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Path analysis of arm muscle strength, leg power, and concentration on underhand passing performance in youth volleyball players

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Abstract

Background: Volleyball is one of the most popular sports and requires effective underhand passing skills to maintain ball control during gameplay. Underhand passing performance is influenced not only by physical factors such as arm muscle strength and leg power but also by psychological factors, particularly concentration. However, the passing ability of junior volleyball players remains relatively low.
Aims: This study aimed to analyze the effects of arm muscle strength, leg power, and concentration on underhand passing performance in youth volleyball players.
Method: This study employed a quantitative associative design using a path analysis approach. The participants consisted of 30 male volleyball players aged under 15 years selected through total sampling. Arm muscle strength was measured using a pull-up test, leg power using a vertical jump test, concentration using the Concentration Grid Test, and underhand passing performance using a standardized volleyball passing test.
Results: The findings showed that arm muscle strength contributed 16% to underhand passing performance, while leg power contributed 5.5%. Concentration also demonstrated a significant contribution to passing ability. Simultaneously, all variables showed a strong influence on underhand passing performance.
Conclusion: Physical and psychological factors significantly affect volleyball underhand passing performance. Future studies are recommended to involve broader samples and different competitive levels.

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INTRODUCTION

Sport has become an important aspect of human life and has developed into an integral component of education, health, recreation, and social interaction in modern society. Participation in sports activities contributes significantly to improving physical fitness, mental well-being, and overall quality of life (Gothe et al., 2020; Herbert, 2022; Liu et al., 2024; Marquez et al., 2020; Trajković et al., 2023). Regular physical activity is also associated with better cardiovascular function, muscular endurance, and body coordination. In educational settings, sports activities are widely implemented to support students' physical and psychological development (Almeida et al., 2025; Piñeiro-Cossio et al., 2021; Rocliffe et al., 2024; T. Wang & Park, 2021). One of the most popular sports practiced by students and communities is volleyball. Volleyball is widely played because it can be performed by individuals of various ages and skill levels in both recreational and competitive

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environments (Coutinho et al., 2021; Trajković et al., 2020). This sport requires athletes to demonstrate technical, tactical, physical, and psychological abilities simultaneously during gameplay. Successful volleyball performance depends on effective teamwork, movement coordination, and the ability to respond quickly to game situations. Therefore, volleyball has become an important area of study in sports science, particularly regarding the factors influencing technical skill performance. Understanding the determinants of volleyball performance is essential for improving athlete development and training effectiveness.

Volleyball performance is strongly influenced by the mastery of fundamental technical skills that support effective gameplay. Several basic techniques must be mastered by volleyball players, including serving, passing, blocking, smashing, and defensive movements. Among these techniques, underhand passing is considered one of the most important skills because it functions as the primary technique for receiving serves and controlling the ball during defensive situations. Effective underhand passing allows players to maintain ball stability and organize offensive attacks more efficiently. Poor underhand passing performance often disrupts team coordination and reduces overall match performance. Preliminary observations conducted during volleyball learning activities indicated that many students experienced difficulties in performing accurate and consistent underhand passing techniques. Most students demonstrated inadequate ball control, unstable movement coordination, and limited passing accuracy during practice sessions. These conditions suggest that several physical factors may influence underhand passing performance among youth volleyball players. One of the most important physical components related to passing performance is arm muscle strength because the arms function as the primary contact point during ball reception (Suhadi et al., 2023). Adequate arm muscle strength enables players to stabilize the ball, control movement direction, and maintain passing consistency during dynamic gameplay situations.

In addition to arm muscle strength, leg power also contributes significantly to volleyball performance because explosive lower-body movement supports body balance, movement speed, and positioning during ball reception. Athletes with better leg power are generally able to react more quickly and perform more stable movements while executing technical skills during matches. The combination of upper-body strength and lower-body explosive movement is therefore essential for improving technical volleyball performance. However, physical ability alone may not be sufficient to achieve optimal passing performance because psychological factors also play important roles in sports activities (Ayranci & Aydin, 2025; Fawver et al., 2020; Purwanto et al., 2025; Wu et al., 2024). One of the most influential psychological components in volleyball performance is concentration. Concentration refers to the ability of athletes to maintain focus on relevant stimuli while ignoring distractions during gameplay. High concentration allows players to process visual information efficiently and coordinate body movements accurately when receiving the ball (W. Chen et al., 2021). Athletes with poor concentration often experience technical errors, unstable passing control, and delayed responses during competitive situations. Despite the importance of physical and psychological factors in volleyball performance, previous studies have mostly examined these variables separately and focused on general volleyball skills rather than underhand passing specifically. Therefore, a more comprehensive investigation integrating arm muscle strength, leg power, and concentration is necessary to better explain underhand passing performance among youth volleyball players.

