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# The Contribution of Arm Muscle Strength to Badminton Smash Accuracy among Students

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***Abstrac***: This study aimed to determine the contribution of arm muscle strength to badminton smash accuracy among students participating in the badminton extracurricular program at SMAN 1 Lintau Buo. A quantitative correlational design was employed involving 10 students selected through total sampling. Arm muscle strength was measured using a 60-second push-up test, while smash accuracy was assessed using a badminton smash accuracy test. Data were analyzed using descriptive statistics, Pearson Product-Moment correlation, and the coefficient of determination at a significance level of 0.05. The results showed no significant relationship between arm muscle strength and smash accuracy (r = 0.058, p = 0.874), with a contribution of only 0.34%. These findings suggest that smash accuracy is influenced more by technical proficiency, coordination, movement timing, and biomechanical factors than by arm muscle strength alone. Therefore, integrated training programs are recommended to improve badminton smash performance.

**Keyword:** Arm Muscle Strength, Badminton, Extracurricular, Smash Accuracy

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## INTRODUCTION

Sports are physical activities performed regularly to improve health, fitness, and quality of life, while also playing a role in shaping character, discipline, responsibility, and sportsmanship. From the perspective of the sociology of sports, sports serve not only as physical activities but also as part of the process of value formation, social interaction, and the development of human resources in community life (Kiram, 2020). In the field of education, sports serve as a vital means of supporting students' physical, mental, and social development; therefore, their cultivation in schools must be carried out systematically to enhance human resource quality and athletic achievement (Zhang & Toldoya, 2026). Philosophically, sports also serve as a medium for character building and the development of human potential through the instillation of values such as hard work, a fighting spirit, discipline, and cooperation (Syafruddin et al. 2022). One of the rapidly growing and widely popular sports in Indonesia is badminton, which is not only a recreational activity but also a competitive sport with various achievements at the international level; thus, development through physical education and extracurricular activities in schools is a strategic step toward fostering students' talents and interests (Edmizal & Soniawan, 2020).

Badminton is a sport that requires technical mastery, physical fitness, and strong concentration (Donie et al., 2023). One of the fundamental techniques that plays a crucial role in the game is the smash, a fast and powerful attacking stroke intended to direct the shuttlecock into the opponent's court to score a point (Ricardo, 2023). The successful execution of this technique requires not only technical proficiency but also adequate physical attributes, particularly upper-body muscle strength, which plays an important role in producing effective and powerful strokes (Kiram, 2019). Consequently, the effectiveness of a smash is determined not only by the power generated but also by the accuracy with which the shuttlecock is directed toward the intended target (Burhan et al., 2026).

Smash accuracy refers to a player's ability to direct the shuttlecock precisely, thereby making it difficult for the opponent to return the shot (Taufik & Hulfian, 2024). A shot with great power but lacking precision in direction is easier for the opponent to anticipate. Therefore, the ability to execute a precise smash is one of the technical aspects that significantly determines the success of an attack and the chances of scoring points in a badminton match (Ardiansyah, 2026).

The ability to execute an accurate smash is closely tied to a player's physical condition. One key component of physical condition is upper-body muscle strength (Yendrizal et al., 2023). Arm muscle strength enables a powerful, stable, and controlled racket swing, allowing the shuttlecock to be struck at high speed while being directed precisely into the opponent's playing area (Kamaruddin et al., 2025). Thus, the greater a player's arm muscle strength, the higher the likelihood of executing an effective smash. Conversely, low arm muscle strength can reduce a player's ability to control both the direction and power of their shots (Edmizal & Soniawan, 2020).

In the context of sports development in schools, badminton as an extracurricular activity serves as a means to develop students' technical skills, physical conditioning, and athletic performance. The training program provided not only focuses on mastering game techniques but also needs to address the development of physical fitness components that support performance, including upper-body strength (Silva et al., 2023). Through planned and sustained training, students are expected to improve the quality of their smashes, making their play more effective and competitive.

SMAN 1 Lintau Buo is one of the senior high schools that organizes badminton extracurricular activities as a platform for developing students' interests and talents in sports. Through regular training sessions, students are expected to master the fundamental techniques of badminton, particularly the smash, while also developing the physical fitness required to support optimal performance during competition. However, based on the researchers' observations, the smash skills of students in the badminton extracurricular program at SMAN 1 Lintau Buo are still not optimal. Some students still have difficulty directing the shuttlecock accurately, as evidenced by the number of shots that go out of bounds, uncontrolled smash trajectories, and shots that are easily returned by opponents. Additionally, some students exhibit suboptimal arm swings, resulting in shots that lack power and accuracy. These conditions

indicate that one of the factors suspected to influence the low accuracy of smashes is suboptimal arm muscle strength. Insufficient arm muscle strength causes students to have difficulty controlling both the direction and power of their shots when performing smashes, even though these two aspects are crucial to the success of an attack in badminton (Martin et al., 2023).

