The contribution of arm muscle strength and hand–eye coordination to badminton long service results in male extracurricular students

Research Article

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Abstract.

Background Badminton long service requires sufficient upper-limb strength and precise hand–eye coordination to produce an effective shuttlecock trajectory. However, some studies indicate that certain students have difficulty generating a long, high shuttlecock trajectory as required by the technical demands of the long serve.

Objectives This study aimed to examine the contribution of arm muscle strength and hand–eye coordination to long service performance among male badminton extracurricular students.

Methods A correlational research design was employed. The population and sample consisted of 20 male students participating in the badminton extracurricular program at SMA Negeri 2 Siak Hulu. Arm muscle strength was assessed using a push-up test, hand–eye coordination was measured using a standardized hand–eye coordination test, and long service performance was evaluated using a badminton long service test. Data were analyzed using correlation and multiple correlation analyses.

Results The findings showed a significant positive relationship between arm muscle strength and long service performance (r = 0.544; r_{table} = 0.444). Hand–eye coordination demonstrated a stronger positive relationship with long service performance (r = 0.706; r_{table} = 0.444). Furthermore, arm muscle strength and hand–eye coordination jointly demonstrated a positive relationship with long service performance (R = 0.719; r_{table} = 0.444).

Conclusion These findings indicate that both physical and perceptual-motor components are associated with badminton long service performance, with hand–eye coordination showing a relatively greater individual association. The results provide practical evidence for incorporating upper-limb strengthening and coordination exercises into badminton extracurricular training programs.

Keywords: arm muscle strength, hand–eye coordination, badminton, long service, extracurricular students.

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INTRODUCTION

Physical education and sport play an important role in the development of students' physical, psychological, social, and motor competencies. In the Indonesian education system, educational sport is positioned as a continuous component of the educational process that aims to develop knowledge, personality, skills, health, and physical fitness (Suhadi et al., 2020; Yani et al., 2024). Physical Education, Sports, and Health therefore extends beyond physical activity. It provides structured learning experiences through which students develop movement competence, physical fitness, discipline, sportsmanship, and healthy lifestyle behaviors (Suratmin et al., 2022). Within this framework, school-based sports extracurricular activities provide additional opportunities for students to develop specific sport skills and physical capacities according to their interests and potential (Basman, 2019; Lonsdale et al., 2016; Mujriah et al., 2022; Supriady, 2024).

Badminton is one of the sports commonly implemented in school extracurricular programs. Successful badminton performance requires the integration of technical skills, physical capacities, perceptual-motor abilities, and tactical decision-making (Cabello-Manrique et al., 2022; Niyati Mukesh et al., 2021). Among the fundamental technical skills, the service has a particularly important role because it initiates every rally and influences the subsequent tactical situation. Badminton service can

generally be classified into short and long services, each serving different tactical purposes. The long service is primarily intended to send the shuttlecock high and deep toward the opponent's backcourt. Effective execution requires an appropriate combination of force, movement timing, shuttlecock contact, and directional control. Consequently, deficiencies in the physical or perceptual-motor components underlying the service may directly affect service accuracy and distance (Liang, 2022; Ma et al., 2021; Rusdiana et al., 2023).

Arm muscle strength is one physical component that may influence long service performance. Producing a high and deep shuttlecock trajectory requires sufficient force during the swing and impact phases. Adequate upper-limb strength can support the generation and transfer of force during the service movement. However, strength alone does not guarantee accurate badminton performance. Badminton is also characterized by rapid visual information processing and precise upper-limb movement. Hand–eye coordination enables players to synchronize visual perception with hand movement, thereby supporting accurate positioning and timing when contacting the shuttlecock. A player may possess adequate arm strength but still produce an ineffective service if the shuttlecock is contacted at an inappropriate position or time (Donie et al., 2023; Nurafiati et al., 2023). The interaction between physical and perceptual-motor components is particularly relevant in badminton. Long service requires not only sufficient force to achieve the required distance but also precise control of the shuttlecock trajectory. Thus, examining arm muscle strength and hand–eye coordination separately may provide an incomplete understanding of the factors associated with long service performance. A combined analysis can provide greater insight into whether these two components collectively explain variation in students' long service ability (Herman, 2019; Zulhendri & Sukoco, 2021).