Previous studies have widely investigated factors influencing volleyball performance, including muscle strength, explosive power, concentration, agility, and neuromuscular abilities among volleyball athletes. Several researchers focused primarily on physical variables such as arm strength, upper-body power, leg explosive power, endurance, and movement coordination in relation to volleyball performance. Other studies emphasized psychological aspects including concentration, attention, confidence, visual cognition, and mental readiness as determinants of sports performance

and decision-making ability (Akbar et al., 2025; Edmizal et al., 2025; Guo et al., 2025). In addition, various studies have applied biomechanical analysis and performance evaluation approaches to examine volleyball technical skills such as serving, smashing, and jumping performance (Ismael, 2024; Oliveira et al., 2020; Ramasamy et al., 2023; Сушко et al., 2021). Although these studies have contributed significantly to volleyball science, most investigations examined physical and psychological variables independently rather than simultaneously. Limited studies have specifically explored underhand passing performance as a dependent variable among youth volleyball athletes. Furthermore, research investigating the direct and indirect relationships among arm muscle strength, leg power, and concentration using a path analysis approach remains very limited. Previous studies also focused predominantly on elite or professional athletes rather than adolescent players participating in school extracurricular activities. Consequently, there is still insufficient understanding regarding the integrated contribution of physical and psychological factors to underhand passing performance in youth volleyball players. Therefore, this study attempts to address this research gap by developing a comprehensive analytical model integrating arm muscle strength, leg power, and concentration to explain underhand passing performance among youth volleyball athletes.

Previous studies have widely examined factors influencing volleyball performance, including mental energy, concentration, self-confidence, muscle strength, leg power, endurance, agility, and neuromuscular performance among volleyball athletes (Martin et al., 2024; Shieh et al., 2023; J. Wang et al., 2025). Several researchers emphasized psychological aspects such as concentration, attention, and visual cognition in improving volleyball performance and decision-making abilities (Valayi et al., 2024), while other studies focused on physical components including arm muscle strength, explosive leg power, and upper-body power as determinants of technical volleyball skills and athletic achievement (Gonçalves et al., 2021; Kitamura et al., 2020). In addition, previous research has applied biomechanical and performance analysis approaches to evaluate volleyball skills such as serving, smashing, and general game performance (Bari et al., 2023; Shoval & Barron, 2021). However, most of these studies investigated physical and psychological variables separately and primarily focused on isolated technical skills rather than underhand passing performance specifically. Furthermore, limited studies have simultaneously examined the direct and indirect relationships among arm muscle strength, leg power, and concentration using a path analysis approach in youth volleyball players. Therefore, this study attempts to fill this gap by developing a comprehensive analytical model integrating physical and psychological factors to explain underhand passing performance among youth volleyball athletes.

This study aimed to analyze the direct and indirect effects of arm muscle strength, leg power, and concentration on underhand passing performance among youth volleyball players. Specifically, this study examined the contribution of arm muscle strength to underhand passing ability and evaluated the influence of leg power on technical passing performance. In addition, this study investigated the role of concentration as a psychological factor affecting underhand passing performance during volleyball activities. The study also explored the mediating effect of concentration on the relationship between physical variables and passing ability. A path analysis approach was employed to provide a more comprehensive explanation of the causal relationships among the investigated variables. This analytical model was expected to reveal both direct and indirect influences between physical and psychological factors in volleyball performance. The findings of this study are expected to contribute theoretically to the development of sports science, particularly in volleyball performance analysis among youth athletes. Practically, the results may provide useful information for coaches and physical education teachers in designing more effective volleyball training programs. The integration of physical conditioning and concentration-based exercises may help improve technical passing performance among youth volleyball players.

Therefore, this study is expected to provide both scientific and practical contributions to volleyball coaching and athlete development.

LITERATURE REVIEW

Volleyball is a dynamic team sport that requires the integration of technical, physical, tactical, and psychological abilities to achieve optimal performance during matches. Athletes are required to respond quickly to changing game situations while maintaining movement coordination and technical accuracy throughout gameplay. The success of volleyball performance depends largely on the mastery of basic technical skills that support both offensive and defensive strategies. Technical skills such as serving, smashing, blocking, setting, and passing are considered fundamental components in volleyball performance development (Astuti et al., 2025; Jariono et al., 2023). Among these skills, underhand passing is one of the most frequently used techniques because it functions as the primary method for receiving serves and controlling defensive ball movement. Effective underhand passing contributes significantly to team coordination and offensive preparation during rallies. In contrast, poor passing ability often disrupts game rhythm and reduces overall team effectiveness during competition. Underhand passing requires athletes to coordinate body posture, arm movement, and lower-body stability simultaneously during ball contact. Therefore, technical passing performance is closely associated with athletes' physical readiness and movement control abilities. Understanding the determinants of underhand passing performance is important for improving athlete development and volleyball training effectiveness.

Physical conditioning is considered one of the primary factors influencing technical performance in volleyball. Athletes with better physical fitness generally demonstrate superior movement efficiency, technical consistency, and competitive performance during matches. One of the most important physical components in volleyball is arm muscle strength because the upper body plays a central role in ball control and movement stabilization during passing activities. Arm muscle strength enables athletes to absorb ball impact, maintain passing direction, and improve movement accuracy during defensive situations (Farley et al., 2020; Hassan & Abdulkareem, 2026; Lindsay et al., 2022). Strong arm muscles also contribute to better endurance and technical stability throughout prolonged gameplay sessions. In addition to upper-body strength, lower-body explosive power is also essential in volleyball performance. Leg power supports rapid movement, jumping ability, body balance, and positioning when receiving or controlling the ball. Athletes with higher leg power are generally able to respond more quickly to changes in ball direction and perform technical movements more effectively. The interaction between upper-body strength and lower-body explosive movement therefore becomes an important factor in volleyball skill execution. Consequently, volleyball training programs commonly emphasize strength and power development to improve technical performance among athletes.

