is shown in Figure 4. The relationship between the average maximal ball flight speed after the spike and the number of repetitions in the sit-up test evaluated by Pearson's linear correlation coefficient (r) reached the value of 0.134. There was no statistically significant relationship ($p > 0.05$) between the observed variables. The determination coefficient (R^2) was 0.018 (1.8%).

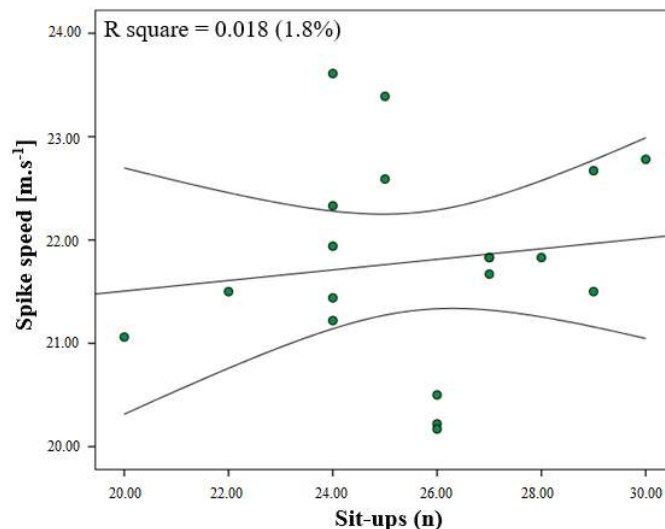


Figure 4 Dependence between the average maximal spike speed and the number of repetitions in the 30-second sit-up test

Discussion

This study shows that the closest to the movement structure of spike is, among our selected tests, the movement structure of the 1 kg ball throw from the kneeling position with the spiking hand. It because their external structures are similar. The relationship between the average maximum spike speed and the performance in the 1 kg ball throwing test reached a correlation coefficient of 0.663. The resulting determination coefficient of 0.439 explains the variability of the dependent variable through the independent variable. The obtained regression model expresses the dependent variable at 43.9%. The other part represents unexplained variability, the impact of random factors and other non-specific influences. These may be the spike technique and the ability to quickly coordinate the different body segments from the lower limbs through the trunk towards the distal parts in the order of shoulder, elbow, wrist and palm in complex movement patterns typical for the execution of a spike. The regression equation model obtained in practice shows that there is a probable change in the spike speed depending on the performance change in the 1 kg ball throw test. If a player changed her performance in the 1kg ball throw test over the course of the season from 17.0 meters to 18.5 meters, this could result in increase in the ball flight speed after the spike from 22.10 m.s⁻¹ to 22.58 m.s⁻¹.

Similarly, we can consider the other regression equations expressed in the results chapter of this study. If the output of the independent variable changes, this should affect the resulting ball flight speed too. Not many scientific papers deal with the search for relationships between throwing results and spike speed in volleyball. Similar results can be found in the study by Cloes et al. (2004), where the author demonstrates a statistically significant relationship between ball flight speed after the spike and performance in throwing an 800 g ball. However, a more careful examination of this issue is lacking.

Another examined variable in relation to ball flight speed was a seemingly unrelated independent variable, absolute spike reach height, where we demonstrated a positive relationship ($p < 0.05$). The correlation coefficient was 0.463. Similar results can be seen in Challoumas and Artemiou's (2018) study in the men's category, where the authors found positive correlations between vertical jump height and higher spike speed. Similarly, Cloes et al. (2004) demonstrated a positive correlation between ball flight speed and the ball hit height when spiking. We assume that players with higher spike range can perform a greater range of arm motion in the swing than players with lower spike range. Players with a lower spike range are limited to a certain extent by the set height of the volleyball net and probably have to spike (or hit) the ball earlier and at a more obtuse angle to the mat than players with a higher range. Our assumptions are supported by statement of Li-Fang et al.'s (2008) that a greater range of motion allows the players to achieve greater acceleration of individual body segments, and thus produce a greater moment of force when stroking the ball.

Statistically insignificant relationships were observed when we evaluated the relationship between the maximum ball flight speed after the spike and the number of repetitions in the 30-second sit-up test ($r = 0.134$; p

> 0.05). This shows that the parameters of the individual players in dynamic and endurance strength of the abdominal and lumbar-femoral muscles evaluated in our test are different in terms of the impact on the spike speed. We are aware of the fact that our research in a given spatial measurement organization took place in a modeled research situation. Such an artificially induced situation does not respect the specific characteristics of volleyball game performance, such as non-standard conditions of game performance, utilization, the variability of game situations and their creative solutions, which are likely to influence the results of this type of research in natural match conditions. It is because in a match, the player does not always try to play a spike with maximal effort in one direction, as we did it in our research. A player is confronted in game with the opponent's defensive position many times, and has to react creatively to emerging game situations, e.g. by variability of her attacking stroke. However, our goal was to achieve same conditions within our possibilities – mainly in terms of passing accuracy on every attempt by every player. We consider passing a key game activity to ensure the implementation of the spike. For this reason, the pass, in this case the throw-in of a ball for spike, was made by one of the team coaches, who has many years of experience with this type of pass and thus with its accuracy too. Thus, the spikers in our research did not implement passing as a prior game activity of an individual in the game chain, nor did they have to deal with the emerging game situation before the actual attack. They focused only on implementation of the "hardest" spike with effort to achieve the maximum ball flight speed in a given direction. If we compare the obtained ball flight speeds with the results of other authors, we see that our measured values are higher. The measured average ball flight speed after the spike in our research was 21.79 ± 0.96 m.s⁻¹. Christopher and Ricard (2002) 19.0 ± 1.0 m.s⁻¹; Ying-Cheng and Chen-fu (2008) 18.93 ± 1.32 m.s⁻¹; Bermejo et al. (2013) 18.51 ± 1.95 m.s⁻¹; and Valades and Palao (2015) 19.78 ± 1.42 m.s⁻¹. The different results of the observed spike speeds can be explained mainly by the different performance level and conditions in which the research was conducted.

This study shows that in strength training, it makes sense to find correlations between tests where chosen muscle groups are involved, for example, in a particular studied game movement test and specific parameters of the player's performance (spike speed or spiked passing, speed of the blocker's moves, etc.).

Conclusion

Based on the presented results and their analysis, we assume that we met the aim of our research. In our study, we tried to evaluate the relationships between the average maximum ball flight speed after a spike implemented from zone 4 to zone 5 and selected strength parameters of the side spikers in women's top-level volleyball. The proven relationships in our statistical testing between the observed strength parameters and the average maximum spike speed explain the connection of the studied relationships more clearly.

The determination coefficients and subsequent regression calculated from the positively evaluated relationships between spike speed and 1 kg ball throw from the kneeling position, the spike reach height, shows that the change in performance in the given tests should be reflected in the resulting ball flight speed. It means that coaches should apply in the training process the strength exercises that were part of the test battery or exercises whose movement structure and involvement of individual muscle groups are similar to the implementation of the spike. Increasing the spike speed in volleyball favours the attacking team due to the time reduction for the defending players of the opponent team and the subsequent implementation of the defensive game phase, or in other words, the response to the spiked ball and the resulting game situation. Increasing the ball flight speed is thus considered one of the prerequisites for increasing the efficiency and success rate of the observed final game activity of individual player.

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