However, these studies have mainly focused on identifying whether a relationship exists between physical and technical variables, while limited attention has been given to measuring the magnitude of the contribution of arm muscle strength to smash accuracy, particularly within school-based extracurricular badminton programs. Furthermore, most previous studies have involved competitive badminton athletes or general badminton players, whereas empirical evidence involving senior high school students participating in extracurricular activities remains scarce. This indicates a research gap regarding how arm muscle strength contributes to smash accuracy among adolescent players in educational settings, whose training characteristics and performance demands differ from those of competitive athletes.

Based on these issues, this study was conducted to determine the extent to which arm muscle strength contributes to smash accuracy among students participating in the badminton extracurricular program at SMAN 1 Lintau Buo. Unlike previous correlational studies that merely examined the existence of relationships between variables, this study specifically quantifies the contribution of arm muscle strength to smash accuracy among high school students involved in an extracurricular badminton program. Therefore, this study provides a scientific contribution by expanding empirical evidence regarding the role of upper-body muscle strength in badminton performance among adolescent players. In addition, the findings are expected to provide practical evidence for physical education teachers and badminton coaches in designing evidence-based training programs that integrate physical conditioning with technical skill development to improve smash accuracy. The results of this study are expected to serve as a source of information for physical education teachers, coaches, and students regarding the importance of developing arm muscle strength in improving smash accuracy, as well as to provide a basis for designing more effective training programs to enhance badminton performance.

## METHOD

### *Research Design*

This study employed a quantitative approach with a correlational research design to examine the contribution of arm muscle strength to badminton smash accuracy among students participating in the badminton extracurricular program at SMAN 1 Lintau Buo. A correlational design was selected because the study aimed to determine the relationship and contribution between the independent variable (arm muscle strength) and the dependent variable (smash accuracy) without providing any treatment to the participants (Creswell & Creswell, 2023; Martin et al., 2023).

### Participants

The study was conducted at SMAN 1 Lintau Buo, Tanah Datar Regency, West Sumatra, during the 2026 academic year. The population consisted of all students who actively participated in the badminton extracurricular program, totaling 10 male students. Because the population was relatively small, the study employed a total sampling technique, in which all members of the population were included as research participants (Sugiyono, 2020). Although the sample size was relatively small, the use of total sampling ensured that the entire accessible population was represented in the study, thereby minimizing sampling bias. Nevertheless, the findings should be interpreted cautiously because the limited number of participants may reduce the generalizability of the results to broader badminton populations. Future studies are encouraged to involve larger and more diverse samples to improve external validity.

Prior to data collection, permission to conduct the study was obtained from the Principal of SMAN 1 Lintau Buo and the badminton extracurricular coach. All participants voluntarily agreed to participate after receiving an explanation of the study objectives, testing procedures, potential risks, and benefits. Written informed consent was obtained from the participants and their parents or legal guardians because all participants were under 18 years of age. Participant

confidentiality and anonymity were maintained throughout the study, and the research was conducted in accordance with the ethical principles of the Declaration of Helsinki.

**Instruments**

Arm muscle strength was measured using the 60-second push-up test, with the total number of correctly completed repetitions recorded as the final score. The 60-second push-up test was selected because it is a simple, practical, and widely used field test for assessing upper-body muscular strength and endurance in adolescents. The test requires minimal equipment, is easy to administer in school settings, and has been extensively applied in physical education and sports performance assessments, making it appropriate for evaluating the upper-body muscular capacity required during badminton smash movements (Yendrizal et al., 2023).

Smash accuracy was assessed using a badminton smash accuracy test, in which each participant performed 10 smash attempts toward predetermined target areas on the opponent's court. Scores were assigned based on the number of shuttlecocks landing within the designated target areas, with higher scores indicating better smash accuracy. The push-up test and badminton smash accuracy test have been widely adopted in sports science research and coaching practice. Previous studies have reported acceptable levels of validity and reliability for both instruments when administered using standardized procedures (Martin et al., 2023; Yendrizal et al., 2023). To ensure measurement consistency, all tests were conducted by the same researcher using identical equipment, testing instructions, and scoring criteria for every participant.

