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3 THE RELATIONSHIP BETWEEN ARM MUSCLE STRENGTH AND EYE-HAND COORDINATION TO UNDERHAND PASS ABILITY IN VOLLEYBALL

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Abstract

Bottom passing is a basic volleyball technique that requires the synergy of biomotor components, especially arm muscle strength and eye-hand coordination, to control the direction of ball bounce. Previous research has predominantly involved junior high school/high school students and has not examined the combination of the two variables in sports college students. The purpose of this study is to test the relationship between arm muscle strength (X_1) and eye-hand coordination (X_2), both partially and simultaneously, with the ability to pass down (Y) in Sports Coaching Education students. The research design was correlational with a sample of 30 students selected through purposive sampling from a population of 319 students. The X_1 variables were measured by a 60-second push-up test, X_2 by a 20-second tennis ball throw-catch test, and Y by a target-scale bottom passing test. Data were analyzed using descriptive statistics, Shapiro–Wilk normality test, and simple regression and multiple regression in the SPSS 27 program. The results showed an average of $X_1 = 28.80$ ($SD = 1.54$), $X_2 = 29.00$ ($SD = 2.38$), and $Y = 11.90$ ($SD = 1.52$); the data distribution of all variables was normally distributed ($p > 0.05$). Simple regression $X_1 \rightarrow Y$ yielded $r = 0.862$; $R^2 = 0.743$; $F(1, 28) = 81.038$; $p = 0.000$, while $X_2 \rightarrow Y$ yielded $r = 0.861$; $R^2 = 0.740$; $F(1, 28) = 79.893$; $p = 0.033$. Double regression of X_1 and X_2 to Y yielded $R = 0.870$; $R^2 = 0.757$; $F(2, 27) = 42.037$; $p = 0.035$. In conclusion, arm muscle strength and eye-hand coordination have a significant relationship with lower passing ability, both partially and simultaneously, with a combined contribution of 75.7%. These findings underscore the importance of integrated training that combines arm muscle strengthening with visuomotor coordination exercises to improve lower passing skills in sports coaching students.

Keywords: Volleyball; Eye-Hand Coordination; Arm Muscle Strength; Bottom Passing; Sports Coaching Students.

INTRODUCTION

The game of volleyball is one of the sports that has taken root in the lives of Indonesian people, both as a means of recreation, education, and achievement (Nasution & Hendryanto, 2024; Rijaluddin et al., 2025). This sport is played by two teams separated by a net on a court measuring 18 m $\times$ 9 m, with the aim of crossing the ball to the opponent's square and dropping it to get points (Darmawati et al., 2025; Fatchurahman & Rahma, 2025). The fast character of the game, alternating between defending and attacking, and requiring tactical decisions in a short period of time, makes volleyball not only require mastery of technique, but also reliable

physical condition support (Wijaya et al., 2025; Paramida et al., 2025). Therefore, each player is required to master basic techniques consistently in order to be able to contribute to the team's game pattern.

Passing is one of the most commonly used basic techniques in volleyball and determines the smooth flow of the attack (Adhi et al., 2023; Ahmad et al., 2020). Bottom passing, in particular, is the first technique mastered by novice players because it is considered the most fundamental and most often appears in situations of receiving serve or receiving opponents' smash (Fadillah & Hadi, 2024; Ompusunggu, 2025). Biomechanically, the bottom passing is performed by uniting both arms from the inner side of the wrist so that the ball bounces in the desired direction (Agustina et al., 2023; Tarigan, 2023). Since incoming balls can come from different directions with different speeds and angles, the ability to pass down requires concentrated work between the eyes as receptors, the brain as signal processors, and the arms as the executors of motion (Adil, 2024; Koesyanto in Agustina et al., 2023).