Besides physical conditioning, psychological factors also contribute significantly to sports performance and technical skill execution in volleyball. One of the most important psychological components affecting athlete performance is concentration. Concentration refers to the ability of athletes to maintain attention on relevant stimuli while ignoring distractions during competitive situations (Cui et al., 2025; Liu et al., 2024; Oliver et al., 2021). In volleyball, concentration is essential because athletes are required to process visual information rapidly and coordinate body movements accurately during gameplay (X. Li et al., 2024; Ottoboni et al., 2021; Valayi et al., 2024). High concentration allows athletes to maintain technical consistency and make effective decisions under pressure. Conversely, poor concentration often leads to technical errors, unstable passing performance, and delayed movement responses during matches. Concentration also supports cognitive processing, reaction speed, and motor coordination during technical execution. Athletes

who demonstrate strong concentration abilities are generally more capable of maintaining performance stability during dynamic game situations. Psychological readiness therefore becomes an important complement to physical conditioning in volleyball performance development. For this reason, concentration-based training strategies are increasingly integrated into modern volleyball coaching programs to optimize athlete performance.

Previous studies have reported that physical and psychological variables are closely associated with sports performance and volleyball skill development. Research investigating muscle strength and explosive power has shown that athletes with superior physical fitness tend to demonstrate better technical abilities and movement efficiency during volleyball activities (Dao, 2025; Farley et al., 2020; Kitamura et al., 2020; Martin et al., 2024). Several studies also reported that concentration and cognitive focus significantly influence technical accuracy and decision-making abilities among athletes. In addition, biomechanical and performance analysis approaches have frequently been applied to evaluate volleyball skills such as serving, spiking, blocking, and jumping performance (Fuchs et al., 2020; Guntur et al., 2022; Oliveira et al., 2020). However, most previous investigations examined physical and psychological variables separately rather than integrating them within a comprehensive analytical framework. Studies focusing specifically on underhand passing performance among adolescent volleyball players also remain relatively limited. Furthermore, research examining the direct and indirect relationships among arm muscle strength, leg power, and concentration using path analysis methods is still underexplored (Pérez et al., 2024; Schulte et al., 2025; Villa-González et al., 2024). Most existing studies have focused predominantly on elite or professional athletes instead of youth athletes participating in school extracurricular programs. This limitation creates insufficient understanding regarding the interaction between physical and psychological factors influencing underhand passing performance among adolescent volleyball players. Therefore, further investigation is necessary to provide a more comprehensive explanation of volleyball passing performance using an integrated analytical approach.

Path analysis is widely used in sports science research to examine direct and indirect relationships among variables within a causal framework. This analytical approach allows researchers to identify the contribution of multiple independent variables simultaneously while also evaluating mediating effects among variables. In volleyball performance studies, path analysis can provide a more comprehensive understanding of how physical and psychological factors interact in influencing technical skills (Altundag et al., 2024; Ayranci & Aydin, 2025; Neumann et al., 2025; Palao et al., 2024). The integration of arm muscle strength, leg power, and concentration into a single analytical model may help explain underhand passing performance more effectively. Understanding these causal relationships is important for designing evidence-based volleyball training programs that address both physical and psychological athlete development. The findings generated through path analysis may also contribute theoretically to sports performance literature by clarifying the interaction between motor and cognitive components in volleyball activities. From a practical perspective, coaches and physical education teachers may use these findings to develop more targeted training interventions for youth athletes. Training programs integrating strength development, explosive power exercises, and concentration enhancement strategies may improve passing consistency and technical performance during gameplay. In addition, the results of this analytical approach may support athlete evaluation and performance monitoring within educational and competitive volleyball settings. Therefore, the application of path analysis is considered relevant and valuable for examining underhand passing performance among youth volleyball players.

METHOD

Research Design

This study employed a quantitative associative research design using a path analysis approach to examine the causal relationships among variables related to volleyball underhand passing performance. The quantitative approach was selected because the study aimed to measure the direct and indirect effects among several independent, intervening, and dependent variables objectively. Path analysis was utilized to determine the magnitude and direction of the relationships among variables within a structural model. In path analysis, causal relationships are generally illustrated using directional arrows connecting exogenous and endogenous variables. This analytical approach allows researchers to identify both direct and indirect contributions among variables simultaneously. The variables investigated in this study consisted of arm muscle strength (X1), leg muscle power (X2), concentration (Y), and underhand passing performance (Z). Arm muscle strength and leg muscle power functioned as independent variables, while concentration acted as an intervening variable in the model. Underhand passing performance was treated as the dependent variable in this study. This research design was considered appropriate because it provides a comprehensive explanation of the causal relationships among physical and psychological factors influencing volleyball technical performance. Therefore, the path analysis model was expected to reveal the structural relationships among variables contributing to underhand passing performance among youth volleyball players.