**Data Collection**

Data collection was conducted directly on the badminton court. Participants first received instructions regarding the testing procedures and completed a standardized warm-up session to reduce the risk of injury. The arm muscle strength test was administered first, followed by the smash accuracy test after an adequate recovery period to minimize the effects of fatigue. During the smash accuracy assessment, each participant performed ten smash attempts toward predetermined target areas under identical testing conditions. Standard badminton equipment, including the same racket type, shuttlecocks, and court dimensions, was used throughout the testing process to ensure consistency. All assessments were supervised by the researcher and the badminton coach to maintain standardized testing procedures.

**Data Analysis**

The collected data were analyzed using descriptive statistics and Pearson Product-Moment correlation analysis. Prior to hypothesis testing, the assumptions of normality and homogeneity were examined. The coefficient of determination ($R^2$) was calculated to determine the contribution of arm muscle strength to badminton smash accuracy. Statistical analyses were performed using SPSS with a significance level of 0.05. Descriptive statistics were used to summarize participant characteristics and variable distributions. Pearson Product-Moment correlation analysis was selected because both variables met the assumptions for parametric testing and the study aimed to examine the strength and direction of the relationship between arm muscle strength and smash accuracy. The coefficient of determination ($R^2$) was subsequently calculated to quantify the percentage contribution of arm muscle strength to badminton smash accuracy.

## RESULT
### Descriptive Data Analysis

**Table 1**. Frequency Distribution of Arm Muscle Strength

| Interval Class | Absolute Frequency | Relative Frequency | Description |
|---|---|---|---|
| ≥ 35,49 | 0 | 0,00% | Excellent |
| 31,23 – 35,48 | 4 | 40,00% | Good |
| 26,97 – 31,22 | 3 | 30,00% | Fair |
| 22,71 – 26,96 | 2 | 20,00% | Poor |
| ≤ 22,70 | 1 | 10,00% | Very Poor |
| **Total** | **10** | **100,00%** | |

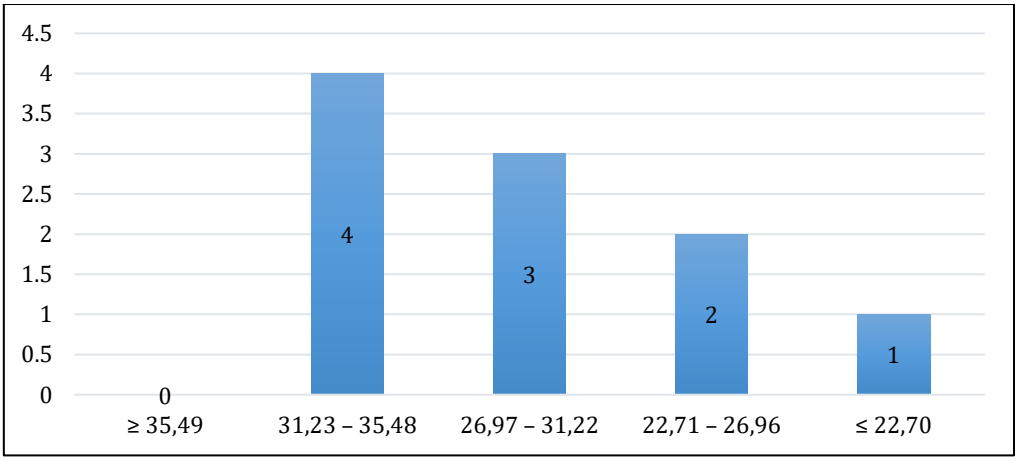


**Figure 1.** Histogram of Arm Muscle Strength

Based on Table and figure 1, of the 10 students in the sample, none had arm muscle strength in the "very good" category. Four students (40%) were in the "good" category, 3 students (30%) in the "moderate" category, 2 students (20%) in the "poor" category, and 1 student (10%) in the "very poor" category. Thus, in general, the arm muscle strength of students in the badminton extracurricular program at SMAN 1 Lintau Buo falls into the "good" category, as the highest frequency is found in the 31.23–35.48 range, accounting for 40%.

