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Students' underhand passing achievement in volleyball: roles of strength, coordination, and concentration

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ABSTRACT

This study aimed to examine the direct and indirect effects of arm muscle strength, hand–eye coordination, and concentration on underhand passing performance in junior volleyball athletes. A quantitative approach with path analysis was applied involving 30 male athletes from a school volleyball team using total sampling. Arm muscle strength was measured using the push-up test, hand–eye coordination using the wall toss test, concentration using the concentration grid test, and passing performance using a standardized underhand passing test. The results showed that arm muscle strength (β = 0.548), hand–eye coordination (β = 0.376), and concentration (β = 0.177) had significant direct effects on passing performance ($p < 0.05$). Indirect effects through concentration were also identified, although relatively small. The model explained 90.4% of the variance in passing performance. These findings indicate that underhand passing is influenced by physical, motor, and cognitive factors, highlighting the importance of integrated training approaches in volleyball development.

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Introduction

Volleyball is a dynamic team sport that requires the integration of technical skills, physical conditioning, and cognitive abilities to achieve optimal performance (Aditya & Darmanto, 2025; Lestaripriyatmoko & Romadhoni, 2025). Among the fundamental techniques, underhand passing (forearm pass) is a core skill that serves as the first control in both defensive and offensive situations. The quality of this skill directly influences subsequent actions such as setting and attacking, making it a critical determinant of team performance, particularly among junior athletes in the developmental stage (Destriana et al., 2024; Esa et al., 2025).

Underhand passing is not merely a basic technical action but involves coordinated biomechanical processes, including body positioning, arm alignment, and force control. Accurate passing requires athletes to stabilize their posture, absorb incoming ball force, and redirect it with precision. Therefore,

the success of this skill is influenced by multiple components, including physical, motor, and cognitive factors that interact simultaneously during gameplay.

In sports science, performance in volleyball has been widely associated with physical attributes such as strength, agility, coordination, and endurance (M. Afifah et al., 2025; Kaimbu et al., 2025). Specifically, upper-body strength plays a key role in controlling ball direction and stability during passing, while coordination enables the synchronization of visual input and motor execution. However, the relative contribution of these components in specific skills such as underhand passing remains insufficiently explored.

Previous studies have shown that arm muscle strength contributes significantly to volleyball performance (Rusli & Aprillah, 2025; Wibowo, 2025). Stronger arm muscles allow athletes to generate and regulate force during ball contact, resulting in improved passing accuracy and consistency (I. Afifah et al., 2025; Hutomono et al., 2023). Despite these findings, most studies focus on general performance outcomes without detailing how strength specifically contributes to underhand passing mechanics.

Hand–eye coordination is another essential factor in volleyball skill execution. It enables athletes to track ball trajectory, anticipate movement, and adjust body positioning accordingly. Empirical evidence suggests that better coordination is associated with improved passing performance due to enhanced timing and precision (Chen, 2025; Singh et al., 2025; Xie & Zhang, 2025). Nevertheless, previous research often treats coordination as an isolated variable without examining its interaction with other performance determinants. In addition to physical and motor aspects, cognitive factors such as concentration are increasingly recognized as important contributors to sports performance. Volleyball requires sustained attention, rapid decision-making, and the ability to maintain focus under dynamic conditions. Athletes with higher concentration levels are more likely to perform consistently and reduce technical errors. However, compared to physical variables, the role of concentration in fundamental skills such as underhand passing remains relatively underexplored (Dingirdan Gultekinler & Bayrakcı Tunay, 2025; Liu, 2025; Liu, Salem, et al., 2025).

Although numerous studies have investigated the relationships between strength, coordination, and volleyball skills, most of them employ correlational or experimental designs that focus primarily on direct effects (De Blasiis et al., 2025; Hassan, 2025; Jinglong, 2025; Wang et al., 2025). These approaches do not adequately explain the underlying mechanisms or potential indirect relationships among variables, particularly the role of cognitive factors as mediators.