Participants

The participants in this study consisted of male students participating in volleyball extracurricular activities at SMPN 5 OKU. The sampling technique used in this research was total sampling because all members of the population were included as research participants. Total sampling is commonly applied when the population size is relatively small and manageable for comprehensive investigation. A total of 30 male students participated in this study, all of whom were categorized as youth volleyball players aged 15 years. The participants had experience participating in school volleyball extracurricular training activities for an average of six years. All participants were actively involved in regular volleyball practice sessions conducted by the school extracurricular program. The inclusion criteria required participants to be physically healthy, actively participating in volleyball training activities, and willing to complete all testing procedures. Participants who experienced injuries or medical conditions affecting physical performance were excluded from the study. Before data collection, the researcher provided explanations regarding the objectives, procedures, and benefits of the research to all participants. The researcher also ensured that all participants completed the tests under similar environmental and physical conditions to maintain data consistency.

Instruments

Several instruments were used to measure the variables examined in this study. Underhand passing performance was measured using a standardized volleyball underhand passing skill test designed to evaluate passing accuracy and ball control. Arm muscle strength was measured using the chin-up test performed for 60 seconds to determine upper-body muscular strength and endurance. Leg muscle power was assessed using the vertical jump test to measure lower-body explosive power. Concentration ability was measured using the Concentration Grid Test, which evaluates the participants' cognitive focus and attention abilities during task performance. Before the testing process began, participants completed a warm-up session consisting of stretching and light physical exercises to reduce the risk of injury and improve testing readiness. Data collection was conducted on the school volleyball court under controlled conditions to ensure consistency during testing

procedures. The tests were administered sequentially according to the predetermined schedule established by the researcher. The researcher and assistants supervised all testing activities to ensure that participants followed the testing instructions correctly and consistently. The results obtained from each instrument were recorded systematically and prepared for statistical analysis.

Data Analysis

The data collected in this study were analyzed quantitatively using path analysis techniques to determine the direct and indirect effects among variables. Statistical analysis was conducted using Jamovi software version 2.6 to evaluate the relationships among arm muscle strength, leg muscle power, concentration, and underhand passing performance. Descriptive statistical analysis was first performed to determine the mean, standard deviation, minimum value, and maximum value for each variable. Before conducting path analysis, several assumption tests were performed to ensure that the data met the statistical requirements. The normality test was conducted using the Shapiro–Wilk test to determine whether the data were normally distributed. Linearity testing was also conducted to identify whether the relationships among variables followed a linear pattern. In addition, multicollinearity testing was performed using tolerance values and variance inflation factor values to examine correlations among independent variables. After all statistical assumptions were fulfilled, path analysis was conducted to determine the magnitude of the direct and indirect contributions among variables. The level of significance used in this study was 0.05. The results of the analysis were then interpreted to explain the structural relationships among physical and psychological factors influencing underhand passing performance among youth volleyball players.

Procedure

The research procedure was conducted systematically to ensure consistency and accuracy throughout the data collection process. Initially, the researcher obtained permission from the school and coordinated with the volleyball extracurricular coach regarding the research schedule and participant preparation. Participants were informed about the research objectives, testing procedures, and the importance of completing all tests according to the instructions provided. Before the tests began, participants completed a standardized warm-up session consisting of stretching and light physical activities to prepare their bodies for performance testing. The testing process started with the chin-up test to measure arm muscle strength, followed by the vertical jump test to assess leg muscle power. After completing the physical performance tests, participants performed the Concentration Grid Test to evaluate concentration ability. Finally, participants completed the volleyball underhand passing skill test on the volleyball court. All tests were conducted under similar environmental conditions to minimize external factors affecting participant performance. The researcher and assistants monitored participants throughout the testing sessions to ensure that all procedures were implemented consistently and accurately. After all data had been collected, the results were tabulated, analyzed statistically, and interpreted to answer the objectives of the study.

