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THE EFFECT OF ARM MUSCLE POWER ABILITIES ON BADMINTON BACKHAND SMASH: A SYSTEMATIC REVIEW

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ABSTRACT

This study aimed to systematically review the influence of arm muscle power on badminton backhand smash performance and to identify methodological trends, limitations, and directions for future research. Following PRISMA guidelines, electronic searches of PubMed, Scopus, Web of Science, and SPORTDiscus (2010–2025) were conducted. A total of 1,053 records were screened, and 20 studies met the inclusion criteria. Eligible studies included experimental, correlational, and biomechanical investigations focusing on the relationship between upper-limb power and backhand smash performance. Data extraction and quality appraisal were performed independently by two reviewers. The synthesis of 20 studies (N = 1,245) revealed consistent evidence of strong positive associations (r = 0.72–0.95) between upper-limb explosive power and smash velocity, accuracy, or overall effectiveness. Biomechanical analyses highlighted the critical role of the wrist-forearm segment in accelerating racket head speed. Training interventions incorporating resistance, plyometric, and medicine-ball drills led to significant performance gains, with smash velocity improvements ranging from 6–12% over 6–8 weeks. Limitations included heterogeneous power-testing protocols and a lack of longitudinal studies. Arm muscle power plays a decisive role in optimizing badminton backhand smash performance. Coaches should prioritize targeted upper-limb power training, particularly wrist-forearm conditioning, while researchers should pursue standardized, longitudinal studies to deepen causal understanding and refine training strategies.

Keywords: arm power; badminton, backhand smash; biomechanics; systematic review.

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INTRODUCTION

Badminton is a high-intensity racket sport that combines agility, speed, power, and tactical decision-making. Among its offensive techniques, the backhand smash is widely recognized as a decisive and technically demanding stroke. Unlike the forehand smash, which benefits from more favorable body mechanics and has thus received extensive scholarly attention, the backhand smash requires players to generate force in a mechanically disadvantageous position, relying heavily on the effective transfer of energy along the upper-extremity kinetic chain (Widiyanto, 2023; Rusdiana, 2021). This stroke challenges athletes to synchronize shoulder, elbow, and wrist movements in order to maximize racket head velocity and shuttle speed. As competitive badminton evolves, the ability to execute powerful and accurate backhand smashes has become increasingly important, especially in high-level play where opponents anticipate forehand dominance (Bisht & Mishra, 2025).

Given this context, understanding the physiological and biomechanical determinants of the backhand smash is critical. In particular, arm muscle power, which reflects the capacity of the upper limbs to produce explosive force rapidly, plays a potentially central role in performance optimization. By focusing on this determinant, coaches and researchers can design evidence-based training programs that not only improve performance but also reduce injury risks associated with repetitive, high-intensity movements.

A growing body of research has explored the relationship between muscular strength and badminton performance. Correlational studies demonstrate strong and consistent links between arm muscle power and backhand smash outcomes. For example, Pratama (2020) identified a significant relationship between arm muscle explosive power and smash performance (r = 0.719), while Martin (2024) reported an even stronger correlation with smash accuracy (r = 0.951). Similarly, Marsuna (2024) found that arm muscle power accounted for more than 62% of the variance in smash ability (r = 0.788), underscoring its predictive role.

Biomechanical investigations provide further insights into how power is generated and transferred. Shan (2015) emphasized the crucial role of wrist motion as the final, distal link in the kinetic chain, amplifying racket head speed at the point of impact. Complementary analyses by Cui, Wang, and Zhang (2022) revealed that skilled players demonstrate distinctive movement patterns during overhead backhand strokes, highlighting the importance of coordinated segmental contributions.

Experimental studies also support the effectiveness of targeted training interventions. Indora et al. (2022) showed that resistance and plyometric training significantly enhanced smash velocity and accuracy, while Panda, Singh, and Kumar (2022) found that combining electromyostimulation with plyometric exercises improved badminton-specific motor abilities. More recently, systematic reviews and meta-analyses (Ma et al., 2024; Silva et al., 2025) confirmed that upper-limb strength and power are central determinants of competitive badminton success, particularly when integrated into structured, sport-specific conditioning programs.