Previous studies in badminton and sport performance have generally examined physical fitness, muscular strength, coordination, or technical performance as separate constructs. Several studies have reported associations between physical components and badminton skills, while others have emphasized the role of coordination in technical execution (Athaya et al., 2023; Ebrahim & Hussein, 2025; Yusroni, 2024). However, there remains limited empirical evidence examining the simultaneous contribution of arm muscle strength and hand–eye coordination specifically to badminton long service performance among male secondary-school extracurricular students. Most existing research has focused on competitive athletes, broader badminton performance, or individual physical and motor components rather than examining their combined contribution to a specific fundamental skill in a school-based population. This creates an important research gap because the determinants of technical performance among developing adolescent players may differ from those observed in trained or competitive athletes.

The present study addresses this gap by examining both individual and joint contributions of arm muscle strength and hand–eye coordination to badminton long service performance among male extracurricular students. The study is also situated in an actual school-based badminton extracurricular context, providing evidence that is directly relevant to physical education teachers and badminton coaches working with adolescent learners (Falaahudin et al., 2024; Hanief et al., 2019; Maliki et al., 2022). The novelty of this study lies in integrating a physical component (arm muscle strength) and a perceptual-motor component (hand–eye coordination) within a single analytical model to explain long service performance in a male secondary-school extracurricular population. Rather than assessing badminton performance as a general outcome, this study focuses specifically on long service as a fundamental technical skill that requires both force production and movement precision.

Initial observations conducted during badminton extracurricular activities at SMA Negeri 2 Siak Hulu on October 1, 2025, indicated that several students had difficulty producing long and high shuttlecock trajectories. Some students were unable to consistently reach the appropriate backcourt area, while others demonstrated insufficient control over service direction and distance. These observations indicate a practical problem that requires empirical investigation into the physical and perceptual-motor factors associated with long service performance. Therefore, this study aimed to determine: (1) the contribution of arm muscle strength to badminton long service performance; (2) the contribution of hand–eye coordination to badminton long service performance; and (3) the joint contribution of arm muscle strength and hand–eye coordination to badminton long service performance among male extracurricular students at SMA Negeri 2 Siak Hulu. The findings are expected to provide an evidence-based foundation for designing badminton extracurricular training programs that integrate strength development and coordination training to improve fundamental technical performance.

METHOD

Participants

The participants were 20 male students enrolled in the badminton extracurricular program at SMA Negeri 2 Siak Hulu, Riau, Indonesia. Because the total number of eligible students was relatively small, a total sampling technique was applied, and all 20 students were included in the study. The inclusion of participants was based on their active participation in the badminton extracurricular program and their ability to perform the required physical and badminton tests. Before data collection, the participants received an explanation of the study procedures and testing requirements. Participation was voluntary, and the testing procedures were conducted under standardized conditions.

Research Design

This study employed a quantitative correlational design to examine the relationships between arm muscle strength, hand–eye coordination, and badminton long service performance. Arm muscle strength (X1) and hand–eye coordination (X2) were treated as predictor variables, whereas badminton long service performance (Y) was treated as the outcome variable. The study investigated both the individual associations of X1 and X2 with Y and their joint association with Y. Three measurement instruments were used (Arikunto, 2018). Arm muscle strength was assessed using the floor push-up test based on the procedure described by Ismaryati (2018).

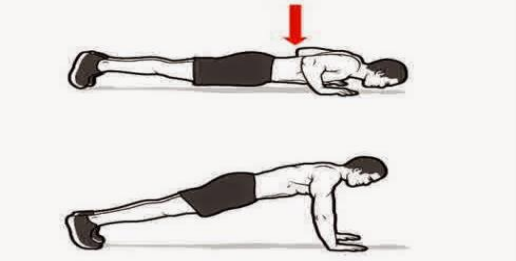

Figure 1. Push Up Test

Participants performed as many correctly executed push-ups as possible without rest. A repetition was considered valid when the participant maintained a straight body position, lowered the body until the chest approached or touched the floor, and returned to a fully extended-arm position. The total number of valid repetitions was recorded as the score. Hand–eye coordination was assessed using the hand–eye coordination test described by Arsil (2010). A circular target with a diameter of 30 cm was placed on a wall at approximately shoulder height. Participants stood 2.5 m from the target and performed 10 alternating-hand throws using a tennis ball. One point was awarded for each throw that hit the target and was successfully caught without the participant crossing the throwing boundary. The total number of successful attempts represented the coordination score.