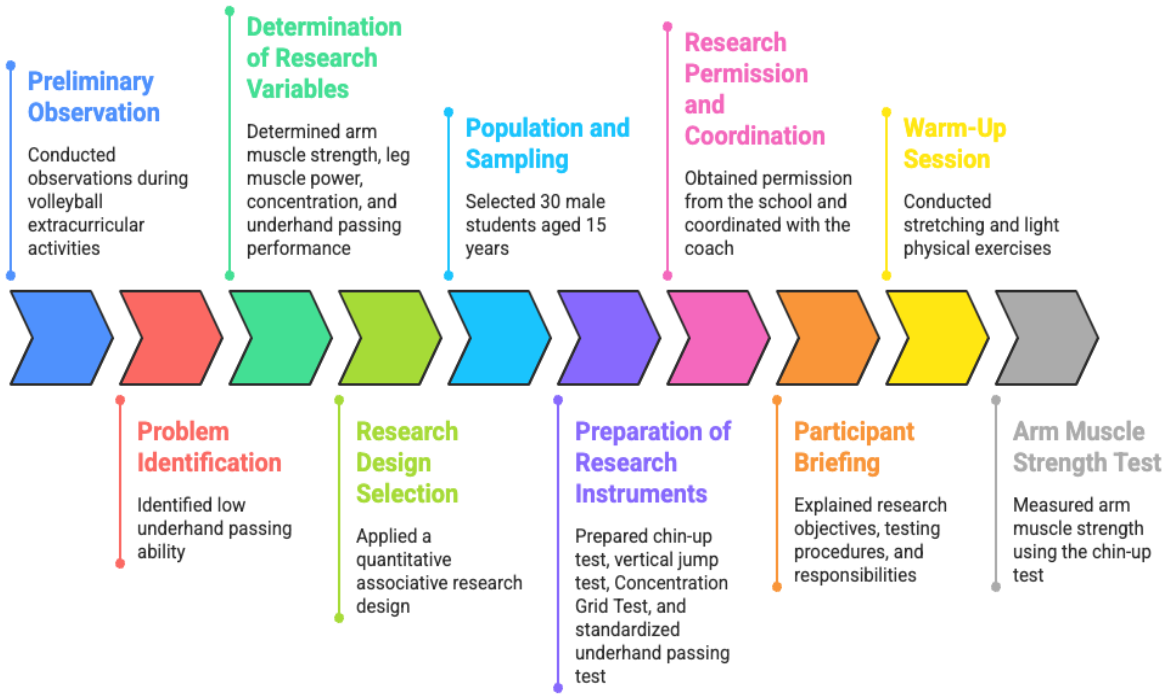

Figure 1. Research Method Flow

RESULTS AND DISCUSSION

Results

The data described in this section is the data obtained from testing each variable after conducting the research and statistically processing it. The data in this study includes four variables: arm muscle strength, leg muscle power, concentration, and volleyball underhand passing ability. The data description includes arm muscle strength/Pull-Up (X1), leg muscle power/Vertical Jump (X2), concentration (Y), and volleyball underhand passing ability (Z).

Tabel 1. Deskriptives

	PULL UP	*VERTICAL JUMP*	CONCENTRATION	*PASSING* DOWN
N	30	30	30	30
Missing	0	0	0	0
Mean	5.97	46.7	11.1	42.5
Median	5.50	48.0	12.0	45.0
Sum	179	1401	333	1276
Standard deviation	2.63	10.2	2.88	8.83
Minimum	2	30	5	24
Maximum	11	66	15	53

Descriptive statistical analysis showed the characteristics of the sample (N=30). The average value of arm muscle strength / Pull Up (X1) was 5.97 (SD=2.63), with a range of 2-11; leg muscle power / Vertical Jump (X2) was 46.7 (SD=10.02), with a range of 30-66; concentration (Y) was 11.1 (SD=2.88), with a range of 5-15; and volleyball underhand passing ability (Z) was 42.5 (SD=8.83), with a range of 24-53. The test performed included a normality test for each data variable. In the analysis requirements test, the first step was a normality test using the Shapiro-Wilk p-test to determine whether the collected data were normally distributed. The test criteria used were: if the probability > 0.05, Ho is accepted and the data are normally distributed; conversely, if the probability ≤ 0.05, Ho is rejected, as the data are not normally distributed

Tabel 2. Normality Test

Normality Tests		
	Statistic	**p**
Shapiro-Wilk	0.954	0.215
Kolmogorov-Smirnov	0.133	0.612
Anderson-Darling	0.421	0.304

Given that the Shapiro-Wilk P-Value is 0.215 > 0.05, Ho is accepted, and the data are normally distributed because the significance value is above 0.05. This study can be further analyzed.

1. Based on the results of the analysis of variance to test the linearity between arm muscle strength/Pull-Up (X1) and concentration, the Sig. value is 0.1533 > α = 0.05. It can be concluded that the relationship model between arm muscle strength/Pull-Up (X1) and concentration (Y) is linear.
2. Based on the results of the analysis of variance to test the linearity between leg muscle power/Vertical Jump (X2) and concentration, the Sig. value is 0.0395 > α = 0.05. It can be concluded that the relationship model between leg muscle power/Vertical Jump (X2) and concentration (Y) is linear.
3. Based on the results of the analysis of variance to test the linearity between arm muscle strength / Pull Up (X1) and volleyball underhand passing ability, the Sig. value is obtained = 0.3660 > α = 0.05, it can be concluded that the relationship model between arm muscle strength / Pull Up (X1) and volleyball underhand passing ability (Z) is linear.
4. Based on the results of the analysis of variance to test the linearity between leg muscle power / Vertical Jump (X2) and volleyball underhand passing ability, the Sig. value is obtained = 0.0887 > α = 0.05, it can be concluded that the relationship model between leg muscle power / Vertical Jump (X2) and volleyball underhand passing ability (Z) is linear.
5. Based on the results of the analysis of variance to test the linearity between concentration (Y) and volleyball underhand passing ability, the Sig. value is obtained. = 0.3798 > α = 0.05, it can be concluded that the relationship model between concentration (Y) and volleyball underhand passing ability (Z) is linear.

