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The Contribution of the Physical Fitness Component to the Accuracy of Volleyball Smash in Physical Education Students of Pamulang University

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Abstract

The accuracy of smash in volleyball is influenced by various components of physical fitness, but the specific contribution of each component to physical education students has not been widely studied. This study aims to identify the contribution of leg muscle explosiveness, eye-hand coordination, and agility to the accuracy of volleyball smash. The research uses a correlational quantitative approach involving forty students of the Physical Education Study Program, Pamulang University who were selected through purposive sampling. Data collection was carried out through a vertical jump test, a ball throw to a wall test, an Illinois agility test, and a validated smash accuracy test. The data was analyzed using simple regression analysis and multiple regression with a significance level of five percent. The results showed that the explosiveness of the leg muscles contributed 55.1%, eye-hand coordination 66.6%, and agility 38.8% to the accuracy of the smash. Simultaneously, all three components contribute 77.1% to the accuracy of volleyball smash. Hand-eye coordination proved to be the most dominant predictor. These findings provide practical implications for the design of exercise programs that focus on developing physical fitness components holistically to optimize the smash abilities of physical education students.

Keywords: *leg muscle explosiveness, eye-hand coordination, agility.*

INTRODUCTION

Volleyball is a team sport characterized by dynamic, high-intensity movements requiring complex multi-limb coordination. Within higher education, particularly in Physical Education study programs, mastering fundamental volleyball technical skills is an essential competency for prospective sports educators. Among all technical elements, the *smash* stands as the most decisive offensive technique in modern volleyball, serving as the primary mechanism for

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scoring points and neutralizing opponent defenses. Successful execution of the *smash* is not solely dependent on technical mastery but is substantially influenced by the athlete's underlying physical fitness condition (Evasari et al., 2023).

Physical fitness is a multidimensional construct encompassing components such as muscle strength, cardiovascular endurance, agility, speed, balance, coordination, muscular explosiveness, flexibility, and precision. Each component contributes distinctively to sport-specific movement execution, and in the biomechanical context of volleyball *smash*, their integration is critical. The *smash* movement involves a complex kinetic chain spanning the approach phase, take-off, aerial phase, arm swing, ball contact, and landing. Each phase demands specific physical qualities: the approach requires speed and acceleration, the take-off demands maximum leg muscle explosiveness to achieve optimal jump height, the contact phase requires precise eye-hand coordination to synchronize palm timing with ball trajectory, and repositioning between plays requires superior agility to adjust body position rapidly following varied pass trajectories (Eriantara et al., 2024; Hakim et al., 2024).

The selection of leg muscle explosiveness, eye-hand coordination, and agility as the focal variables in this study is grounded in biomechanical and neuromuscular theoretical frameworks. Leg muscle explosiveness directly determines the vertical height achieved during the take-off phase, which establishes the angular advantage for ball placement a mechanism empirically linked to *smash* accuracy (Hakim et al., 2024). Eye-hand coordination reflects the integration of visuomotor neural pathways that govern the temporal precision of ball contact, representing the dominant neurocognitive mechanism underlying targeting accuracy (Eriantara et al., 2024). Agility, as a multidimensional physical attribute, supports dynamic postural adjustment and rapid directional change in response to unpredictable pass trajectories (Karim et al., 2025). Other fitness components such as cardiovascular endurance, static balance, and flexibility while relevant to general volleyball performance operate as distal rather than proximal determinants of *smash* accuracy, and their exclusion was guided by biomechanical prioritization models consistent with prior correlational research in attack technique studies.

Field observations at Pamulang University reveal considerable variability in *smash* accuracy among Physical Education students despite equivalent instructional exposure. Some students demonstrate forceful but imprecise smashes, while others exhibit accurate but insufficiently powerful attacks. This disparity suggests that differential physical fitness profiles, rather than instructional factors alone, may account for individual variation in *smash* performance. Identifying which fitness components exert the greatest influence enables evidence-based prioritization in training design, a principle supported by Karim et al. (2025), who demonstrated that component-targeted training yields significantly greater performance gains than general fitness programs.