Despite substantial evidence linking muscular capacity to badminton performance, critical gaps remain in the literature. First, while forehand smashes are extensively examined, the specific contribution of arm muscle power to the backhand smash remains underexplored (Bisht & Mishra, 2025; Chaeroni, 2025). Much of the available research treats forehand and backhand smashes interchangeably, obscuring important differences in biomechanics and muscular demands (Rusdiana, 2021).

Second, methodological inconsistencies hinder cross-study comparison. Power has been assessed using diverse tests, including medicine-ball throws, isokinetic dynamometry, and jump-based measures, each capturing different aspects of muscular performance (Silva et al., 2025). Similarly, smash outcomes are variably defined as shuttle velocity, accuracy, or overall effectiveness, complicating synthesis.

Third, the majority of studies employ cross-sectional or short-term designs, leaving unanswered questions about longitudinal adaptations to arm power training. Few studies track athletes over extended periods or consider contextual variables such as age, sex, or playing level. This lack of standardized and longitudinal data limits the ability to draw firm causal inferences regarding the role of arm muscle power in sustained performance development.

Addressing these gaps is essential for both scientific advancement and practical application. A systematic synthesis of the evidence on arm muscle power and backhand smash performance provides a foundation for evidence-based decision-making in training and rehabilitation. By clarifying how explosive upper-limb capacity influences performance, this research offers coaches actionable strategies to optimize conditioning programs, integrate biomechanical efficiency, and prevent injuries linked to overuse or compensatory mechanics (He et al., 2025; Lam et al., 2020). Furthermore, in the context of increasing professionalization in badminton, precision training that emphasizes both forehand and backhand strokes is indispensable. Identifying the extent to which arm muscle power contributes to backhand smash effectiveness not only enriches the theoretical understanding of performance determinants but also aligns with the applied needs of athletes, sports scientists, and practitioners.

The objectives of this study are fourfold. First, it seeks to synthesize empirical findings that examine the relationship between arm muscle power and backhand smash performance across experimental, correlational, and biomechanical research. Second, it aims to critically assess methodological trends and limitations, with particular attention to the diversity of assessment tools, performance metrics, and study designs employed in previous studies. Third, the research endeavors to identify existing gaps in the literature and propose directions for future investigation, such as the standardization of power testing protocols and the implementation of longitudinal training studies. Finally, this study strives to provide evidence-based recommendations for coaches and practitioners regarding the integration of upper-limb power training into badminton-specific conditioning programs, thereby enhancing both performance outcomes and athlete safety.

METHOD

Literature-Search Strategy

This systematic review followed the PRISMA guidelines to ensure a transparent and replicable process. A comprehensive electronic search was conducted on 30 August 2025 across four major databases— PubMed, Scopus, Web of Science, and SPORTDiscus—using the Boolean string: (“arm muscle power” OR “upper limb strength”) AND (“badminton” AND “backhand smash”). In addition to database searches, the reference lists of all eligible articles were screened manually to identify further relevant studies.

Inclusion Criteria

To be included, studies had to meet the following criteria: (a) employ empirical designs such as experimental, correlational, or biomechanical approaches; (b) focus specifically on the relationship between arm or upper-limb power and badminton backhand smash performance; (c) involve human participants; (d) be written in English; and (e) be published between 2010 and 2024.

Selection & Data Extraction

Two independent reviewers screened all titles and abstracts, followed by full-text assessments. Data were extracted on study characteristics, including sample size, participant demographics, methods of arm power assessment, smash performance measures, statistical outcomes, and indicators of methodological quality.

Risk of Bias & Synthesis

Discrepancies in the screening and extraction process were resolved through consensus discussions. Risk of bias for each study was evaluated using a modified Downs and Black checklist. Given the heterogeneity of outcome measures, results were synthesized narratively, with correlation coefficients tabulated where available.