The multicollinearity test aims to determine whether there is a high correlation between the independent variables in a model. This means that if there is a high correlation between the independent variables, the relationship between the independent variables and the dependent variable will be disrupted. According to Ghozali (2011), "multicollinearity symptoms do not occur if the tolerance value is > 0.100 and the VIF value is < 10.00."

Tabel 3. Multicolinierity Test

Collinearity Statistics		
	VIF	**Tolerance**
PULL UP	1.84	0.545
VERTICAL JUMP	1.62	0.616
KONSENTRASI	2.37	0.422

Given that the VIF value for the variables included in the independent model is <10, it can be concluded that the data does not exhibit multicollinearity, or the multicollinearity test has met the criteria.

1. Path Coefficient of Vertical Jump (X2) on Concentration
   The p-value is 0.003 <α = 0.05, indicating that Vertical Jump (X2) has a direct positive effect on Concentration (Y). The beta coefficient is 0.395, which can be rounded to 0.40. The magnitude of the effect is (0.40*2)x100 = 16%.
2. Path Coefficient of Vertical Jump (X2) on Underpassing

The p-value is 0.018 <α = 0.05, indicating that Vertical Jump (X2) has a direct positive effect on Underpassing (Z). The beta coefficient is 0.235, which can be rounded to 0.24. The magnitude of the effect is = (0.24*2)x100 = 5%.

3. Path Coefficient of Concentration (Y) on Underpassing
   The p-value is 0.001 <α = 0.05, meaning that Concentration (Y) has a direct positive effect on Underpassing (Z). The beta coefficient is 0.424, which can be rounded to 0.42. The magnitude of the effect is = (0.42*2)x100 = 17.64%.
4. Path Coefficient of Pull-Up (XI) to Concentration (Y) on Underpassing
   The p-value is 0.021 <α = 0.05, meaning that Pull-Up (XI) to Concentration (Y) has an indirect positive effect on Underpassing (Z). The beta coefficient is 0.210, which can be rounded to 0.21. The magnitude of the effect is (0.17*2)x100 = 4.4%.
5. Coefficient of the Vertical Jump (X2) to Concentration (Y) Path on Underhand Passing
   The p-value is 0.009 <α = 0.05, meaning that the Vertical Jump (X2) to Concentration (Y) has a positive indirect effect on Underhand Passing (Z). The beta coefficient is 0.168, which can be rounded to 0.17. The magnitude of the effect is (0.17*2)x100 = 3%.
6. Path Coefficient of Pull-Up (XI) to Vertical Jump (X2) to Concentration (Y) on Underhand Passing
   Table 17 shows a p-value of 0.001 <α = 0.05, indicating that Pull-Up (XI), Vertical Jump (X2), and Concentration (Y) have a simultaneous effect, as evidenced by the R-square value of 0.831. This means that the remaining 83.1% is influenced by factors outside of this study.

Discussion

The findings of this study demonstrated that physical factors significantly influenced underhand passing performance among youth volleyball players. Arm muscle strength contributed 16% to underhand passing performance, indicating that upper-body strength plays an important role in volleyball technical execution. This finding confirms that arm muscle strength is essential for stabilizing ball control and directing the ball accurately during passing activities. In volleyball mechanics, the arms function as the primary contact surface responsible for absorbing and redirecting the force generated by the incoming ball. Athletes with greater arm muscle strength are generally able to maintain more stable passing movements and reduce technical errors during defensive situations. These results are consistent with previous studies reporting that upper-body muscular strength contributes positively to volleyball technical performance and movement efficiency among athletes (C. Chen et al., 2025; Curovic et al., 2024; Leeuw et al., 2022; Martin et al., 2024). Earlier investigations also found that athletes possessing stronger upper-body muscles demonstrated improved passing accuracy and ball control during volleyball gameplay. Research in volleyball biomechanics further explained that arm strength supports movement stabilization and enhances the consistency of technical execution during passing activities (Ismael, 2024; Ozawa et al., 2025). The findings of this study therefore strengthen previous evidence indicating that arm muscle strength is closely associated with volleyball passing performance among adolescent athletes. Consequently, volleyball training programs should emphasize upper-body strengthening exercises to improve underhand passing consistency and technical performance among youth volleyball players.

The present study also revealed that leg muscle power contributed 5.5% to underhand passing performance among participants. Although this contribution was lower than that of arm muscle strength, leg power remained an important determinant of technical volleyball performance. Explosive lower-body movement supports body balance, mobility, reaction speed, and movement preparation during ball reception. Athletes with greater leg muscle power are generally more capable of adjusting their body position rapidly before making contact with the ball. Strong lower-body muscles also assist athletes in maintaining stable posture during dynamic gameplay situations.