**Table 2**. Frequency Distribution of Badminton Smash Accuracy

| Interval Class | Absolute Frequency | Relative Frequency | Description |
|---|---|---|---|
| ≥ 42,77 | 1 | 10,00% | Excellent |
| 40,46 – 42,76 | 2 | 20,00% | Good |
| 38,15 – 40,45 | 5 | 50,00% | Fair |
| 35,84 – 38,14 | 1 | 10,00% | Poor |
| ≤ 35,83 | 1 | 10,00% | Very Poor |
| **Total** | **10** | **100,00%** | |

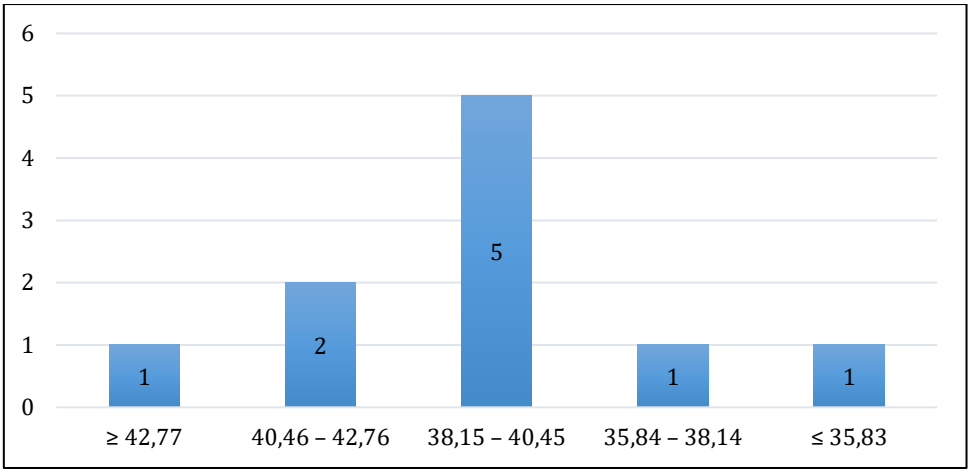


**Figure 2.** Histogram of Smash Accuracy

Based on Table and figure 2, of the 10 students who took the badminton smash accuracy test, 1 student (10.00%) was categorized as "very good," 2 students (20.00%) as "good," 5 students (50.00%) as "average," 1 student (10.00%) was categorized as poor, and 1 student (10.00%) was categorized as very poor. Thus, the badminton smash accuracy skills of the extracurricular students at SMAN 1 Lintau Buo are generally in the average category, as the majority of students (50.00%) fell within the score range of 38.15–40.45. These results indicate that the students' smash accuracy still needs to be improved through more targeted training, particularly in the areas of target accuracy, movement coordination, shot timing, and mastery of smash technique, so that their skills can progress to the "good" and "very good" categories.

**Normality Test**

The normality test aims to determine whether the data for the variables of arm muscle strength (X) and badminton smash accuracy (Y) are normally distributed. The test was conducted using the Liliefors test at a significance level of α = 0.05. The data are considered to be normally distributed if the calculated L-value (Lo) is less than the table L-value (Lt). The results of the normality tests for the two research variables are presented in Table 3.

**Table 3**. Normality Test Results

| Variable | n | $L_o$ | $L_{table}$ | Description |
|---|---|---|---|---|
| Arm Muscle Strength | 10 | 0.144 | 0.258 | Normal |
| Badminton Smash Accuracy | 10 | 0.172 | 0.258 | |

Based on Table 3, the results of the normality test show that the arm muscle strength variable (X) has a value of Lo = 0.144, while Lt = 0.258. Since Lo < Lt (0.144 < 0.258), the arm muscle strength data are normally distributed. Similarly, for the badminton smash accuracy variable (Y), Lo = 0.172 and Lt = 0.258, so Lo < Lt (0.172 < 0.258). Thus, both research variables are normally distributed and satisfy one of the assumptions for parametric statistical analysis using Pearson's product-moment correlation.

**Homogeneity Test**

A homogeneity test was conducted to determine the equality of variances between the variables of arm muscle strength (X) and badminton smash accuracy (Y) as one of the prerequisites for parametric analysis. The test used the F-test at a significance level of α = 0.05. The data were considered homogeneous if the calculated F-value was less than the critical F-value; conversely, if the calculated F-value was greater than the critical F-value, the data were considered non-homogeneous. The results of the homogeneity test for the two research variables are presented in Table 4.