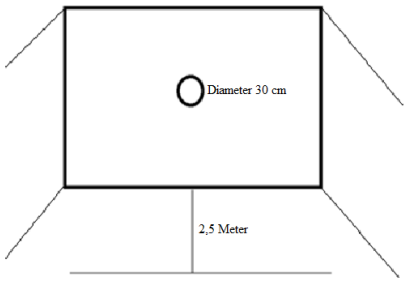

Figure 2. Hand–Eye Coordination Test Court (Illustration)

Badminton long service performance was assessed using the long service accuracy test described by Nurhasan (2001). Participants performed 20 long services toward the designated target area on the badminton court. The test was designed to assess the accuracy of directing the shuttlecock toward the opponent's rear court using a high and long service trajectory. The target consisted of graded scoring zones positioned in the rear area of the court. The total score obtained from the 20 service attempts represented the participant's long service performance. All tests were administered by trained test personnel using the same equipment, test area, and standardized procedures for all participants. Testing

was conducted during the badminton extracurricular program to ensure consistency with the participants' normal training environment.

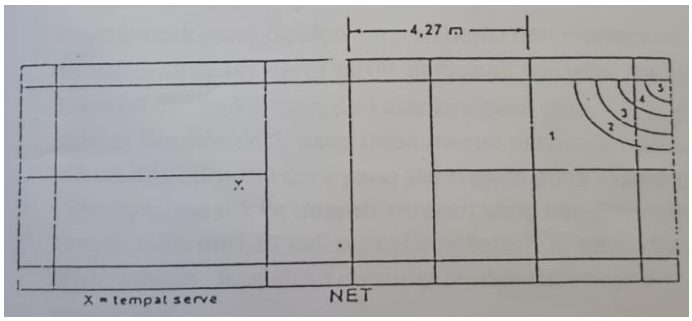

Figure 3. Court for the Badminton Long Service Test

Data Analysis

The data were analyzed using descriptive and inferential statistical procedures. Descriptive statistics were calculated for each variable, including the mean, standard deviation, minimum, and maximum values. Before inferential analysis, the normality and linearity assumptions were examined to determine the suitability of parametric correlation analysis. Pearson's product-moment correlation was used to examine the association between arm muscle strength (X1) and badminton long service performance (Y), as well as between hand–eye coordination (X2) and badminton long service performance (Y). Pearson correlation was also used to examine the relationship between the two predictor variables (X1 and X2). To examine the joint relationship of arm muscle strength and hand–eye coordination with long service performance, multiple correlation analysis was performed. The multiple correlation coefficient (R) was used to determine the strength of the combined association between X1 and X2 and the outcome variable Y. The coefficient of determination (R^2) was subsequently calculated to estimate the proportion of variance in long service performance associated with the predictor variables.

Statistical significance was evaluated at an alpha level of 0.05. The magnitude of the correlation coefficient was interpreted as follows: 0.00 indicated no correlation, 0.01–0.19 very low, 0.20–0.39 low, 0.40–0.59 moderate, 0.60–0.79 strong, and 0.80–1.00 very strong correlation. All statistical analyses were performed using statistical software, and the results were reported using the correlation coefficient (r), multiple correlation coefficient (R), coefficient of determination (R^2), and corresponding significance values.

