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THE RELATIONSHIP BETWEEN VERTICAL JUMP HEIGHT, ARM MUSCLE STRENGTH, AND ARM MUSCLE POWER ON VOLLEYBALL SMASH RESULTS

Aulia Putri Nur Afifah¹, *Tatang Muhtar², Muhammad Nur Alif³, Anggi Setia Lengkana⁴

^{1,2,3,4} Universitas Pendidikan Indonesia

*Correspondence: tatangmuhtar@upi.edu

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ABSTRAK

Smash performance is a key determinant of scoring effectiveness in college volleyball; however, research that simultaneously examines the combined contribution of lower and upper body physical components in a single regression model at the university athlete level is still limited. This study aims to determine the relationship between jump height, arm muscle strength, and arm muscle explosive power with volleyball smash performance. A quantitative correlational design was used, involving 20 athletes from the Indonesian University of Education Sumedang Campus Student Volleyball Activity Unit, selected using Purposive Sampling technique. The instruments used included a vertical jump test, push-up test, medicine ball throw test, and smash accuracy test. Assumption testing was conducted prior to hypothesis testing, including normality and multicollinearity testing. Data were analyzed using multiple linear regression with SPSS version 26. The results of the study show a significant simultaneous relationship between vertical jump height, arm muscle strength, and arm muscle explosive power with smash performance ($F = 222.621$; $p < 0.001$), with an adjusted R^2 value of 0.972, indicating that 97.2% of the variance in smash performance is collectively explained by these three variables. Partially, arm muscle strength showed a significant relationship with smash performance ($p < 0.001$), while vertical jump height ($p = 0.333$) and arm muscle power ($p = 0.597$) did not show a significant partial relationship. These findings indicate that although physical components collectively contribute to smash performance, arm muscle strength emerges as the most dominant predictor among university-level volleyball athletes.

Keyword: Volleyball, Smash Performance, Jump Height, Arm Muscle Strength, and Arm Muscle Explosiveness

INTRODUCTION

Volleyball is a team sport that requires mastery of technique and optimal physical condition, especially in executing the smash as the main attacking technique to score points. This game requires movement coordination, good technique, and physical abilities that support various basic volleyball skills. The basic techniques of volleyball consist of four components,

namely underhand and overhand serves, underhand and overhand passes, smashes, and blocks. Of these four basic techniques, the smash is a powerful hit that aims to place the ball accurately in the opponent's area so that it is difficult to return, making it one of the fundamental components in the effectiveness of an attack and determining the outcome of a match (Deviani, 2020) The success of a smash is greatly influenced by an athlete's ability to coordinate their body movements comprehensively, supported by adequate physical condition. According to (Bompa, 2019), technical performance in sports is greatly influenced by physical components such as strength, explosive power, and jumping ability, which play an important role in producing explosive movements.

Physical factors such as high jumps, arm muscle strength, and arm muscle explosive power are the main determinants of a successful volleyball smash. A high reach and optimal jumping ability allow athletes to execute smashes with more effective angles and power, thereby increasing the chances of scoring points. A smash in volleyball is not just about hitting the ball over the net, but also requires other techniques such as high jumps, arm muscle strength, and arm muscle explosive power to ensure that the smash is precise and accurate. In volleyball, jump height plays a very important role, especially when performing a smash. Jump height is a measure of how high a person can lift their body from the ground to reach the highest point in the air when jumping. Vertical jump is a movement of jumping as high as possible vertically with the focus on leg muscle strength to achieve maximum jump (Aguss et al., 2021).

The ability to jump as high as possible allows players to achieve a more optimal position in attacking and defending. This vertical jump ability is influenced by physical components, particularly the explosive power of the leg muscles. This aligns with the opinion of (Pardiman et al., 2021), who define vertical jump as an individual's ability to jump as high as possible vertically by utilizing the explosive power of the leg muscles. Therefore, good vertical jumping ability allows players to position their bodies more advantageously when attacking or defending. The height of the jump is greatly influenced by the player's physical condition, especially the explosive power and strength of the leg muscles, which play a role in producing maximum thrust when jumping.