The two biomotor components that are thought to most determine the quality of lower passing ² are arm muscle strength and eye-hand coordination. Arm muscle strength is defined as the ability of a group of arm muscles to generate tension in overcoming resistance or lifting weights to the maximum (Lamusu & Lamusu, 2023; Romadan et al., 2024; Sembiring, 2024). The dominant muscles that work in lower passing include the triceps brachii, biceps brachii, and deltoid, which play a role in maintaining elbow fixation so that the ball bounce remains stable (Amelia et al., 2024; Supriyanto & Martiani, 2019). Meanwhile, ³ eye-hand coordination is an integration between the sense of sight ⁴ as a receiver of information and the hand as the executor of movements in an efficient movement pattern (Akhmady & Duwila, 2022; Dio, 2023). This ⁴ coordination allows players to read the trajectory of the ball, estimate the point of fall, and precisely adjust the force and angle of the bounce (Ali, 2023; Tober, 2021).

Initial observations of students of Sports Coaching Education at the University of Muhammadiyah Bone show that technical difficulties are still found when making down passes. Some students seem to be less able to maintain the

direction of the ball bounce, often experience errors in determining the point of contact on the arm, and show insynchrony between visual capture of the ball and reaching arm movements. This condition places ¹ arm muscle strength and eye-hand coordination as two physical components that should be studied in a measurable manner to obtain empirical evidence regarding their contribution to lower passing skills at the level of sports coaching colleges, where students are expected to become prospective coaches who will also transmit technical knowledge to their fostered athletes.

A number of previous studies have examined these two variables, but still leave relevant gaps to be answered. SUBEDE (2021) found a significant influence ² of arm muscle strength, balance, and eye-hand coordination on the lower passing of SMPN 40 Makassar students. Jahrir (2019) reported the combined ² contribution of arm muscle strength, eye-hand coordination, and arm length to students' underside passing. Akhmady and Duwila (2022) limited the sample to the STKIP Kie Raha Ternate women's team. Darmawati et al. (2025) examined the upper passing, not the bottom passing, in Madrasah Ibtidaiyah students. Fatchurahman and Rahma (2025) examined the oblique serve, not the bottom passing, in high school students. Marzuki et al. (2021) only associate arm muscle strength with lower passing accuracy without including eye-hand coordination as a companion variable. The pattern shows that studies that combine ³ arm muscle strength and simultaneous eye-hand coordination with lower passing in sports coaching program students are still rare, even though this population has different motor characteristics than students due to the more intensive curricular burden of coaching.

Understanding the relationship between the two variables simultaneously is important for the development of an efficient, structured, and evidence-based underpass training program. PKO students as prospective coaches need to obtain a clear mapping of which physical components should be prioritized in underpassing training, so that the training design that they will prepare in the future can be scientifically accounted for. This research is expected to add to the treasure of empirical literature in the field of volleyball coaching, especially at the university

level, which is relatively different from the dominance of research at the high school level. The novelty claimed to be proportional, namely the contextual novelty at the level of the sports coaching college population with a combination of arm muscle strength variables and eye-hand coordination that has not been widely studied simultaneously.

Based on this description, the objectives of this study are: (1) to test the relationship between arm muscle strength (X_1) and lower passing ability (Y); (2) to test the relationship between eye-hand coordination (X_2) and Y ; and (3) to test the relationship between X_1 and X_2 simultaneously to Y in PKO students of the University of Muhammadiyah Bone. The research hypothesis is formulated as follows: H_{a1} there is a significant relationship between X_1 and Y ; H_{a2} there is a significant relationship between X_1 and X_2 to Y ; and H_{a3} there is a significant relationship between X_1 and X_2 simultaneously with Y .

METHODS

Design

This study uses a descriptive-explanatory correlational design. The correlational design was chosen because the main purpose of the study is to describe and explain the relationships between variables without manipulating or intervening on the subject (Syahrizal & Jailani, 2023; Hardi & Mutmainna, 2024). This approach is in line with the characteristics of the research question, which is to test the extent to which the variables are freely correlated with the bound variables. The correlation results are reported in the form of correlation coefficient (r) for simple analysis, determination coefficient (R^2), and F and p values for statistical significance testing.

