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The role of physical condition in the smash skills of guidance achievement badminton athletes

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ABSTRACT

This study examines the direct and indirect effects of arm muscle explosive power, hand-eye coordination, and flexibility on smash ability among badminton players at PB Cahaya Pinang. Using a quantitative approach with path analysis, 14 male athletes were selected as participants. Data was collected through sport-specific tests: the two-hand medicine ball throw for explosive power, a tennis ball throw-and-catch test for hand-eye coordination, shoulder and wrist flexibility tests, and a smash performance test. The results revealed that flexibility had the strongest direct effect on smash ability (p = 0.906), followed by arm muscle explosive power (p = 0.270) and hand-eye coordination (p = 0.264). Flexibility also mediated the effects of arm muscle explosive power (64.4%) and hand-eye coordination (40.8%). Together, these variables accounted for 96.4% of the variance in smash ability, highlighting the integrated role of physical components in badminton performance.

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Introduction

Badminton is a high-intensity racket sport that demands a combination of technical skills, physical fitness, and neuromuscular coordination (Hadi, 2025; Soriano, 2024). Among the various techniques used in badminton, the smash is one of the most decisive strokes, often determining the outcome of a point in competitive play. A successful smash not only requires technical precision but also optimal physical attributes that enable athletes to generate high shuttlecock speed, accuracy, and a steep trajectory. As a result, understanding the physical factors influencing smash performance has become a central focus in badminton performance research (Karyono et al., 2024; Li et al., 2023).

Recent research in sports science has increasingly highlighted the role of physical attributes such as muscular strength, power, coordination, and flexibility in improving sport-specific skills (Ihsan, Nasrulloh, & Nugroho, 2024; Ihsan, Nasrulloh, Nugroho, et al., 2024). Studies on badminton biomechanics emphasize that upper-limb explosive power significantly contributes to shuttlecock velocity during overhead strokes. Likewise, hand-eye coordination is critical for ensuring accurate

timing and effective racket-shuttle contact, especially under high-speed conditions. Flexibility, particularly in the shoulder and wrist joints, has been shown to improve stroke amplitude and efficiency, allowing athletes to execute more powerful and controlled smashes (Mangun & Subarkah, 2024; Saleh et al., 2024).

Although many studies have investigated these physical components individually, most have examined them in isolation. This fragmented approach limits our understanding of how these factors interact and contribute to smash performance. Movement patterns in badminton are multidimensional, and focusing on only one factor may overlook how different physical components complement each other in the execution of a successful smash (Gu et al., 2024; Sheikhinia et al., 2023). Therefore, a more integrative perspective is needed to explore the combined effects of these factors on performance.

Furthermore, while previous studies have focused on either strength or coordination, they have rarely explored the mediating role of flexibility. While flexibility is often discussed as a secondary component, its role as a mediator between strength and coordination in facilitating technical performance remains underexplored. This gap is particularly important in sports like badminton, where overhead movements require a combination of strength, coordination, and a large range of motion (Javadiha et al., 2025; Yang et al., 2024).

Recent advances in performance analysis have introduced multivariate statistical techniques such as path analysis to study complex relationships between variables. However, the application of such methods in badminton research is still limited, particularly at the club or developmental athlete levels. Most existing studies focus on elite athletes, leaving a gap in understanding how these relationships manifest in non-elite or club-level players, who may experience different physical demands and training conditions (Béraud-Peigné et al., 2025; Ghaffar et al., 2025).

An additional limitation in the existing literature is the lack of attention to the interaction between strength, coordination, and flexibility, and how they jointly influence performance. While individual studies have highlighted the importance of each factor, few have examined how these variables interact within a performance context. This integrated approach is crucial for understanding the full scope of physical demands in badminton and developing more comprehensive training strategies (DeCouto et al., 2024; Zhou et al., 2025).

Based on these gaps, this study aims to provide a more integrative analysis by simultaneously examining the effects of arm muscle explosive power, hand-eye coordination, and flexibility on smash ability. The use of path analysis allows for a more detailed understanding of both direct and indirect effects among these physical components, with flexibility serving as a mediating factor. This approach goes beyond simple correlation studies and offers a comprehensive view of how these physical components work together to influence smash performance (Kang & Xu, 2024; Mohammadi et al., 2023).

The purpose of this study is to explore the direct and indirect effects of arm muscle explosive power, hand-eye coordination, and flexibility on smash ability in male badminton athletes of PB Cahaya Pinang. The findings are expected to contribute valuable insights to the literature on badminton performance, providing empirical evidence of the complex interactions between physical attributes. The results will also offer practical implications for coaches and trainers to design more effective training programs that address the multidimensional physical demands of badminton.