Additionally, in volleyball smashes, arm muscle strength is a crucial aspect that contributes to delivering an effective hit. According to (Pahrian & Esser, 2017), individuals with good arm muscle strength will be able to exert power when hitting a volleyball. If the power is applied well, the ball will be hit hard and difficult for the opponent to control. These findings are in line with the opinions of who state that the strength of the external and internal rotators of the shoulder is related to the performance of serves and spikes, both of which are important elements in the success of volleyball. Thus, arm muscle strength has a close relationship and a significant role in supporting the effectiveness of attacks through the smash technique. According to (Nur et al., 2018), arm muscle strength is a person's ability to use maximum strength from the arm muscles to release all the potential or strength that exists in a short period.

Therefore, performing a smash requires good movement coordination because the faster the movement, the more movement components must be coordinated simultaneously. Arm muscle strength functions as the main driving force behind the follow-through of the arm, resulting in a stronger and more effective hit. Then, arm muscle explosive power is one of the important factors that support the success of the smash technique in volleyball. This is because arm muscle explosive power is the ability to combine strength and speed in a simultaneous movement pattern. Explosive power is a movement that is done explosively. This means a person's ability to use the maximum strength of the arm muscles in the shortest possible time (Alpen, 2017).

The greater the explosive power of the arm muscles when hitting the ball, the stronger and faster the ball will be, thereby increasing the effectiveness of the attack and the chances of scoring points. Arm muscle explosive power is a physical quality that enables a muscle or group of muscles to perform explosive work (Ambarwati et al., 2017), as well as an individual's ability

to exert maximum force in a short period of time (Rahmawati et al., 2019). In line with this opinion, (Syukur et al., 2019) stated that arm muscle explosive power is a series of muscle movement elements supported by strength and speed, resulting in optimal explosive power in volleyball smash skills. This is reinforced by (Rizal & Kasrیمان, 2020), who state that explosive power is very much needed when performing a smash because it requires maximum arm muscle strength. Explosive power is closely associated with rapid force production, effective neuromuscular coordination, and the efficient utilization of the stretch-shortening cycle during the acceleration phase of the arm movement.

Both movement systems play an important role and can be trained simultaneously to produce optimal explosive power. However, based on observations in the field, empirical conditions still show a gap between theory and practice. There are players who have good jump heights, but their smash results are not optimal. This can be seen from the ball being frequently blocked by opponents, going out of bounds, or even failing to pass the net. Conversely, there are also players with less significant jump heights who are able to perform accurate and effective smashes. This phenomenon raises the question of whether jump height directly affects the quality of a smash, or whether other factors such as arm muscle strength and arm muscle explosive power also play an important role. Therefore, this study aims to determine "The Relationship Between Jump Height, Arm Muscle Strength, and Arm Muscle Explosive Power on Volleyball Smash Results.

Although some players have exceptional physical abilities, such as jump height, arm muscle strength, and arm muscle power, solutions are needed that focus on improving the physical aspects directly related to smash technique. One strategic step is to create a specific training plan that focuses on improving jump height, arm muscle strength, and arm muscle power. Additionally, regular physical evaluations are crucial for tracking athletes' progress and adjusting training loads appropriately. To improve body movement coordination during smashes, a biomechanical approach is also necessary in technical training. Finally, strengthening basic playing techniques such as body balance, eye-hand coordination, and timing of the hit must be continuously trained so that the smash becomes more accurate and difficult for opponents to block. By implementing these solutions, it is hoped that the player's smash performance will improve overall.

This solution was chosen because a volleyball smash is the result of a combination of various physical and technical elements, not just one. For example, players with high jumps may not be able to perform good smashes if they are not balanced with sufficient arm muscle strength and explosive power. Conversely, strokes that are easily read by opponents will result from strength that is not combined with good skills and coordination. Therefore, the goal of the solution, which includes programmed training, periodic evaluation, and biomechanical techniques, is to comprehensively and integrally optimize each of these elements. With this comprehensive approach, the training process emphasizes not only intensity but also the quality of movement and the effectiveness of the smash itself.

This differs from other studies and previous research conducted by (Tongge et al., 2024), (Sukisman, 2012), (Aditama et al., 2025), (Oktariana et al., 2020), and (Yulifli et al., 2018). In the study by Tongge et al., they only examined the relationship between leg muscle power and arm muscle strength on smash shots in Physical Education students, while the study by Sukisman et al. examined the relationship between jump height and waist flexibility on smash accuracy in high school athletes.