Place and Time of Research

Data collection was carried out on the volleyball court of the University of Muhammadiyah Bone campus, Bone Regency, South Sulawesi, in July 2025. The selection of the location is based on accessibility to the target population, the availability of standard volleyball facilities (courts, net poles, and volleyball according to regulations), and the ease of supervision by the supervisor. The test is

scheduled for the morning (07.00-09.30 WITA) to minimize the influence of academic fatigue and environmental temperature.

Population and Sample

The population of this study is all students of the Sports Coaching Education Study Program, University of Muhammadiyah Bone who are actively registered ¹⁰ in the even semester of the 2024/2025 academic year, totaling 319 people (Mulyana et al., 2024). A sample of 30 students was taken using the purposive sampling technique. The inclusion criteria used include: (a) active student status; (b) have taken volleyball skills courses; (c) in physical health as evidenced by a health questionnaire; and (d) willing to become participants and sign an informed consent sheet (Mushofa et al., 2024; Sarbiansyah et al., 2025). The selection of 30 samples was based on statistical feasibility considerations for parametric tests with a degree of adequate freedom as well as operational limitations in the field.

Operational Variables and Definitions

This study involved two independent variables and one bound variable (Hardi & Syahrudin, 2021). The first free variable (X_1) was arm muscle strength, operationally defined as the number of push-up repetitions performed correctly for 60 seconds. The second free variable (X_2) was eye-hand coordination, defined as the average number of tennis ball throws that hit the target and successfully recaptured for two 20-second opportunities each. The bound variable (Y) was the lower passing ability, defined as the target scale lower passing test score developed by Ismaryati and Muhyi (2018).

Research Instruments

The instruments used were tests and measurements, with three standardized test sets (Arikunto in Rahmawati et al., 2021; Ismaryati & Muhyi, 2018). First, a ⁴ 60-second push-up test was used to measure the strength and endurance of the arm muscles. Participants were face down, placed their palms on the floor under the chest, and performed down-and-down movements with their chests touching the floor. The score was the number of correct repetitions for 60 seconds, with a normative category of scores of 5 (≥ 38 for men/ ≥ 21 for women) to a score of 1 (4–11 for men/1– for women).

Second, the ¹⁰ tennis ball throw-catch test was used to measure eye-hand coordination. Participants stood 2.5 meters from the wall with the goal at shoulder height, then threw the ball downward to the target and caught the bounce with the same hand for 20 seconds. The test was conducted twice, and the final score was the average number of successful throws. Normative categories: excellent (>35), good (30–35), medium (25–29), poor (20–24), and very poor (<20).

Third, a target-scale lower passing test is used to measure bottom passing skills. The net poles are installed 2.30 m high for men and 2.15 m for women. Participants stand behind the line of attack, the ball is thrown from the next field, and the participant makes a low pass five times. The score is determined by the number on the target where the ball fell; a zero score is given when the ball is played unlawfully (lifting, pushing, or the ball does not go over the rope).

Data Collection Procedure

The research procedure was carried out chronologically. The preparation stage included research permission from the faculty leader, socialization to prospective participants regarding objectives and procedures, and the signing of informed consent. On the day of the implementation, participants did a general warm-up for 10–15 minutes guided by a research assistant. Next, participants conducted three tests in a row: the push-up test, the tennis ball throw-catch test, and the bottom passing test, with a 5-minute break between tests to minimize the cumulative fatigue effect. Each test was supervised by two observers: one was in charge of calculating repetitions/scores, the other monitoring the validity of movements.

⁵**Data Analysis Techniques**

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) program version 27. The analysis stage began with descriptive statistics (mean, standard deviation, minimum value, maximum value, and amount) to provide an overview of the data characteristics. Furthermore, the Shapiro–Wilk normality test was chosen because the sample count was less than 50 (Field, 2018). When the distribution of data was normal ($p > 0.05$), the analysis was followed by simple regression to test H_{a1} and H_{a2} , as well as multiple regression to test H_{a3} . The

significance criterion was set at $\alpha = 0.05$; the null hypothesis was rejected when the $p\text{-value} < 0.05$. The determination coefficient (R^2) was reported as an indicator of the magnitude of the contribution of the free variable to the bound variable, while the calculated F-value and the degree of freedom were reported to support the replication of the study.