Existing literature has examined physical fitness contributions to volleyball *smash* performance predominantly in club athletes and secondary school populations, leaving a substantive empirical gap regarding university-level Physical Education students in Indonesia a population theoretically distinct due to their dual role as learners and future sports educators (Ashari et al., 2025). The novelty of this study is threefold. First, it simultaneously examines three biomechanically proximal fitness predictors within a unified multiple regression framework, producing a more comprehensive predictive model than single-variable correlational studies. Second, it applies both partial and simultaneous regression analysis to quantify the independent and synergistic contributions of each variable, enabling hierarchical interpretation of predictor dominance. Third, it targets a theoretically distinctive population Physical Education undergraduates at Pamulang University whose fitness-skill relationship has not been empirically modeled, and whose professional formation makes such evidence directly applicable to pedagogical curriculum design.

This study aims to determine the partial and simultaneous contribution of leg muscle explosiveness, eye-hand coordination, and agility to the accuracy of volleyball *smash* among Physical Education students of Pamulang University. Findings are expected to provide empirical foundations for evidence-based exercise program design, and to serve as a practical reference for lecturers in prioritizing fitness development within volleyball course curricula.

METHODS

Research Design

This study employed a quantitative approach with a correlational design, selected because it enables the identification of the magnitude and direction of relationships between variables without experimental manipulation, thereby allowing broader generalization of the observed patterns (Qudsi et al., 2021).

Participants

Participants consisted of 40 students from the Physical Education Study Program, Pamulang University. The sample size was determined using the Slovin formula applied to a population of 120 active students enrolled in volleyball courses, yielding a minimum required sample of 38 participants, which was rounded up to 40 to enhance statistical stability. Purposive sampling was applied with the following inclusion criteria: active enrollment in the fifth to seventh semester, absence of musculoskeletal injury in the preceding three months, and a minimum of one year of volleyball playing experience. These criteria ensured that all participants possessed the physiological and technical prerequisites relevant to the research variables (Insanistyo et al., 2023).

Instruments and Research Procedures

Data collection was conducted across four structured sessions. Leg muscle explosiveness was measured using the vertical jump test with a digital jump meter, recording the highest value from three maximal attempts, an instrument with established concurrent validity in volleyball contexts (Setiawan & Mukarohim, 2024). Eye-hand coordination was assessed through a tennis ball wall-throw-and-catch test at three meters for 30 seconds. Agility was measured using the Illinois Agility Run Test, recording the best time from three trials, a widely validated instrument for team sport populations (Destriana et al., 2024). Smash accuracy was evaluated using a validated nine-zone target test over ten attempts, confirmed through expert content validation and test-retest reliability of $r = 0.87$ (Nugraha et al., 2025).

Data Analysis

Data were analyzed using descriptive statistics, followed by prerequisite tests including the Kolmogorov-Smirnov normality test and linearity test.

Hypothesis testing employed simple and multiple regression analysis at a significance level of 5% to determine both partial and simultaneous contributions of each fitness component to smash accuracy (Oktadinata & Prabowo, 2025).

RESULTS

This study involved 40 Physical Education students of Pamulang University who met the established inclusion criteria. Data were collected over four weeks across four measurement sessions, covering three independent variables leg muscle explosiveness, eye-hand coordination, and agility alongside volleyball smash accuracy as the dependent variable. All data subsequently underwent prerequisite statistical testing prior to hypothesis testing.