Furthermore, prior research tends to examine physical and motor variables separately, without integrating cognitive components such as concentration into a comprehensive model. This limitation creates a gap in understanding how physical readiness and cognitive control interact to influence performance. A more holistic approach is needed to capture the multidimensional nature of skill execution in volleyball.

Therefore, this study proposes an integrated analytical model that examines both direct and indirect relationships among arm muscle strength, hand–eye coordination, and concentration in relation to underhand passing ability. By employing path analysis, this research aims to explore not only the individual contributions of each variable but also the mediating role of concentration in linking physical and motor factors to performance (Anugrah et al., 2025; Hasmuddin et al., 2026).

Based on this framework, the purpose of this study is to determine the direct and indirect effects of arm muscle strength, hand–eye coordination, and concentration on the underhand passing ability of junior volleyball athletes. It is expected that the findings will provide both theoretical and practical contributions by offering a more comprehensive understanding of performance determinants and supporting the development of integrated training strategies in volleyball coaching (Ningsih et al., 2025; Panuntun et al., 2026).

Method

This study employed a quantitative approach using a path analysis design to examine the direct and indirect relationships among variables. The research was conducted in January 2026 at the volleyball court of SMP Negeri 1 Banuhampu. The participants consisted of 30 male junior volleyball athletes aged

13–15 years who were actively involved in school training programs. A total sampling technique was applied due to the relatively small population, ensuring that all athletes were included in the study.

The variables in this study included arm muscle strength (X1), hand–eye coordination (X2), and concentration (X3) as independent variables, while underhand passing performance (Y) served as the dependent variable. Concentration (X3) was also treated as an intervening variable to examine indirect effects. Underhand passing performance was operationally defined as the ability to accurately control and direct the ball using forearm passing techniques, measured through a standardized underhand passing test based on successful target-directed passes.

Arm muscle strength was measured using a standardized 1-minute push-up test, with the total number of correct repetitions recorded as the score. Hand–eye coordination was assessed using the Hand Wall Toss Test, where participants threw and caught a ball against a wall for 30 seconds, and the number of successful catches was recorded. Concentration was measured using the Concentration Grid Test, which required participants to sequentially identify numbers within a limited time, and the total correct responses were used as the score. All instruments used in this study have been widely applied in sports science research and demonstrate acceptable levels of validity and reliability in measuring their respective constructs.

Data collection was conducted under controlled and standardized conditions to minimize bias. All participants were tested at the same time of day to reduce fatigue effects, and standardized instructions were provided prior to each test. Participants were given sufficient rest between tests to avoid performance interference. A preliminary trial session was also conducted to familiarize participants with the testing procedures.

Descriptive statistical analysis was first performed to determine the mean, standard deviation, minimum, and maximum values of each variable. Prior to hypothesis testing, several assumption tests were conducted, including normality (Kolmogorov–Smirnov test), homogeneity of variance (Levene's test), linearity, and multicollinearity (Variance Inflation Factor and tolerance values). These tests ensured that the data met the requirements for parametric and path analysis.

Hypothesis testing was conducted using path analysis to estimate both direct and indirect relationships among variables. The significance of indirect effects was further examined using a mediation test approach. Statistical significance was set at an alpha level of 0.05. All analyses were performed using SPSS software, and the results were interpreted based on path coefficients, significance values, and the overall model fit to provide a comprehensive understanding of the relationships among variables.

Results and Discussions

This study examined the direct and indirect effects of arm muscle strength, hand–eye coordination, and concentration on underhand passing ability in male volleyball players of SMP Negeri 1 Banuhampu. A total of 30 athletes participated in the study. The results are presented in four main parts: descriptive statistics, categorical distribution of the variables, testing of statistical assumptions, and path analysis for hypothesis testing.