RESULTS

Descriptive Data and Statistics Characteristics

The test result data of 30 participants were analyzed descriptively to provide a preliminary picture of the score distribution. A summary of descriptive statistics is presented in Table 1.

Table 1. Descriptive Statistics of Research Variables (n = 30)

Statistics	Arm Muscle Strength (X_1)	Eye-Hand Coordination (X_2)	Passing Bawah (Y)
Quantity (N)	30	30	30
Rerata (Mean)	28,80	29,00	11,90
Standard Deviation (SD)	1,540	2,378	1,517
Minimum Score	26	25	9
Maximum Value	32	33	15
Total Score (Σ)	864	870	357

Based on Table 1, the arm muscle strength score ranged from 26 to 32 with an average of 28.80 and a standard deviation of 1.540. The eye-hand coordination score ranged from 25–33 with an average of 29.00 and a standard deviation of 2.378. The lower passing score ranged from 9–15 with an average of 11.90 and a standard deviation of 1.517. The variation in scores in X_2 was relatively greater than that of X_1 and Y, which indicates that there was a more noticeable difference in coordination ability between participants than the difference in arm muscle strength.

Statistical Assumption Test

Before hypothesis testing, the distribution of data was tested for normality using the Shapiro-Wilk test. The test results are presented in Table 2.

Table 2. Shapiro-Wilk Normality Test Results

Variabel	N	Statistics W	p	Conclusion
Arm Muscle Strength (X_1)	30	0,961	0,122	Normal
Eye-Hand Coordination (X_2)	30	0,952	0,170	Normal
Passing Bawah (Y)	30	0,948	0,189	Normal

Criteria: the data is declared to be normally distributed if $p > 0.05$.

All three variables have a $p >$ value of 0.05, so that all data are distributed normally. Thus, parametric regression analysis is feasible for hypothesis testing.

The Relationship of Arm Muscle Strength to Lower Passing

The results of the simple regression between X_1 and Y are presented in Table 3.

Table 3. Simple Regression Results of X_1 to Y

Variabel	r	R ²	F	df	p	Verdict
$X_1 \rightarrow Y$	0,862	0,743	81,038	1; 28	0,000	Signifikan

The null hypothesis was rejected at $p < 0.05$.

The value of $r = 0.862$ indicates a very strong and positive relationship between arm muscle strength and lower passing ability. The determination coefficient $R^2 = 0.743$ means that arm muscle strength explains 74.3% of the lower passing ability variance, the rest is influenced by other factors outside the model. The value $F(1, 28) = 81.038$ with $p = 0.000$ ($p < 0.001$) indicates that the relationship is statistically significant, so H_{a1} is accepted.

The Relationship of Eye-Hand Coordination to Lower Passing

The results of the simple regression between X_2 and Y are presented in Table 4.

Table 4. Simple Regression Results of X_2 to Y

Variabel	r	R ²	F	df	p	Verdict
$X_2 \rightarrow Y$	0,861	0,740	79,893	1; 28	0,033	Signifikan

The null hypothesis was rejected at $p < 0.05$.

The value of $r = 0.861$ indicates a very strong and positive relationship between eye-hand coordination and lower passing ability. $R^2 = 0.740$ means that eye-hand coordination explains 74.0% of the lower passing variance. The value of $F(1, 28) = 79.893$ with $p = 0.033$ (< 0.05) indicates statistical significance, so H_{a2} is accepted.

Simultaneous Relationship of X_1 and X_2 to Y

The results of the multiple regression between X_1 and X_2 simultaneously with respect to Y are presented in Table 5.