**Table 4**. Homogenity Test Results

| Variable | n | $F_o$ | $F_{table}$ | Description |
|---|---|---|---|---|
| Arm Muscle Strength | 20.1 | 3.76 | 5.35 | Homogen |
| Badminton Smash Accuracy | 20.1 | 3.76 | 5.35 | |

Based on Table 4, the results of the homogeneity test show that the two variables have an F-calculated value of 3.76, while the F-table value is 5.35. Since F-calculated < F-table (3.76 < 5.35), the data are considered homogeneous. Thus, the variances of the arm muscle strength and badminton smash accuracy data are equal, thereby fulfilling one of the prerequisites for conducting a parametric statistical analysis.

**Hypothesis Test**

**Table 5**. Hypothesis Test Results

| Variable | $R_{value}$ | $P_{value}$ | $R^2$ | Description |
|---|---|---|---|---|
| Contribution of Arm Muscle Strength to Badminton Smash Accurary | 0,058 | 0.874 | 0.34 | Not Significant |

Based on Table 5, the Pearson correlation analysis showed a very weak positive correlation between arm muscle strength and badminton smash accuracy (r = 0.058, p = 0.874). Because the p-value exceeded the significance level of 0.05, the relationship was not statistically significant. Furthermore, the coefficient of determination ($R^2$ = 0.34%) indicates that arm muscle strength explained only 0.34% of the variance in smash accuracy, whereas the remaining 99.66% may be attributed to other factors such as hand–eye coordination, technical proficiency, lower-body explosive power, balance, flexibility, stroke timing, playing experience, and training intensity. However, these findings should be interpreted with caution because the study involved only ten participants. Although the use of total sampling represented the entire accessible population, the small sample size may have limited the statistical power of the analysis and the generalizability of the findings.

**DISCUSSION**

The results of the study show that there is no significant relationship between arm muscle strength and the accuracy of badminton smashes among students in the extracurricular program at SMAN 1 Lintau Buo. These findings indicate that the ability to execute an accurate smash is not only determined by the arm muscles' ability to maintain contraction during the activity but is also influenced by various physical components and technical skills that interact with one another. The smash is one of the most complex attacking techniques in badminton because it requires overall body coordination, from the approach step, body rotation, and arm swing to the contact between the racket and the shuttlecock. Therefore, the success of a smash is determined more by the quality of movement execution than by arm muscle strength alone (Darajat, 2024; Li et al. 2017).

From the perspective of motor control and biomechanical theory, the execution of a badminton smash represents a coordinated movement involving the entire kinetic chain rather than the isolated action of a single muscle group (Tajik et al., 2025). During a smash, force is generated sequentially from the lower limbs, transferred through trunk rotation, and finally transmitted to the shoulder, arm, forearm, wrist, and racket. Consequently, although arm muscle strength contributes to force production, its influence on smash accuracy depends on effective intersegmental coordination, movement timing, and neuromuscular control (Tariq, 2024; Triatmaja et al., 2025). If these components are not well integrated, greater arm muscle strength alone will not necessarily result in more accurate smash performance.

Physiologically, arm muscle strength contributes to the ability to generate high levels of force during the acceleration phase of the smash. However, generating force alone is insufficient to ensure accurate shuttlecock placement because successful smash execution also depends on neuromuscular coordination, body balance, movement timing, and technical proficiency.

Therefore, players with greater arm muscle strength may still demonstrate poor smash accuracy if these complementary performance components are not adequately developed.

This interpretation is supported by observations made during the study, which showed that some students with good arm muscle strength still achieved low smash accuracy scores. Conversely, there were students with moderate arm muscle strength who were able to achieve better smash accuracy due to more precise movement coordination, body positioning, and shot timing. This finding suggests that smash ability is the result of the integration of various biomotor components and technical skills; therefore, improving just one component of physical fitness does not necessarily lead to improved shot accuracy. These findings are supported by a coefficient of determination of 0.34%, indicating that arm muscle strength contributes only minimally to badminton smash accuracy. This means that 99.66% of the variation in smash accuracy is influenced by factors other than those examined in this study. These factors include hand-eye coordination, arm muscle strength, lower-body explosive power, body balance, wrist flexibility, footwork quality, mastery of basic smash techniques, playing experience, and the intensity of regular training. This demonstrates that smash accuracy is a multidimensional skill that requires the simultaneous development of various aspects.