Descriptive Statistics

Leg muscle explosiveness measured via the vertical jump test yielded a mean of 54.3 cm (SD = 6.2), with scores ranging from 42 cm to 65 cm. Distribution by category showed 8 students (20%) in the very good category (60–65 cm), 15 students (37.5%) in the good category (55–59 cm), 12 students (30%) in the moderate category (48–54 cm), and 5 students (12.5%) in the poor category (40–47 cm). Eye-hand coordination assessed through the wall throw-and-catch test produced a mean of 36.5 repetitions (SD = 5.8), ranging from 24 to 50 repetitions, with 7 students (17.5%) in the very good category, 13 students (32.5%) in the good category, 14 students (35%) in the moderate category, and 6 students (15%) in the poor category. Agility measured by the Illinois Agility Run Test yielded a mean completion time of 16.6 seconds (SD = 1.1), ranging from 15.2 to 18.4 seconds, with 9 students (22.5%) classified as very good, 16 students (40%) good, 11 students (27.5%) moderate, and 4 students (10%) poor. Smash accuracy scores ranged from 46 to 89, with a mean of 65.2 (SD = 9.4), where 6 students (15%) were in the very good category, 17 students (42.5%) good, 13 students (32.5%) moderate, and 4 students (10%) poor. The complete descriptive statistics are presented in Table 1.

Table 1. Descriptive Statistics of Research Variables

Variable	N	Min	Max	Mean	SD
Leg Muscle Explosiveness (cm)	40	42	65	54.3	6.2
Eye-Hand Coordination (reps)	40	24	50	36.5	5.8

Variable	N	Min	Max	Mean	SD
Agility (seconds)	40	15.2	18.4	16.6	1.1
Smash Accuracy (score)	40	46	89	65.2	9.4

Table 1 shows that all four variables demonstrated adequate variability across the 40 participants, indicating a sufficiently diverse sample for regression analysis.

Prerequisite Tests

Prior to hypothesis testing, normality and linearity assumptions were verified. The Kolmogorov-Smirnov normality test produced significance values of 0.087 for leg muscle explosiveness, 0.112 for eye-hand coordination, 0.094 for agility, and 0.106 for smash accuracy all exceeding 0.05, confirming that all variables were normally distributed. Results are presented in Table 2.

Table 2. Normality Test Results (Kolmogorov-Smirnov)

Variable	Statistic	Sig.	Conclusion
Leg Muscle Explosiveness	0.118	0.087	Normal
Eye-Hand Coordination	0.102	0.112	Normal
Agility	0.115	0.094	Normal
Smash Accuracy	0.104	0.106	Normal

The linearity test confirmed linear relationships between each predictor and smash accuracy: leg muscle explosiveness ($p = 0.000$), eye-hand coordination ($p = 0.000$), and agility ($p = 0.001$), all below 0.05, qualifying all variables for regression analysis. The multicollinearity test revealed Variance Inflation Factor (VIF) values of 1.456 for leg muscle explosiveness, 1.532 for eye-hand coordination, and 1.387 for agility all below the threshold of 10. Tolerance values were 0.687, 0.653, and 0.721 respectively, all exceeding 0.1. These results confirm the absence of multicollinearity among the independent variables. Full results are displayed in Table 3.

Table 3. Multicollinearity Test Results

Variable	Tolerance	VIF	Conclusion
Leg Muscle Explosiveness	0.687	1.456	No multicollinearity
Eye-Hand Coordination	0.653	1.532	No multicollinearity
Agility	0.721	1.387	No multicollinearity

Hypothesis Testing Simple Regression Analysis

Three simple regression analyses were conducted to test the partial contribution of each fitness component to smash accuracy. Leg muscle explosiveness yielded r = 0.742, r^2 = 0.551 (55.1%), p = 0.000. Eye-hand coordination yielded r = 0.816, r^2 = 0.666 (66.6%), p = 0.000 — the highest partial contribution among the three variables. Agility yielded r = 0.623, r^2 = 0.388 (38.8%), p = 0.000. All three variables produced statistically significant results at the 5% significance level. The complete results of the simple regression analysis are summarized in Table 4.

Table 4. Simple Regression Analysis Results

Independent Variable	r	r^2	Contribution (%)	Sig.
Leg Muscle Explosiveness	0.742	0.551	55.1%	0.000
Eye-Hand Coordination	0.816	0.666	66.6%	0.000
Agility	0.623	0.388	38.8%	0.000

Table 4 demonstrates that eye-hand coordination produced the largest coefficient of determination, followed by leg muscle explosiveness, and agility as the smallest partial contributor.