Tabel 1. Correlation Coefficient Criteria

Correlation Value	Category
Equal To 0,00	No correlation
Less Than 0,01-0,199	Very low
Between 0,20-0,399	Low
Between 0,40-0,599	Moderate
Between 0,60-0,799	Strong
Between 0,80-1,000	Very strong

RESULTS AND DISCUSSION

Results

The analysis showed a positive association between arm muscle strength and badminton long service performance. The Pearson correlation coefficient was r = 0.544, indicating a moderate positive relationship based on the predefined correlation criteria. The coefficient of determination was R^2 = 0.296, indicating that arm muscle strength was associated with approximately 29.59% of the variance in long service performance. The remaining 70.41% may be associated with other factors not examined in the present study, including technical execution, coordination, balance, flexibility, and psychological factors. Hand–eye coordination demonstrated a stronger positive association with badminton long service performance than arm muscle strength. The Pearson correlation coefficient was r = 0.706,

indicating a strong positive relationship. The coefficient of determination was $R^2 = 0.498$, indicating that hand–eye coordination was associated with approximately 49.84% of the variance in long service performance. The remaining 50.16% may be explained by other physical, technical, perceptual-motor, and psychological factors that were not included in the present analysis.

When arm muscle strength and hand–eye coordination were considered jointly, the multiple correlation coefficient was R = 0.719. This value indicated a strong positive association between the two predictor variables and badminton long service performance. The coefficient of determination was $R^2 = 0.517$, indicating that the combination of arm muscle strength and hand–eye coordination was associated with approximately 51.70% of the variance in long service performance. The descriptive and correlation results are summarized in Table 1.

Table 1. Correlation and Explained Variance of Arm Muscle Strength and Hand–Eye Coordination

Predictor variable	Correlation coefficient	R^2	Explained variance	Relationship
Arm muscle strength	0.544	0.296	29.59%	Moderate positive
Hand–eye coordination	0.706	0.498	49.84%	Strong positive
Arm muscle strength + hand–eye coordination	0.719	0.517	51.70%	Strong positive

Note. r represents the Pearson correlation coefficient for individual predictors, whereas R represents the multiple correlation coefficient for the combined predictors.

The results indicate that hand–eye coordination showed a stronger individual association with long service performance than arm muscle strength. The difference in explained variance was approximately 20.25 percentage points (49.84% vs. 29.59%). However, the joint model produced an explained variance of 51.70%, indicating that the two variables collectively accounted for a greater proportion of variation in long service performance than either variable considered independently. The findings also indicate that approximately 48.30% of the variance in long service performance was not accounted for by the two variables included in the present model. Potential factors include technical proficiency, racket grip, body and foot positioning, swing mechanics, wrist and shoulder mobility, lower-limb and trunk stability, explosive power, and psychological factors such as concentration and confidence. These factors should be considered in future studies to provide a more comprehensive model of badminton long service performance.

Discussion

The present study examined the relationships of arm muscle strength and hand–eye coordination with badminton long service performance among male extracurricular students at SMA Negeri 2 Siak Hulu. The findings showed positive associations between both predictor variables and long service performance. Arm muscle strength demonstrated a moderate positive association with long service performance (r = 0.544), whereas hand–eye coordination demonstrated a stronger positive association (r = 0.706). When considered jointly, the two variables produced a multiple correlation coefficient of R = 0.719 and explained 51.70% of the variance in long service performance. These findings indicate that long service performance is associated with both force-related and perceptual-motor characteristics. The first finding showed a positive association between arm muscle strength and badminton long service performance (r = 0.544; $R^2 = 29.59\%$).

This result indicates that students with better upper-limb strength tended to demonstrate better long service performance. The finding is biomechanically plausible because a long service requires the racket to generate sufficient impulse to project the shuttlecock toward the rear area of the opponent's court. Research on shuttlecock aerodynamics has demonstrated that both the strength and angle of the stroke influence shuttlecock trajectory, while aerodynamic drag substantially affects shuttlecock flight (Karim & Rashid, 2023; Mehamad et al., 2021; Rahman & Warni, 2017). The role of upper-limb force should nevertheless be interpreted within the context of the badminton kinetic chain. Producing an effective stroke is not simply a matter of generating force through the arm. Biomechanical research on badminton strokes has shown that skilled performance involves coordinated movement across multiple body segments, including trunk rotation, shoulder rotation, elbow movement, and wrist control. Greater range of motion and coordinated proximal-to-distal movement can increase racket speed and influence shuttlecock release characteristics. Therefore, the present finding suggests that arm muscle strength is an important physical component, but it should not be interpreted as an independent determinant of long service performance (Suryadi et al., 2023).