These findings are consistent with previous studies reporting that leg explosive power significantly contributes to volleyball movement efficiency and technical execution (Dao, 2025; Esposito et al., 2024; Lin et al., 2025; Mercado-Palomino et al., 2021; J. Wang et al., 2025). Earlier research found that athletes with superior vertical jump performance demonstrated better movement coordination and agility during volleyball matches. Studies focusing on youth athletes also showed that lower-body explosive power positively influences reaction speed and movement readiness during sports activities. Furthermore, biomechanical investigations indicated that lower-body power supports postural stability and movement efficiency during defensive volleyball actions. Therefore, despite its relatively smaller contribution compared to arm muscle strength, leg muscle power remains an essential physical component supporting underhand passing performance among youth volleyball players.

An important finding in this study was the substantial contribution of concentration to underhand passing performance, reaching 17.64%, which represented the highest individual contribution among all variables examined. This result indicates that psychological factors play a critical role in determining technical volleyball performance among adolescent athletes. Athletes with high concentration abilities are generally more capable of processing visual information rapidly and coordinating body movements accurately during gameplay situations. Concentration enables players to maintain focus on ball direction while minimizing distractions that may interfere with technical execution. Without adequate concentration, athletes may experience unstable passing control, inaccurate ball direction, and delayed movement responses during matches. These findings are consistent with previous studies reporting that concentration and attentional control significantly influence sports performance and technical consistency among volleyball athletes (de Arruda et al., 2024; Hanzlíková et al., 2025; Shieh et al., 2023; Trecroci et al., 2021; Valayi et al., 2024). Earlier research in sports psychology also demonstrated that athletes with strong concentration abilities showed better decision-making skills and reduced technical errors during competitive situations. Investigations involving adolescent athletes further revealed that concentration positively affects skill acquisition, motor coordination, and learning effectiveness during sports training activities. In addition, studies related to cognitive performance indicated that concentration supports reaction speed and movement synchronization during technical execution. Therefore, the present findings confirm that concentration is not only a psychological component but also a crucial determinant of underhand passing performance in volleyball.

The path analysis conducted in this study further demonstrated that concentration acted as an intervening variable mediating the relationship between physical factors and underhand passing performance. Arm muscle strength contributed an indirect effect of 4.4% through concentration, while leg muscle power contributed an indirect effect of 3% through the same mediating variable. These findings indicate that concentration functions as a psychological mechanism that optimizes the utilization of athletes' physical abilities during technical execution. Athletes who possess strong physical capacities may still demonstrate poor technical performance if they are unable to maintain concentration during gameplay. This result supports theoretical perspectives suggesting that sports performance is influenced by the interaction between physical readiness and cognitive control. Previous studies also reported that concentration contributes significantly to movement coordination, motor control, and technical decision-making during athletic performance (Lachowicz et al., 2024; Q. Li et al., 2026; Lucia et al., 2023; Piechota & Majorczyk, 2023). Research focusing on cognitive processes among athletes found that attentional control enhances movement accuracy and technical consistency during high-pressure situations. In addition, studies involving youth athletes demonstrated that concentration-based training improves learning adaptation and technical execution during sports activities. The present findings therefore strengthen previous evidence indicating that physical conditioning alone is insufficient to optimize volleyball performance without

adequate psychological preparation. Consequently, volleyball coaches should integrate concentration training with physical conditioning programs to maximize underhand passing performance among youth volleyball players.

Simultaneously, the results of this study demonstrated that arm muscle strength, leg muscle power, and concentration collectively exerted a very strong influence on underhand passing performance, with an R-square value of 0.831. This finding indicates that 83.1% of the variation in underhand passing performance among participants was explained by the integration of physical and psychological variables examined in this study. The remaining 16.9% may have been influenced by other factors not investigated in this research, such as eye-hand coordination, flexibility, technical experience, tactical understanding, and competitive exposure. These findings confirm that volleyball performance is a multidimensional phenomenon requiring the integration of physical fitness and psychological readiness. Previous studies generally investigated physical and psychological factors separately, whereas this study integrated both components within a single path analysis framework. Therefore, the present study provides a more comprehensive explanation regarding the structural relationships influencing underhand passing performance among youth volleyball athletes. The findings also support sports performance theories emphasizing that successful technical execution depends on the interaction between motor abilities and cognitive functions. From a practical perspective, the results suggest that volleyball training programs should not focus solely on physical conditioning but should also incorporate concentration-based exercises and psychological preparation strategies. Integrative training approaches may help athletes improve movement efficiency, technical consistency, and passing accuracy during gameplay situations. Therefore, this study contributes both theoretically and practically to the development of volleyball performance research and evidence-based athlete training programs.