Hypothesis Testing Multiple Regression Analysis

Multiple regression analysis examining the simultaneous contribution of all three fitness components to smash accuracy yielded R = 0.878, R^2 = 0.771 (77.1%), adjusted R^2 = 0.752, F = 34.8, p = 0.000. These results indicate that the three variables collectively and significantly predict smash accuracy, with 22.9% of variance attributed to factors outside the model. The multiple regression equation derived from the analysis is:

$$\mathbf{Y = 12.456 + 0.634X_1 + 0.812X_2 - 1.234X_3}$$

Where Y = smash accuracy, X_1 = leg muscle explosiveness, X_2 = eye-hand coordination, and X_3 = agility (in seconds, where lower values indicate better performance). Individual regression coefficients for leg muscle explosiveness (B = 0.634, t = 5.678, p = 0.000), eye-hand coordination (B = 0.812, t = 6.892, p = 0.000),

and agility (B = −1.234, t = −4.123, p = 0.000) were all statistically significant. These results are presented in Table 5 and Table 6 below.

Table 5. Multiple Regression Analysis Results

Model	R	R^2	Adjusted R^2	F	Sig.
Multiple Regression	0.878	0.771	0.752	34.8	0.000

Table 6. Multiple Regression Equation Coefficients

Variable	B	t	Sig.
Constant	12.456	2.345	0.024
Leg Muscle Explosiveness (X_1)	0.634	5.678	0.000
Eye-Hand Coordination (X_2)	0.812	6.892	0.000
Agility (X_3)	−1.234	−4.123	0.000

To provide a clearer visual representation of the contribution of each physical fitness component to smash accuracy both partially and simultaneously a bar diagram is presented below.

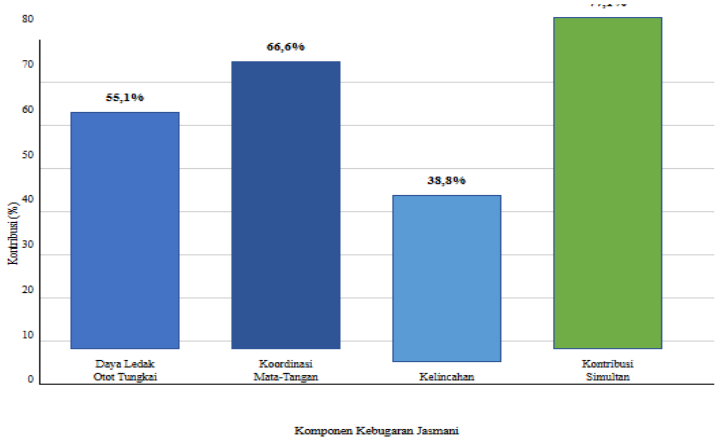

Figure 1. Bar Diagram of Physical Fitness Component Contributions to Volleyball Smash Accuracy

Figure 1 illustrates the percentage contribution of each variable: leg muscle explosiveness (55.1%), eye-hand coordination (66.6%), agility (38.8%), and the simultaneous contribution of all three variables (77.1%). The diagram visually confirms that the combined contribution of the three fitness components

substantially exceeds any individual partial contribution, reflecting a synergistic predictive effect within the multiple regression model.

Inter-predictor correlation analysis showed a moderate positive correlation between leg muscle explosiveness and eye-hand coordination (r = 0.423), a weak positive correlation between leg muscle explosiveness and agility (r = 0.287), and a moderate positive correlation between eye-hand coordination and agility (r = 0.356). These values confirm that while the three components are interrelated, the degree of overlap is insufficient to cause multicollinearity, and each variable retains a unique and independent contribution to the prediction of smash accuracy.