Table 1. Descriptive Statistics of the Study Variables

Variable	Mean	SD	Minimum	Maximum
Arm muscle strength (X1)	26.57	7.33	11	40
Hand–eye coordination (X2)	16.33	5.25	5	23
Concentration (X3)	9.67	2.78	4	15
Underhand passing ability (Y)	24.87	8.85	10	40

Table 1 shows that underhand passing ability had a mean score of 24.87 with a standard deviation of 8.85, indicating a moderate spread of scores among participants. Arm muscle strength had a mean of 26.57, hand–eye coordination had a mean of 16.33, and concentration had a mean of 9.67. Overall, the descriptive statistics indicate that the participants demonstrated varied performance across all variables, with the widest score dispersion found in underhand passing ability.

Table 2. Frequency Distribution and Category Summary of the Variables

Variable	Dominant Score Interval	Frequency	Percentage	Dominant Category
Underhand passing ability (Y)	>25	16	53.3%	Very good
Arm muscle strength (X1)	20–28	13	43.3%	Moderate
Hand–eye coordination (X2)	16–21	12	40.0%	Good
Concentration (X3)	11–15*	23	57.5%	Moderate

*Based on the original research table provided.

As presented in Table 2, the majority of athletes were classified in the very good category for underhand passing ability, with 53.3% of participants scoring above 25. For arm muscle strength, most athletes were in the moderate category (43.3%), while hand–eye coordination was predominantly in the good category (40.0%). Concentration was mostly classified as moderate (57.5%). These findings suggest that although the players generally demonstrated strong underhand passing performance, their supporting physical and cognitive characteristics varied across categories.

Table 3. Assumption Testing Results

Test	Variables	Statistic / Sig.	Criterion	Conclusion
Normality (Kolmogorov–Smirnov)	X1	0.200	p > 0.05	Normal
	X2	0.200	p > 0.05	Normal
	X3	0.146	p > 0.05	Normal
	Y	0.200	p > 0.05	Normal
Homogeneity (Levene's test)	Y over X1	0.089	p > 0.05	Homogeneous
	Y over X2	0.096	p > 0.05	Homogeneous
	Y over X3	0.460	p > 0.05	Homogeneous
Linearity	Y and X1	0.287	p > 0.05	Linear
	Y and X2	0.978	p > 0.05	Linear
	Y and X3	0.436	p > 0.05	Linear
	X3 and X1	0.386	p > 0.05	Linear
	X3 and X2	0.578	p > 0.05	Linear
	X2 and X1	0.690	p > 0.05	Linear

Table 3 indicates that all variables met the assumptions required for path analysis. The normality test showed that all variables had significance values greater than 0.05, indicating normal data distribution. The homogeneity test also demonstrated that the data were homogeneous, as all significance values exceeded 0.05. In addition, the linearity test confirmed that the relationships among variables were linear. Therefore, the dataset was appropriate for further analysis using path analysis.

Table 4 demonstrates that arm muscle strength, hand–eye coordination, and concentration all had significant direct effects on underhand passing ability. Among these predictors, arm muscle strength showed the strongest direct effect ($\beta = 0.548$), followed by hand–eye coordination ($\beta = 0.376$) and concentration ($\beta = 0.177$). In addition, arm muscle strength and hand–eye coordination also influenced underhand passing indirectly through concentration. The total effect of arm muscle strength on underhand passing was 0.667, with a contribution of 44.49%, while the total effect of hand–eye coordination was 0.404, with a contribution of 16.32%. Simultaneously, the three predictors explained 90.4% of the variance in underhand passing ability, indicating a strong combined contribution to performance.

Table 4. Path Analysis Results for Direct, Indirect, and Simultaneous Effects

Path / Effect	Beta / Effect Size	Sig.	Interpretation
X1 → X2	0.680	0.000	Significant
X1 → X3	0.675	0.000	Significant
X2 → X3	0.157	0.040	Significant
X1 → Y	0.548	0.000	Significant direct effect
X2 → Y	0.376	0.000	Significant direct effect
X3 → Y	0.177	0.020	Significant direct effect
Indirect effect: X1 → X3 → Y	0.119	—	Positive indirect effect
Total effect: X1 on Y	0.667	—	Direct + indirect
Contribution of total effect: X1 on Y	44.49%	—	Substantial effect
Indirect effect: X2 → X3 → Y	0.028	—	Positive indirect effect
Total effect: X2 on Y	0.404	—	Direct + indirect
Contribution of total effect: X2 on Y	16.32%	—	Moderate effect
Simultaneous effect of X1, X2, X3 on Y (R^2)	0.904	0.000	Significant simultaneous effect