Implications

The findings of this study provide important theoretical and practical implications for the development of volleyball performance training among youth athletes. Theoretically, this study strengthens the understanding that volleyball underhand passing performance is influenced not only by physical factors but also by psychological components, particularly concentration. The integration of arm muscle strength, leg power, and concentration within a path analysis model offers a more comprehensive explanation of the multidimensional nature of volleyball performance. This study also contributes to sports science literature by demonstrating the mediating role of concentration in optimizing the relationship between physical abilities and technical execution. From a practical perspective, the results suggest that volleyball training programs should adopt a more integrative approach combining physical conditioning and concentration-based exercises. Coaches are encouraged to implement upper-body strengthening and lower-body explosive power training to improve passing consistency and movement stability during gameplay. In addition, concentration training activities such as focus drills, reaction exercises, and attention-control strategies should be incorporated into regular volleyball practice sessions. Physical education teachers may also use these findings to design more effective volleyball learning methods for adolescent students in school environments. The high contribution of concentration to underhand passing performance further indicates that psychological readiness is an essential factor supporting technical skill development among youth athletes. Furthermore, the findings may serve as a reference for athlete performance evaluation and talent development programs in volleyball coaching settings. The application of path analysis in this study also provides methodological implications for future sports performance research involving multidimensional variables. Therefore, this study offers valuable contributions for coaches, educators, researchers, and sports practitioners in developing evidence-based volleyball training and athlete development programs.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting the findings. First, the sample size used in this research was relatively small, consisting of only 30 male youth volleyball players from a single school extracurricular program, which may limit the generalizability of the findings to broader volleyball populations. Second, the participants were limited to adolescent male athletes aged 15 years, so the results may not fully represent female athletes or athletes from different age groups and competitive levels. Third, this study focused only on three independent variables, namely arm muscle strength, leg power, and concentration, while other factors potentially influencing underhand passing performance were not investigated. Variables such as eye-hand coordination, agility, flexibility, reaction time, technical experience, motivation, and tactical understanding may also contribute significantly to volleyball technical performance. In addition, the cross-sectional design applied in this study only measured participant performance at one point in time and did not evaluate long-term training effects or performance development. The use of school-based extracurricular athletes may also limit the applicability of the findings to elite or professional volleyball players with different training intensities and competitive experiences. Furthermore, environmental and psychological conditions during testing sessions may have influenced participant performance despite efforts to maintain consistent testing procedures. Future studies are therefore recommended to involve larger and more diverse samples from different schools, regions, genders, and competitive categories to improve the external validity of the findings. Further research should also incorporate additional physical, technical, tactical, and psychological variables to provide a more comprehensive explanation of volleyball underhand passing performance. Longitudinal or experimental research designs are also recommended to evaluate the effectiveness of integrated physical and concentration-based training programs over time. In addition, future researchers may apply more advanced analytical approaches such as structural equation modeling to examine more complex relationships among performance variables. Therefore, further investigation is necessary to strengthen the understanding of multidimensional factors influencing volleyball technical performance among youth athletes.

CONCLUSION

This study concludes that arm muscle strength, leg muscle power, and concentration significantly influence underhand passing performance among youth volleyball players. The findings demonstrated that arm muscle strength contributed substantially to passing performance by supporting ball control, movement stabilization, and passing accuracy during gameplay situations. Leg muscle power also played an important role in improving movement readiness, body balance, and explosive positioning during underhand passing execution. Among all variables examined in this study, concentration showed the highest individual contribution to underhand passing performance, indicating that psychological readiness is a crucial determinant of volleyball technical ability. The results further revealed that concentration functioned as an intervening variable mediating the relationship between physical factors and underhand passing performance. This finding indicates that physical abilities alone are insufficient to optimize volleyball technical performance without adequate cognitive focus and attentional control. Simultaneously, arm muscle strength, leg muscle power, and concentration collectively explained a very large proportion of the variation in underhand passing performance among participants. These findings confirm that volleyball performance is multidimensional and influenced by the interaction between physical conditioning and psychological readiness. The application of path analysis in this study also provided a more comprehensive explanation regarding the direct and indirect relationships among variables influencing technical volleyball performance. From a practical perspective, the findings suggest that

volleyball training programs should integrate physical conditioning exercises with concentration-based training strategies to improve athlete performance more effectively. Coaches and physical education teachers are therefore encouraged to design training programs that simultaneously develop upper-body strength, lower-body explosive power, and psychological focus among youth volleyball players. Overall, this study contributes both theoretically and practically to the development of sports science research and evidence-based volleyball athlete training programs.

AUTHOR CONTRIBUTIONS STATEMENT

Wahid Adi Kusuma conceptualized the study, developed the research framework, and supervised the overall implementation of the research project. Umar contributed to the research design, coordinated participant recruitment, and conducted data collection during volleyball extracurricular activities at SMPN 5 OKU. Wilda Welis was responsible for administering the physical performance tests, including the arm muscle strength and leg muscle power assessments, and ensuring testing consistency throughout the study. Yendrizal contributed to the development of the research instruments and assisted in validating the testing procedures used in this research. Ardo Okilanda performed the statistical analysis using the path analysis approach and interpreted the quantitative findings obtained from the study. Wahid Adi Kusuma and Umar collaboratively drafted the manuscript and prepared the introduction, literature review, and methodology sections. Wilda Welis contributed to the preparation of the results and discussion sections by comparing the findings with relevant previous studies. Yendrizal critically reviewed the manuscript and provided important revisions related to sports science concepts and volleyball performance analysis. Ardo Okilanda assisted in refining the interpretation of the data and improving the academic quality of the manuscript. All authors participated in discussing the research findings and contributed to the development of the conclusion, implications, and recommendations for future research. All authors reviewed the final version of the manuscript and approved it for publication. All authors agree to be accountable for the integrity, accuracy, and originality of the research presented in this study.

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