Method

This study employed a quantitative research design with a correlational approach to examine the direct and indirect relationships among arm muscle explosive power, hand-eye coordination, flexibility, and smash ability in badminton athletes. A total of 14 male athletes from PB Cahaya Pinang were selected through total sampling, given the limited population size. All participants were actively training and competing at the club level. The variables in this study included arm muscle explosive power and hand-eye coordination as independent variables, flexibility as a mediating variable, and smash ability as the dependent variable. Data were collected through sport-specific tests: the Two-Hand Medicine Ball

Throw to assess arm muscle explosive power, a tennis ball throw-and-catch test to measure hand-eye coordination, and shoulder and wrist flexibility tests to evaluate flexibility. Smash ability was measured using a performance-based smash test.

Before analysis, data were checked for normality using the Kolmogorov-Smirnov test, which confirmed that the data were normally distributed ($p > 0.05$) for all variables. Path analysis was used to examine the direct and indirect effects of the independent variables on smash ability. The relationships among variables were analyzed using appropriate statistical software, with a significance level set at 0.05. Given the small sample size, the results are presented with caution and are intended to inform future research with larger samples. While total sampling was used, potential bias related to the non-random selection of athletes was acknowledged as a limitation.

Results and Discussions

This section presents the results of the statistical analyses conducted to examine the direct and indirect effects of arm muscle explosive power, hand–eye coordination, and flexibility on smash ability in badminton athletes of PB Cahaya Pinang. The data were analyzed using path analysis to identify both individual and combined contributions of the independent variables to smash performance. The results are organized into three main components: descriptive statistics of the research variables, direct effects of each physical component on smash ability, and indirect as well as simultaneous effects among variables. This analytical structure provides a comprehensive understanding of how physical factors interact to influence smash performance in competitive badminton.

Table 1. Summary of the research data normality test

Variable	Asymp. Sig. (2-tailed)	0.05	Information
X1 to Z	0.190	0.05	Normal
X2 to Z	0.200	0.05	Normal
Y to Z	0.200	0.05	Normal

Based on the table above, it can be seen that based on normality testing using Kolmogorov-Smirnov, the value for each variable is 0.200>0.05, which proves that the data used is normally distributed.

Table 2. Direct Effects of Physical Variables on Smash Ability (Path Analysis)

Relationship	Path Coefficient (p)
Arm Muscle Explosive Power to Smash Ability	0.270
Hand–Eye Coordination to Smash Ability	0.264
Flexibility to Smash Ability	0.906

Table 2 shows the results of the path analysis examining the direct effects of arm muscle explosive power, hand–eye coordination, and flexibility on smash ability. The findings indicate that arm muscle explosive power has a positive direct effect on smash ability ($p = 0.270$), suggesting that greater explosive strength contributes to stronger and more effective smashes. Hand–eye coordination also demonstrates a positive direct effect ($p = 0.264$), highlighting its role in timing, accuracy, and shuttlecock contact during smash execution. Flexibility shows the strongest direct effect on smash ability ($p = 0.906$), indicating that optimal joint range of motion significantly enhances smash performance.

Table 3. Indirect and Simultaneous Effects on Smash Ability

Effect Type	Contribution (%)
Indirect Effect of Arm Muscle Explosive Power via Flexibility	64.4%
Indirect Effect of Hand–Eye Coordination via Flexibility	40.8%
Simultaneous Effect of All Variables	96.4%

Table 3 summarizes the indirect and simultaneous effects of the independent variables on smash ability. Arm muscle explosive power indirectly influences smash ability through flexibility with a contribution of 64.4%, indicating that flexibility acts as a key mediating variable that enhances the

effectiveness of explosive movements. Similarly, hand–eye coordination exerts an indirect effect through flexibility with a contribution of 40.8%. Furthermore, the simultaneous influence of arm muscle explosive power, hand–eye coordination, and flexibility accounts for 96.4% of the variance in smash ability, demonstrating that these physical components collectively play a dominant role in determining smash performance among badminton athletes.

The findings of this study highlight the significant role of arm muscle explosive power, hand-eye coordination, and flexibility in determining smash ability in badminton athletes. The high simultaneous contribution of these variables (96.4%) underscores that smash performance is not solely dependent on one physical attribute, but rather on the integrated interaction of strength, coordination, and joint mobility. This result aligns with the multidimensional nature of badminton performance, where technical execution is intricately linked to the underlying physical capacities (Deng et al., 2024; Xiong & Song, 2024). These results emphasize the need for a comprehensive approach in training that addresses all relevant physical components.