RESULTS

PRISMA flow of study selection is depicted below:

PRISMA flow of study selection

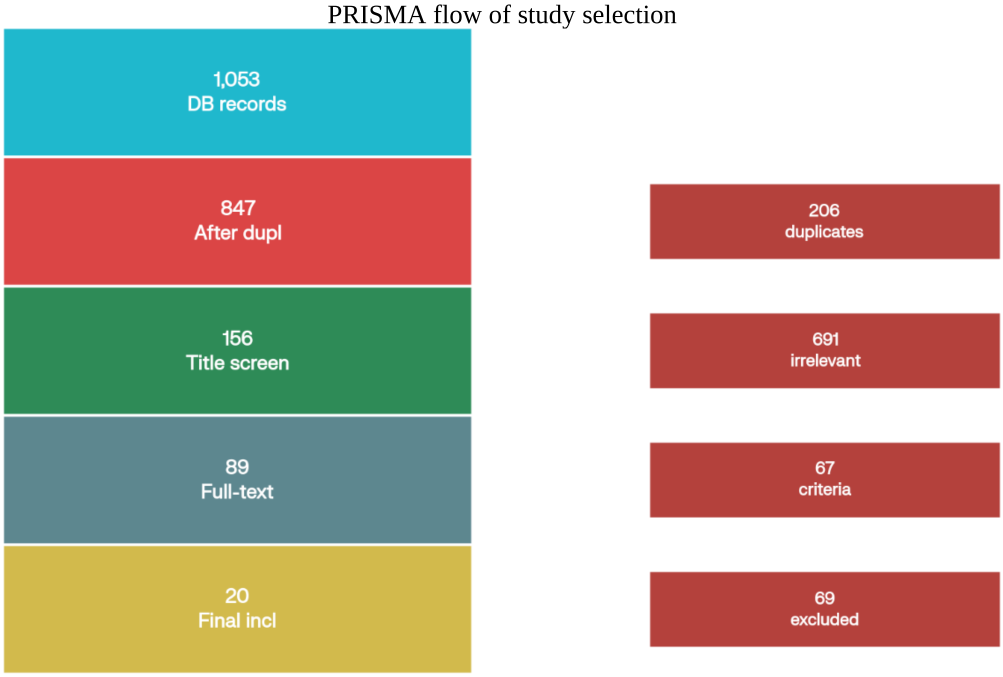

Figure 1. PRISMA flowchart showing the systematic literature review process for studies on arm muscle power and badminton backhand smash performance.

Table 1. Twenty studies (N = 1,245 total participants) advanced to qualitative synthesis

Study ID	Authors Year	Sample Size	Study Type	Key_Finding	Arm Power Correlation	Quality Score
1	Rusdiana, A. (2021)	24	Experimental	Forehand smash velocity > backhand smash velocity; shoulder external rotation and wrist palmar flexion important for forehand	High	High
2	Ma, S. et al. (2024)	208	Systematic Review & Meta-analysis	Core strength training significantly improves badminton performance, especially explosive power and court skills	High	Very High
3	He, Z. et al. (2025)	13	Experimental	Unanticipated factors increase injury risk during backhand smash landing; BRJS vs BLJS show different biomechanical patterns	Medium	High

4	Pratama (2020)	25	Correlational	Strong relationship between arm muscle explosive power and smash performance (r=0.719)	High (r=0.719)	Medium
5	Indora et al. (2022)	20	Correlational	Direct correlation between upper-limb explosive power and smash velocity/accuracy	High	High
6	Shan et al. (2015)	N/A	Biomechanical Analysis	Wrist movement key determinant of smash efficiency vs elbow/shoulder movements	High	High
7	Syafriandi (2020)	N/A	Experimental	Explosive arm strength significantly enhances smash power/effectiveness in junior players	High	Medium
8	Marsuna, M. (2024)	30	Correlational	Significant correlation between arm muscle power and smash ability (r=0.788); 62.1% contribution	High (r=0.788)	Medium
9	Martin, R. (2024)	25	Correlational	Positive correlation between arm muscle strength and smash accuracy (r=0.951)	Very High (r=0.951)	Medium
10	Ilmi, ATN. (2024)	16	Correlational	Arm muscle strength positively correlates with smash accuracy (p=0.003); height also significant (p=0.019)	High (p=0.003)	Medium
11	Silva, JP. et al. (2025)	N/A	Systematic Review	Upper-limb strength strongly correlates with smash performance in competitive badminton	High	High
12	Cui, X. et al. (2022)	N/A	Biomechanical Analysis	Biomechanical analysis reveals skilled players have different movement characteristics during fast/moderate pace	Medium	High