DISCUSSION

The findings of the study showed that the explosiveness of the leg muscles made a significant contribution of fifty-five points one percent to accuracy *Smash* volleyball for Physical Education students of Pamulang University. These results confirm that the explosive ability of the muscles of the lower limbs plays a fundamental role in determining the quality of technique execution *Smash*. Eye-hand coordination was shown to make the most dominant contribution among the three components of fitness studied with a contribution of sixty-six points six percent to volleyball *smash accuracy* . These findings indicate that neuromuscular integration between the visual perception system and fine motor responses plays a crucial role in determining the accuracy of ball placement to the targeted target area.

The results of this study are in line with the findings (Puspita, 2025) that identifies that eye-hand coordination has a very strong relationship with ability to *Smash* which is proven by the value of the correlation coefficient reaching 0.770 with a very high level of significance at alpha five percent. Eye-hand coordination has a strong correlation with volleyball serving ability in students with a value of r = 0.908, suggesting that this component is cross-technique and relevant to a wide range of volleyball skills that require high accuracy (Medeiros et al., 2024). Experimental research provides empirical evidence that structured exercise programs focused on improving eye-hand coordination are able to improve accuracy *Smash* Significantly, with a T-count value of 5.017 which far exceeds the T-table value of 1.699, demonstrating the effectiveness of coordination training

interventions in improving technical performance. Experimental studies on junior volleyball players also found that stroboscopic-based visual exercises aimed at improving visuomotor coordination significantly improved reaction speed and technique movement accuracy, reinforcing the argument that structuredly trained eye-hand coordination has a direct impact on the accuracy of smash technique execution (Medeiros et al., 2024).

Agility contributes thirty-eight decimal points eight percent to accuracy *Smash*, which despite being the lowest contribution among the three components studied nevertheless shows strong statistical significance (Hern et al., 2023). These findings indicate that although agility is not a dominant predictor, it still has a substantive role in supporting execution *Smash* which is accurate especially in dynamic and unpredictable game situations. A player with a superior level of agility is able to anticipate movements, reposition of the legs, and adjust body angles more quickly so that they can reach the optimal position to perform *Smash* even when receiving a pass that is less than ideal in terms of height, distance, or direction.

The capacity to maintain dynamic balance during explosive changes of direction also contributes to the stability of the body when performing the aerial phase in execution *Smash*. (Satardi et al., 2023) In his study identified that agility contributes to the adaptability of movements required in a variety of techniques *Smash* from various positions on the field, both from the front, middle, and back zones. In a comprehensive review they also affirm that agility is an important component of physical condition for volleyball athletes because it facilitates the ability to change direction quickly and efficiently in unpredictable game situations, while also contributing to posture stability when performing explosive moves such as smashes (Addivinola et al., 2021).

Multiple regression analysis yielded a very significant finding that all three components of physical fitness simultaneously contributed seventy-seven points one percent to accuracy *Smash* ball. The much higher simultaneous contribution value compared to the partial contribution of each component separately provides strong evidence of a synergistic effect between fitness components that work in an integrated manner in producing optimal engineering performance. The explosiveness of the leg muscles results in optimal jumping height, eye-hand

coordination ensures precise timing and contact accuracy, while agility facilitates position adjustment and dynamic balance, and these three components work simultaneously in a series of movements *Smash* cohesive. These findings are consistent with the results of the study (Hassan & Al, 2025) who found that the combination of eye-hand coordination, wrist flexibility, and limb muscle explosiveness simultaneously contributed to eighty-nine point seven percent to the ability to *Smash* Student Volleyball.

The difference in contribution value between this study and Karim's research can be explained by the variation of the components studied, where Karim included wrist flexibility as an additional variable that also had high biomechanical relevance to the punch mechanism *Smash*. (Suhardiman et al., 2024) In his research also found that *Explosive Power* and physical fitness together exert a significant influence on skills *Smash* with a contribution of up to forty percent, although with a lower value than this study it is likely due to differences in the operationalization of the variables and characteristics of the study sample. The correlation found that the correlation coefficient of arm muscle explosiveness to smash ability reached 0.957, while eye-hand coordination obtained a value of r = 0.852, which consistently supports the position of eye-hand coordination as the strongest predictor of attack accuracy and quality in volleyball in various populations of athletes (Esa, 2025).