The explained variance of 29.59% further supports this interpretation. Approximately 70.41% of the variance remained unexplained by arm muscle strength alone. This finding is important because it demonstrates that a student's ability to perform a long service depends on multiple interacting factors. Technical proficiency, racket control, wrist movement, body positioning, balance, flexibility, timing, and perceptual-motor skills may all influence the final outcome. Contemporary badminton performance research increasingly emphasizes the importance of combining biomechanical, movement, and stroke-quality variables rather than evaluating performance through a single physical characteristic. From a practical perspective, strength development can therefore be incorporated into badminton extracurricular training. However, strength training should be integrated with technical practice rather than implemented as an isolated intervention (Dhivya Shree Y et al., 2024; Tamim, 2017; Yenen et al., 2023). Exercises targeting the upper limbs and shoulder complex may provide a physical foundation for stroke production, while badminton-specific drills should teach students to transfer that physical capacity into an efficient service movement (Ruslan et al., 2021).

The second finding demonstrated a stronger positive association between hand–eye coordination and badminton long service performance ($r = 0.706$; $R^2 = 49.84\%$). Compared with arm muscle strength, hand–eye coordination showed a substantially greater explained variance. This finding suggests that the ability to coordinate visual information with upper-limb movement may be particularly relevant to the execution of an accurate long service among adolescent extracurricular players. Long service requires the player to control several events simultaneously. The player must position the body and racket appropriately, establish an appropriate contact point with the shuttlecock, regulate the timing of the racket movement, and direct the shuttlecock toward the intended target area. Consequently, adequate strength may not produce an effective service when the player cannot coordinate the timing and direction of the movement (Adnan et al., 2020; Zulhendri & Sukoco, 2021).

This interpretation is consistent with contemporary badminton research emphasizing the importance of precise stroke execution and the relationship between the hitting point, movement pattern, and final shuttlecock position (Fitri et al., 2022; Komaludin & Sabri, 2019; Meo et al., 2021). A recent multimodal badminton dataset study identified landing position, hitting point, movement, and stroke quality as important dimensions for understanding badminton stroke performance (Gupta et al., 2016). These findings provide a broader biomechanical basis for the present result because long service performance involves not only force production but also the accurate organization of movement toward a defined spatial target. The relatively high explained variance of 49.84% should, however, be interpreted cautiously. It does not mean that hand–eye coordination causes 49.84% of long service performance. Rather, within this correlational sample, hand–eye coordination was statistically associated with approximately 49.84% of the observed variance in long service scores. Other variables may account for the remaining variance, including technical proficiency, strength, balance, flexibility, experience, racket characteristics, and psychological readiness.

The finding has practical implications for school badminton programs. Coordination training can be incorporated through target throwing and catching, reaction drills, shuttlecock tracking, racket-control exercises, and repeated service practice. However, these exercises should progressively approximate the visual and motor demands of actual badminton. Training should therefore move from general coordination tasks toward badminton-specific tasks that require visual tracking, timing, racket positioning, and target accuracy. The third finding showed that arm muscle strength and hand–eye coordination jointly demonstrated a strong positive association with badminton long service performance ($R = 0.719$). The coefficient of determination indicated that the two variables jointly explained 51.70% of the variance in long service performance. This result provides an important finding because it suggests that physical force production and perceptual-motor coordination should be considered together when explaining badminton long service performance.

The joint finding is consistent with the biomechanical characteristics of badminton strokes. Effective racket strokes involve coordinated movements between multiple body segments rather than isolated movement of the arm. Research comparing skilled and novice badminton players has demonstrated that differences in trunk rotation, shoulder rotation, elbow and wrist movement, and the sequencing of body segments can influence racket and shuttlecock performance (Duncan et al., 2020; Rossi et al., 2022). Thus, strength provides part of the physical capacity required to produce the stroke, whereas coordination helps organize that capacity into a controlled and accurate movement. The present result also has an important practical implication. A training program that focuses exclusively on upper-limb strength may improve the physical capacity to generate force but may not fully transfer

that capacity into accurate long service performance. Conversely, coordination training without adequate force production may limit the ability to achieve the required shuttlecock distance (Hülsdünker et al., 2018; Jafari et al., 2014; Suryadi et al., 2023). An integrated program combining upper-limb strengthening, coordination, and repeated badminton-specific service practice may therefore be more appropriate for developing long service skills in adolescent extracurricular players.