Table 5. Results of Double Regression of X_1 and X_2 to Y

Variabel	R	R ²	F	df	p	Verdict
$X_1 + X_2 \rightarrow Y$	0,870	0,757	42,037	2; 27	0,035	Signifikan

The null hypothesis was rejected at $p < 0.05$.

A value of $R = 0.870$ indicates a very strong combined relationship. $R^2 = 0.757$ means that the combination of arm muscle strength and eye-hand coordination explains 75.7% of the lower passing variant; the remaining 24.3% is explained by other factors outside the model. The value of $F(2, 27) = 42.037$ with $p = 0.035 (< 0.05)$ indicates statistical significance, so H_{a3} is accepted.

DISCUSSION

The Relationship of Arm Muscle Strength with Lower Passing

The results of the analysis showed a correlation coefficient of $r = 0.862$ with $R^2 = 0.743$ and $p < 0.001$, so that arm muscle strength has a very strong, positive, and significant relationship with lower passing ability. These findings are in line with SUBEDE (2021) which reported the significant contribution of arm muscle strength to the lower passing of SMPN 40 Makassar students, and Marzuki et al. (2021) who found the relationship between arm muscle strength and lower passing accuracy. Similar studies on other volleyball skills also support this finding, such as Amelia et al. (2024) who found the contribution of arm muscle strength to upper serve, Fatchurahman and Rahma (2025) to slant serve, and Supriyanto and Martiani (2019) and Utomo (2022) to smash skills. The similarity of the trajectory findings between studs indicates that arm muscle strength is a biomotor component that is consistently relevant across volleyball techniques.

Biomechanically, this relationship can be explained through the role of the triceps brachii, biceps brachii, and deltoid muscles in maintaining elbow fixation and arm position when in contact with the ball (Supriyanto & Martiani, 2019). When the ball comes at a certain speed, the arm muscles must generate enough tension to dampen the momentum and bounce the ball towards the target. Without sufficient strength, the arm will give too soft a response so that the ball bounces short or strays, whereas excessive force without control will result in too tight bounces and off-track (Marzuki et al., 2021). In addition, good arm muscle strength also reduces the risk of wrist injury because it is able to reduce impacts proportionally (Utomo, 2022). Ardana (2023) who researched three-point shooting in basketball also showed a similar pattern: arm muscle strength provides the

mechanical basis for precise shooting skills, so that the function of strength in the sport of the game is cross-branched.

The high contribution of arm muscle strength to lower passing in this study can also be related to sample characteristics. PKO students were curricular exposed to relatively structured strength training, so the distribution of push up scores tended to be in the "good" category according to test norms. This condition allowed for a more clearly visible relationship compared to heterogeneous populations in strength training. However, it should be noted that arm muscle strength works not in isolation, but in synergy with reaction speed, agility, and timing to produce effective passing.

The Relationship of Eye-Hand Coordination with Lower Passing

Simple regression results showed $r = 0.861$; $R^2 = 0.740$; $p = 0.033$, so ¹eye-hand coordination has a very strong and significant relationship with lower passing ability. These findings corroborate Akhmady and Duwila (2022) who found a correlation between eye-hand coordination and lower passing in the STKIP Kie Raha Ternate women's team, and Darmawati et al. (2025) who found the contribution of eye-hand coordination to passing on MI Nurul Imam students. Studies in other branches of the game also support this finding, such as Dio (2023) on top serve, Amalia (2024) on basketball lay-up shots, and Assidiq (2025) on bottom serves, both of which place eye-hand coordination as an important predictor.

The neurological mechanism behind this relationship lies in the integration of the visuo-motor system (Dio, 2023; Ali, 2023). The eye picks up on the trajectory of the ball, the speed, and the angle of the come, then sends information to the visual cortex which is then passed on to the motor cortex to regulate the contraction of the arm muscles in a coordinated manner. Repetitive motor exercises will form memory trails in the central nervous system, so that players with good coordination are able to perceive the ball and move the arm at the right timing (Tober, 2021). Without adequate coordination, players tend to misjudge the point of dropping the ball, manage the position of the arm too late, or produce imprecise touches (Amelia et al., 2024; Amalia, 2024). This condition explains why eye-hand coordination is one

of the most critical biomotor components in sports that demands quick reactions to moving objects, including volleyball.