The present study provides empirical evidence that arm muscle strength, hand–eye coordination, and concentration contribute to underhand passing performance in junior volleyball athletes (Mutawa et al., 2025; Pan et al., 2025). However, these findings should be interpreted cautiously given the relatively small sample size and the specific context of school-level athletes. The high explanatory power of the model suggests a strong relationship among variables, yet it may also indicate the need for further validation in broader populations. These results support the view that underhand passing is a multidimensional skill involving both physical and cognitive components (Liu, Huang, et al., 2025; Zenke & Laborieux, 2025).

The significant effect of arm muscle strength on underhand passing ability highlights the importance of muscular capacity in controlling ball movement. From a biomechanical perspective, stronger upper-body muscles allow athletes to better absorb and redirect incoming ball force while maintaining body stability. This contributes to improved accuracy and consistency in passing. Nevertheless, the dominance of strength in this model should be interpreted within the context of the testing conditions, as actual game situations may involve additional factors such as pressure and tactical demands (Lima et al., 2025; Zhang et al., 2025).

Hand–eye coordination also demonstrated a substantial contribution to passing performance, emphasizing the role of perceptual-motor integration. The ability to synchronize visual input with motor responses enables athletes to adjust positioning and timing more effectively during ball contact. This finding aligns with previous research suggesting that coordination is essential for precise execution of volleyball skills (Kim et al., 2025; Leung & Shi, 2025; Ryan et al., 2025). However, coordination in this study was measured in a general form, and future studies should consider more sport-specific coordination assessments.

The role of concentration as a significant predictor reinforces the importance of cognitive processes in volleyball performance (Marion et al., 2025; Pawlik et al., 2025). Although its direct effect was smaller compared to physical variables, concentration contributes to maintaining focus, reducing technical errors, and supporting decision-making during gameplay. It is important to note that concentration is a multidimensional construct, including aspects such as sustained attention and selective attention, which were not differentiated in this study (Maselli et al., 2025; Verdoes et al., 2025).

This study also found that concentration mediates the relationship between physical and motor variables and passing performance. While the indirect effects were relatively small, they suggest that physical readiness may enhance performance partly through improved attentional control. Nevertheless, the mediating role identified in this study should be interpreted with caution, as the statistical testing of mediation effects requires further validation using more robust methods in future research (Figueroa Poblete et al., 2025; Ghaffar et al., 2025).

The high coefficient of determination ($R^2 = 0.904$) indicates that the combination of arm muscle strength, hand–eye coordination, and concentration explains a large proportion of variance in passing performance. However, this value should be critically considered, as it may reflect model limitations or overlapping contributions among variables. Other factors such as technical proficiency, playing experience, and tactical understanding were not included in the model but are likely to influence performance outcomes (Sahabuddin et al., 2021; Setiawan & Makorohim, 2024).

From a practical perspective, these findings suggest that volleyball training programs should adopt a more integrated approach by combining physical conditioning, coordination exercises, and cognitive training. However, training recommendations should be implemented carefully, considering individual differences among athletes and the developmental stage of junior players. Future research is recommended to include additional variables, apply longitudinal designs, and use larger sample sizes to strengthen the generalizability and theoretical contribution of these findings (Putri et al., 2025; Rifqi et al., 2025).

Conclusions

This study concludes that arm muscle strength, hand–eye coordination, and concentration significantly contribute to the underhand passing ability of junior volleyball athletes, both individually and simultaneously. Among these variables, arm muscle strength showed the strongest influence, followed by hand–eye coordination and concentration. In addition, concentration plays an important mediating role in strengthening the relationship between physical and motor abilities and passing performance. These findings indicate that improving underhand passing ability requires an integrated training approach that combines physical conditioning, coordination development, and cognitive focus enhancement to optimize students' volleyball performance achievement.

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