Another consideration when interpreting the present findings is the relatively small sample size. Although total sampling allowed the inclusion of all members of the accessible population, the limited number of participants may have reduced the statistical power of the correlation analysis. Consequently, the absence of a statistically significant relationship should not be interpreted as definitive evidence that arm muscle strength has no role in smash accuracy. Rather, the findings indicate that within this specific sample, the contribution of arm muscle strength was minimal. Future studies involving larger samples are required to improve statistical power and provide more robust estimates of the relationship between physical fitness components and badminton performance.

The findings of this study are consistent with the research by Taufik and Hulfian (2024), which states that smash accuracy is more influenced by the ability to control stroke direction, hand–eye coordination, and proper timing when the racket contacts the shuttlecock. Similarly, Ramasamy et al. (2024) reported that the effectiveness of the forehand jump smash is primarily determined by biomechanical factors, including racket-head velocity, trunk rotation, and intersegmental coordination, rather than by a single physical component. These findings indicate that successful smash performance depends on the integration of technical proficiency, coordination, and movement mechanics. Therefore, arm muscle strength plays a supporting role in maintaining performance during play but is not the primary factor determining smash accuracy.

These findings are further supported by the international study conducted by Ramli et al. (2021) which explained that the performance of a forehand smash is the result of biomechanical interactions among all body segments within the kinetic chain, including trunk rotation, shoulder, elbow, and wrist movements, as well as racket-head velocity at the moment of shuttlecock impact. The study demonstrated that intersegmental coordination contributes more substantially to stroke performance than any single physical component considered independently. Similarly, Ramasamy et al. (2024) reported that the speed and effectiveness of the forehand jump smash among elite badminton players are primarily influenced by biomechanical characteristics, such as racket swing velocity, trunk rotation, and movement coordination, rather than arm muscle strength alone. Furthermore, Towler & King (2023) emphasized that successful smash performance depends largely on technical efficiency and movement coordination throughout the execution of the stroke. Therefore, technique-specific training is considered more effective in enhancing smash performance than physical conditioning conducted in isolation.

Based on these findings, an important practical implication of this study is that school badminton extracurricular training programs should not focus solely on improving arm muscle strength. Instead, coaches should implement integrated training programs that systematically combine technical drills with coordination exercises. Such training may include target smash drills, multishuttle drills, hand–eye coordination exercises, footwork training, and timing drills to improve the accuracy of racket–shuttlecock contact. An integrated training approach is expected

to enhance smash accuracy more effectively because it simultaneously develops physical fitness and technical skills.

Overall, the findings indicate that arm muscle strength is not the primary factor influencing badminton smash accuracy among students participating in the badminton extracurricular program at SMAN 1 Lintau Buo. Therefore, efforts to improve smash performance should adopt a more comprehensive training approach by emphasizing technical proficiency, movement coordination, muscle strength, explosive power, balance, and playing experience. Developing these components simultaneously is expected to have a greater impact on improving smash accuracy than focusing exclusively on arm muscle strength.

This study has several limitations that should be considered when interpreting the findings. First, the study involved only ten participants from a single senior high school, which limits the generalizability of the results to broader badminton populations. Second, the correlational design allows the identification of relationships between variables but cannot establish causal relationships. Third, arm muscle strength was the only physical fitness component examined, whereas badminton smash accuracy is influenced by multiple factors, including hand–eye coordination, lower-body explosive power, balance, flexibility, movement timing, and technical proficiency. Finally, although standardized field tests were employed, field-based measurements may not fully capture the complex biomechanical characteristics involved in badminton smash performance. Future studies are recommended to include larger and more diverse samples, additional physical and technical variables, and more comprehensive biomechanical assessments to provide a deeper understanding of the determinants of smash accuracy.

## CONCLUSION

Based on the findings, it can be concluded that arm muscle strength does not significantly contribute to badminton smash accuracy among students participating in the badminton extracurricular program at SMAN 1 Lintau Buo. These findings indicate that smash accuracy is influenced by multiple factors beyond arm muscle strength, including technical proficiency, motor coordination, shot timing, and other components of physical fitness. Scientifically, this study contributes empirical evidence that arm muscle strength alone is not the primary determinant of smash accuracy among high school students, highlighting the multidimensional nature of badminton performance.

Practically, badminton coaches and physical education teachers are encouraged to implement integrated training programs that combine physical conditioning with technical, coordination, and movement training to improve smash accuracy more effectively. This study was limited by the small sample size and the examination of only one physical fitness component. Therefore, future research should involve larger and more diverse samples, investigate additional physical, technical, and biomechanical variables, and employ experimental designs to provide a more comprehensive understanding of the factors influencing badminton smash accuracy.

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