It is natural that eye-hand coordination explains the proportion of lower passing variants that are almost equivalent to arm muscle strength (74.0% versus 74.3%). Lower passing does require the player to ²read the direction of the ball in milliseconds and move the arm at the right angle so that the ball bounces off the target. This is what makes visuomotor coordination a functional prerequisite, while arm muscle strength is a structural prerequisite for movement execution.

¹**Simultaneous Relationship of Arm Muscle Strength and Eye-Hand Coordination**

Multiple regression analysis yielded $R = 0.870$; $R^2 = 0.757$; $F(2, 27) = 42.037$; $p = 0.035$, which suggests that the combination of the two free variables has a very strong and significant relationship to the lower passing. The combined contribution of 75.7% is slightly higher than the partial contribution of each variable. This pattern confirms that ¹arm muscle strength and eye-hand coordination work complementary, not substitutive. Arm muscle strength provides the structural-mechanical foundation for generating reflected stress, while eye-hand coordination provides timing and direction precision. The combination of the two results in stable and accurate lower passing execution. These findings corroborate Jahrir (2019) who reported the combined ²contribution of arm muscle strength, eye-hand coordination, and arm length to students' lower passing, and SUBEDE (2021) who combined ¹arm muscle strength, eye-hand coordination, and balance as predictors of lower passing.

However, $R^2 = 0.757$ leaves 24.3% of the lower passing variants that are not described by the model. Other factors that could potentially explain the rest of the variants include agility (Samsudin, 2022), reaction speed, motivation and concentration (Nasution & Hendryanto, 2024), training experience, wrist flexibility (Utomo, 2022), balance (SUBEDE, 2021; Darmawati et al., 2025), and specific game techniques. These limitations need to be recognized as a marker that the lower passing is a multidimensional skill that cannot be reduced to two biomotor components alone.

Theoretical and Practical Implications

Theoretically, these findings reinforce the view that motor skills in game sports are multidimensional and are explained by the convergence of structural (strength) and functional (coordination) components. This is in line with the motor learning framework that places strength as a prerequisite for capacity and coordination as a prerequisite for motion control (Schmidt & Lee, 2011). For the context of volleyball, Ziv and Lidor (2010) assert that biomotor components such as strength, power, and coordination are key determinants of player performance, and ⁵ the findings of this study add to the empirical evidence that this pattern also applies at the college level of sports coaching.

In practical terms, the results suggest that volleyball skills course coaches and lecturers design a bottom-passing training program that integrates arm muscle strength exercises (e.g., push ups, planks, light weight exercises) with eye-hand coordination exercises (e.g., throw-catch drills, bounce ball reactions, and paired passing drills with variations in the direction of the ball's coming). The integration of these two types of exercises is more effective than exercises that target only one component. In addition, regression results can be the basis for diagnostic assessments: students with low lower passing scores can be further evaluated to identify whether their weaknesses are dominant in the components of strength, coordination, or both, so that interventions can be designed more targeted.

CONCLUSION

Based on the results of data analysis and discussion, this study concludes three main things. First, ³ there is a significant relationship between arm muscle strength and lower passing ability in Sports Coaching Education students, with a correlation coefficient of $r = 0.862$ and an effective contribution of 74.3% ($p < 0.001$). Second, ³ there is a significant relationship between eye-hand coordination and lower passing ability, with $r = 0.861$ and contribution of 74.0% ($p = 0.033$). Third, the combination of ³ arm muscle strength and simultaneous eye-hand coordination has a significant relationship with lower passing, with $R = 0.870$ and a combined contribution of 75.7% ($p = 0.035$). These findings confirm that lower passing is a multidimensional skill that requires the support of structural (strength) and functional (coordination) components synergistically

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