The combined model explained 51.70% of the variance, leaving 48.30% unexplained. This substantial unexplained proportion indicates that long service performance is a multidimensional skill. Technical execution, racket grip, stance, swing mechanics, wrist and shoulder mobility, trunk and lower-limb contribution, balance, explosive power, training experience, and psychological factors may contribute to individual differences in performance. Biomechanical research on badminton supports this multidimensional perspective by showing that stroke quality can depend on the interaction of movement across the trunk and upper-limb segments rather than on a single physical characteristic. The findings also indicate that future research should move beyond simple physical fitness testing and incorporate direct biomechanical measures. Recent badminton research has used motion capture, wearable sensors, video analysis, and shuttlecock trajectory measurements to investigate stroke mechanics and performance quality. Such approaches could provide more precise information regarding racket velocity, shuttlecock velocity, contact point, swing angle, and landing accuracy.

Practical Implications

The findings provide several implications for badminton extracurricular programs. First, coaches should assess upper-limb physical capacity because adequate force production may support the ability to generate the distance required in long service. Second, coordination should be trained systematically because hand–eye coordination demonstrated a stronger individual association with long service performance than arm muscle strength in the present sample. Third, physical and coordination training should be integrated with badminton-specific technical practice. The results also suggest that coaches should avoid evaluating long service solely on the basis of whether the shuttlecock reaches the backcourt. Contemporary badminton performance assessment increasingly considers multiple dimensions of stroke quality, including shuttlecock trajectory, landing position, hitting point, and movement characteristics. A more comprehensive assessment could therefore provide better information for identifying the specific weaknesses of adolescent players.

Limitations

Several limitations should be considered when interpreting the findings. The sample consisted of only 20 male students from a single school, which limits the statistical power and generalizability of the findings. The results should therefore not be generalized to female students, competitive badminton athletes, or students from different schools and training environments without further evidence. The study used a cross-sectional correlational design. Therefore, the observed relationships do not establish causal effects. The finding that arm muscle strength and hand–eye coordination were associated with long service performance does not demonstrate that increasing either variable will necessarily improve service performance. Longitudinal or experimental intervention studies are required to establish causal relationships.

Overall Interpretation

Overall, the findings indicate that arm muscle strength and hand–eye coordination are positively associated with badminton long service performance among male extracurricular students. Hand–eye coordination demonstrated the stronger individual association, while the combination of the two variables explained 51.70% of the variance in service performance. The results support an integrated approach to badminton training in which physical capacity and perceptual-motor coordination are developed alongside technical skill. However, the correlational design, small sample, and limited measurement of biomechanical and technical variables require cautious interpretation. Future experimental research should examine whether targeted strength and coordination interventions can produce measurable improvements in badminton long service performance.

CONCLUSION

This study demonstrated positive associations between arm muscle strength, hand–eye coordination, and badminton long service performance among male extracurricular students at SMA

Negeri 2 Siak Hulu. Arm muscle strength showed a moderate positive association with long service performance and accounted for 29.59% of the observed variance. Hand–eye coordination demonstrated a stronger positive association and accounted for 49.84% of the observed variance. When considered jointly, arm muscle strength and hand–eye coordination showed a strong positive association with long service performance, accounting for 51.70% of the observed variance. Among the two individual predictors, hand–eye coordination demonstrated a greater association with long service performance than arm muscle strength. These findings suggest that badminton extracurricular training should integrate upper-limb physical conditioning with coordination-based and badminton-specific technical exercises. However, because this study used a correlational design and involved a relatively small sample from a single school, the findings should not be interpreted as evidence of causal effects or generalized beyond similar populations without further investigation. Future studies should employ larger samples and experimental or longitudinal designs and incorporate technical and biomechanical variables to develop a more comprehensive model of badminton long service performance.

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AUTHOR CONTRIBUTION STATEMENT

Rangga Fajar Firmansyah & Rices Jatra Responsible for the entire script.

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