The limb muscle's explosive power coefficient of 0.634 occupies the second position in the hierarchy of predictive importance, suggesting that although not as dominant as eye-hand coordination, the increase in explosive power still makes a substantial contribution to accuracy *Smash*. The negative coefficient of the agility variable of -1.234 is conceptually accurate because agility is measured through travel time where a lower value indicates better performance, so a reduction in travel time will result in increased accuracy *Smash*. (Keoliya et al., 2024) In a comprehensive literature review identified that the explosiveness of the arm muscles contributes in the range of twenty-five to forty-one percent to accuracy *Smash*, where athletes with the capacity to *Explosive Power* those who are taller tend to have superior motor control so that they are able to execute *Smash* with a more optimal level of accuracy and strength.

The most important thing is that these three components must be developed holistically and integrated in one cohesive training program, since a simultaneous contribution of seventy-seven points one percent suggests that isolated development on just one component will result in suboptimal improvements. (Putra et al., 2024) in his research found that the level of skill *Smash* Physical education students are in the good category with a percentage of fifty-two percent, indicating that there is still significant room for improvement through more systematic and evidence-based exercise interventions. Keoliya et al. (2024) found that arm muscle strength contributed seventy-three percent to the skill *Smash*, showing that in addition to the three components studied in this study, there are still other physical components such as arm and shoulder muscle strength that also need attention in a comprehensive exercise program.

The implementation of this scientific evidence-based training model is expected to be able to improve the quality of physical education graduates who are not only pedagogically competent but also have qualified psychomotor skills as professional capital in teaching volleyball in schools (Zwierko et al., 2023). However, this study has several limitations that need to be considered. First, the sample comes from only one institution so the generalization of the results needs to be done carefully. Second, the correlational design does not allow the definitive determination of causal relationships between fitness components and smash accuracy. Third, there is a possibility that moderator variables such as playing experience, motivation, and quality of learning techniques also affect the relationships found but not controlled in this study.

Experimental research with a pre-test post-test control group design is needed to confirm the causal effect of increased fitness components on accuracy *Smash*. Fourth, technical factors such as feed quality, timing *Approach*, arm swing technique, and angle of engagement were not controlled or measured in this study even though they were likely to have an influence on the results. Future research is suggested to involve more physical fitness components in the analysis model, use a larger and more diverse sample from a variety of institutions, apply experimental designs to establish causality, and integrate biomechanical analysis to understand the technical mechanisms that link fitness components to performance *Smash*.

(Triatmaja et al., 2025) showed that arm muscle strength and arm muscle explosiveness also have a very significant correlation with ability *Smash* with coefficient values of 0.803 and 0.830, respectively, so these components are very important to include in future studies to obtain a more comprehensive and accurate prediction model of the determinants of accuracy *Smash* ball.

CONCLUSION

This study concludes that leg muscle explosiveness contributed 55.1%, eye-hand coordination contributed 66.6%, and agility contributed 38.8% to volleyball smash accuracy in Physical Education students of Pamulang University each partial contribution being statistically significant. Simultaneously, all three components collectively contributed 77.1% to smash accuracy, confirming a significant synergistic effect. Eye-hand coordination was established as the most dominant individual predictor. These findings confirm that holistic and integrated physical fitness development, addressing all three components concurrently, represents the most effective strategy for improving volleyball smash accuracy among Physical Education undergraduates.

RESEARCH IMPLICATIONS

These findings carry direct practical implications for volleyball instruction within Physical Education programs. Training curricula should prioritize eye-hand coordination development through visual tracking and wall-throw exercises, given its dominant predictive contribution. Plyometric programs targeting leg muscle explosiveness and multidirectional agility drills should be integrated simultaneously rather than in isolation, as the synergistic effect of all three components produced the highest collective contribution (77.1%) to smash accuracy. Lecturers and coaches are encouraged to adopt this evidence-based, component-prioritized training model to optimize students' smash performance within limited instructional time.

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