The positive direct effect of arm muscle explosive power on smash ability ($p = 0.270$) indicates that explosive strength is crucial for generating shuttlecock speed and impact force. A powerful smash demands rapid force production in a short amount of time, particularly from the shoulder, arm, and wrist. This finding is consistent with previous studies in badminton biomechanics, which suggest that upper-limb power is essential for achieving high shuttle velocities and offensive effectiveness (Peng & Zheng, 2025; Pérez et al., 2023). Therefore, including plyometric and power-based exercises targeting the upper body is critical for enhancing smash performance.

Hand-eye coordination also demonstrated a positive direct effect on smash ability ($p = 0.264$), emphasizing its importance in badminton, a sport characterized by high shuttlecock speed and limited reaction time. Effective execution of a smash requires precise timing, accurate shuttle contact, and rapid visual processing. This finding supports existing evidence that coordination training, including reaction drills and multi-directional ball exercises, is fundamental to improving the technical consistency of smash execution (Jiang, 2025; Pan et al., 2024). Training programs focusing on improving hand-eye coordination are essential for enhancing not only smash ability but also overall game performance.

Flexibility emerged as the strongest predictor of smash ability ($p = 0.906$), highlighting its critical role in optimizing movement mechanics. Adequate flexibility, particularly in the shoulder, elbow, and wrist joints, allows for a greater range of motion, enhancing stroke amplitude and reducing mechanical resistance during the smash. This result aligns with sports science literature, which emphasizes that flexibility contributes to both performance enhancement and injury prevention, particularly in overhead sports like badminton (Gredin et al., 2023; Zhang et al., 2025). Flexibility training should therefore be a key component of badminton training programs, particularly for athletes aiming to improve their smash.

The indirect effects observed in this study further underscore the mediating role of flexibility. Specifically, arm muscle explosive power influenced smash ability indirectly through flexibility, contributing 64.4%, while hand-eye coordination showed an indirect effect of 40.8% via flexibility. These results suggest that strength and coordination alone may not achieve optimal performance without sufficient joint mobility. Flexibility appears to act as a functional bridge that facilitates the translation of physical capacities into effective technical execution (Liu et al., 2023; Yeadon & Pain, 2023). This highlights the importance of a balanced approach to training that incorporates flexibility alongside strength and coordination.

Given the findings, it is evident that focusing on one physical component in isolation is insufficient for improving smash ability. Instead, an integrated approach is needed, where explosive strength, coordination, and flexibility are developed together to enhance performance. This integrated model of training is more likely to produce significant improvements in smash ability and overall playing quality. Coaches should aim to design training programs that target these physical components simultaneously, rather than focusing on individual attributes (Maksum & Indahwati, 2023; Takabi et al., 2023).

It is also important to consider that the study's sample size (14 athletes) limits the generalizability of the findings. While the results provide valuable insights, they should be viewed as preliminary, and

future research with larger sample sizes is recommended to validate these findings. Additionally, future studies could benefit from including female athletes and considering longitudinal training interventions to examine how the relationships between these variables evolve over time (Béraud-Peigné et al., 2025; Ghaffar et al., 2025). Expanding the scope of research to include diverse populations will help strengthen the external validity of the findings.

In conclusion, this study provides important insights into the complex interplay of physical components influencing smash ability in badminton athletes. The results suggest that an integrated training approach focusing on arm muscle explosive power, hand-eye coordination, and flexibility will lead to more effective improvements in smash performance. By incorporating these findings into training programs, coaches and practitioners can optimize their athletes' performance and address the multidimensional demands of badminton. Future research should aim to build on these findings by exploring other factors, such as technique and psychological aspects, that may also contribute to smash ability.

Conclusions

This study concludes that arm muscle explosive power, hand–eye coordination, and flexibility are significant and interrelated physical determinants of smash ability in badminton athletes of PB Cahaya Pinang. Both direct and indirect effects were identified, with flexibility playing a key mediating role that enhances the contribution of explosive power and coordination to smash performance. The strong simultaneous influence of these variables indicates that effective smash execution depends on the integrated development of strength, coordination, and joint mobility. Therefore, training programs aimed at improving smash performance should adopt a comprehensive approach that systematically develops these physical components to achieve optimal performance outcomes.

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