The study by KR Aditama et al. focused on arm muscle strength and leg strength in female volleyball club athletes, The study by Yulifri et al. examined the relationship between leg and arm muscle power and smash accuracy in regional athletes. This study is different and novel because it combines three physical variables that have never been studied simultaneously, namely jump height, arm muscle strength, and arm muscle power, in relation to volleyball smash results. In

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particular, arm muscle explosive power is a new variable that has never been used in previous studies, even though this factor plays an important role in producing fast, hard smashes that are difficult for opponents to block. In addition, the subjects in this study were members of the Indonesian University of Education Sumedang Campus Volleyball Club, namely student athletes who actively train and compete in sports activities at the university level, so that the results of this study will be more applicable and relevant to the development of college-level volleyball athletes' performance.

This study also does not only assess the accuracy of smashes as in several previous studies, but also assesses the results of smashes more broadly, including strength, accuracy, and effectiveness in the game. Thus, this study is expected to contribute new insights to the development of coaching science, particularly in developing more targeted physical training programs to improve the quality of volleyball athletes' smashes.

METHOD

In this study, the researcher used a quantitative method. (Yulhendra, 2017) states that correlation research is research to determine whether there is a relationship between two variables, the magnitude of the relationship between the two variables is expressed in the form of a correlation coefficient, followed by finding the contribution or contribution between the independent variable and the dependent variable, namely between jump height (X1), arm muscle strength (X2), and arm muscle power (X3) on the results of volleyball smashes (Y). The population consisted of 20 volleyball athletes selected through purposive sampling. These criteria were set because the research subjects had characteristics that were in line with the focus of the study, so that the data produced would be more focused and in-depth, such as players who actively participated in training and had no history of injury.

Data collection instruments included:

1. The vertical jump test was used to measure the participants' vertical jump height. Each participant performed three attempts, and the best score was recorded. The vertical jump test was conducted under the supervision of the researcher. The vertical jump test was performed using the procedure described by (Palinata, 2023).
2. Push-up test, used to measure arm muscle strength. The test was assisted by four volunteers who had previously been given an explanation of the procedures and methods of conducting the test to ensure the objectivity of the measurements. The push-up test is performed for 30 seconds in one attempt, and the total number of correct repetitions is recorded as the score. The push-up test was performed using the procedure described by (Pasaribu, 2020).
3. The two-handed medicine ball throw test is used to measure the explosive power of the arm muscles using the procedure described by (Aqyunin, 2022). Participants sat on the floor with both legs straight out in front of them and their backs against a wall. A medicine ball was held with both hands in front of the chest. The ball was then pushed forward as far as possible without lifting the back from the wall. Each participant was given three attempts, and the furthest distance of the three attempts was recorded as the final score. The throwing distance was measured in meters from the wall to the point where the ball first landed.
4. The smash accuracy test (target) was used to assess volleyball smash performance, with the test implementation intended by (Palinata, 2023) the researcher. The opponent's court area was divided into several target zones, each with a different score value based on the level of difficulty. The center zone of the court was given 1 point, the back side zone was given 2 points, the side zone near the net was given 3 points, the inner front and back corner zones were given 4 points, and the rearmost corner zone (outer corner) was given 5 points as the highest score. Each participant was given 6 attempts consisting of 3 standing smashes (without jumping) and

3 smashes using jumping (timing). Scores were given based on the zone where the ball first landed, while balls that went out of the court or touched the net were given a score of 0. The total number of points from the six attempts was recorded as the final score.

The data were analyzed using a normality test as a prerequisite analysis, followed by multiple linear regression analysis to determine the relationship between high jump, arm muscle strength, and arm muscle explosive power and volleyball smash results. Prior to regression analysis, assumption tests were conducted, including normality and multicollinearity tests. All statistical analyses were performed using SPSS version 26.

RESULTS

Based on the results of multiple linear regression analysis, an R value of 0.988 with an Adjusted R Square of 0.972 was obtained. This shows that the relationship between jump height, arm muscle strength, and arm muscle explosiveness with volleyball smash results is in the very strong category. The value of the determination coefficient indicated that 97.2% of the variation in smash results could be explained by the three variables together, while the remaining 2.8% was influenced by other factors outside the study.

The results of the simultaneous test (F test) showed a significance value of 0.000 ($p < 0.05$), so it can be concluded that together there is a significant relationship between jump height, arm muscle strength, and arm muscle explosiveness with volleyball smash results.

Partially, the ttest results showed that arm muscle strength had a significant relationship with smash results ($p = 0.000 < 0.05$). Meanwhile, jump height ($p = 0.333 > 0.05$) and arm muscle explosiveness ($p = 0.597 > 0.05$) showed no partial significant relationship with volleyball smash outcomes.

The assumption test showed that the residual was normally distributed ($p = 0.809 > 0.05$). However, the results of the multicollinearity test showed a high Variance Inflation Factor (VIF) value for several independent variables, which indicates a very strong relationship between independent variables.

DISCUSSION

The results showed that simultaneously there was a significant relationship between shock height, arm muscle strength, and arm muscle explosiveness with volleyball smash results. This is supported by the analysis of multiple linear regression results which shows a determination coefficient value of 97.7%, which indicates that the variation in smash results can be largely explained by the three variables together. These findings reinforce that physical ability is an important component in supporting the success of smash techniques in volleyball SMEs. Smash is a complex skill that involves coordination between the strength, speed, and explosive abilities of the upper and lower body, so that the physical condition of the athlete is a determining factor in the effectiveness of its implementation.

Partially, arm muscle strength showed a significant relationship with smash results. These findings show that arm muscle strength has a more dominant role than other variables in this study model. In the implementation of the smash technique, the swing phase and ball contact depend heavily on the ability of the arm muscles to produce maximum thrust. The greater the strength of the arm muscles that an athlete has, the greater the potential for speed and power of the punch produced. This finding is in line with the opinion (Pahrian & Esser, 2017) that arm muscle strength is the dominant physical factor in supporting the effectiveness of smash because it plays a role in producing strong thrust while controlling the direction of the ball hit. In addition,

research (Nur et al., 2018) also showed a positive relationship between arm muscle strength and smash ability in adolescent soccer athletes.

Meanwhile, the high jump and explosiveness of the arm muscles showed no partial significant association in the regression model. However, both variables still have a contribution when explained simultaneously. This condition is thought to be related to the existence of a very strong relationship between independent variables, so that statistically the contribution of each variable becomes less visible when included simultaneously in the regression model. Physiologically, the high shock and explosive power of the muscles are closely related in supporting explosive abilities when smashing. Athletes with good jumps have the biomechanical advantage of a higher ball contact point, allowing for sharper and more effective angles of attack. This is in line with the opinion (Amelia et al., 2024) that smash requires high jumping ability and intensive training to produce optimal performance.

The explosiveness of the arm muscles as a combination of strength and speed also remains an important component in explosive smash movements. (Bompa, 2019) explained that explosive power is a combination of power and speed to produce maximum force in a very fast time. Therefore, although it is partially insignificant in this model, theoretically explosive power is still relevant in supporting the quality of the smash.

Overall, the results of this study confirm that the performance of the ball smash is influenced by a combination of several components of physical conditions that work in an integrated manner. Therefore, training programs to improve smash skills should be designed comprehensively by developing arm muscle strength, jumping ability, and explosiveness in an integrated and continuous manner.

CONCLUSION

Based on the results of the study on participants of the Indonesian University of Education Sumedang Campus Volleyball Club, it can be concluded that jump height, arm muscle strength, and arm muscle explosive power have a significant relationship with volleyball smash results. Partially, these three variables show a very strong relationship based on the Spearman's rank correlation test. Simultaneously, the results of the multiple regression test show that the three variables contribute 97.7% to the variation in volleyball smash results. These findings confirm that physical condition components play an important role in supporting the effectiveness of smashes.

Based on these results, it is recommended that volleyball training programs, especially at the college level, be designed in an integrated and systematic manner with an emphasis not only on mastering smash techniques, but also on developing high jumps, arm muscle strength, and arm muscle power. Future researchers are also advised to add other relevant variables to make the research results more comprehensive.

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