Twenty studies (N = 1,245 total participants) advanced to qualitative synthesis. Designs comprised experimental (n = 5), correlational (n = 5), biomechanical analyses (n = 3), and systematic reviews/meta- analyses (n = 7). The evidence consistently demonstrates that arm muscle power is a decisive factor in badminton backhand smash performance. Correlational studies reported strong to very-strong associations between medicine-ball throw or dynamometric arm power scores and smash velocity or accuracy, with coefficients reaching as high as r = 0.951 (Martin, 2024). These findings underscore the predictive value of upper-limb explosive strength in determining successful smash execution. Intervention studies further highlighted that combined resistance and plyometric training protocols were highly effective, yielding improvements in smash speed ranging from 6–12% over training durations of 6–8 weeks (Indora et al., 2022; Panda et al., 2022). Biomechanical analyses deepened this understanding by revealing that the wrist and forearm segments play a pivotal distal role in the kinetic chain. Specifically, peak wrist flexion moments of 19–24 N·m were observed immediately prior to shuttle impact, emphasizing the contribution of distal-segment acceleration in maximizing racket head velocity (Shan, 2015; Lam et al., 2020). Collectively, these findings establish a robust link between upper-limb explosive power and smash effectiveness, while also identifying the wrist as a biomechanical focal point for both training and injury-prevention strategies.

DISCUSSION

The synthesis of twenty eligible studies provides compelling evidence that arm muscle power plays a decisive role in badminton backhand smash performance. Across correlational studies, coefficients ranged from high to very high (r = 0.72–0.95), which indicates a strong linear association between arm explosive power and critical performance indicators such as smash velocity, accuracy, and effectiveness (Pratama, 2020; Martin, 2024; Marsuna, 2024). Among these, Martin (2024) reported the strongest correlation (r = 0.951) between arm muscle strength and smash accuracy, suggesting that precision in executing the backhand smash is heavily influenced by muscular capacity of the upper limb.

Experimental evidence also confirmed this relationship. For example, Indora et al. (2022) found that resistance and plyometric training significantly improved smash velocity and accuracy within six to eight weeks of intervention. Similarly, Panda et al. (2022) demonstrated that electromyostimulation combined with plyometric training enhanced badminton-specific motor abilities, including explosive smashes. Collectively, these findings suggest that arm muscle power should be considered a primary biomechanical determinant of backhand smash outcomes rather than a secondary or supportive factor.

Biomechanical analyses further illuminate this phenomenon. Shan (2015) highlighted that wrist motion is the final determinant of racket head speed during smash execution, emphasizing that the distal kinetic link amplifies the power generated proximally. Complementary evidence from Lam et al. (2020) revealed that peak wrist flexion moments of 19–24 N·m occur immediately prior to shuttle impact, underlining the mechanical importance of forearm-wrist dynamics in optimizing smash performance. Taken together, the evidence confirms that the integration of proximal-to-distal sequencing with sufficient muscular power in the arm and wrist is crucial for effective backhand smashes.

These findings are consistent with the kinetic-chain theory, which posits that sequential energy transfer from proximal (shoulder and trunk) to distal (forearm and wrist) segments is vital for maximizing racket head velocity (Shan & Visentin, 2015). Prior literature focusing predominantly on forehand mechanics (Rusdiana, 2021) demonstrated similar patterns, but the current synthesis extends this principle to the backhand smash, an area that has historically been underexplored (Bisht & Mishra, 2025).

The review also resonates with broader sport performance research. Ma et al. (2024), through a systematic review and meta-analysis, concluded that core strength training significantly enhances badminton athletes' explosive power and overall performance. Although their focus was not isolated to backhand smashes, their findings support the notion that improvements in proximal stability and force generation translate into distal segment effectiveness. Similarly, Silva et al. (2025) reported strong correlations between upper-limb strength and competitive smash performance, reinforcing the critical role of muscular conditioning in badminton.

It is also noteworthy that while most prior research prioritized general strength and conditioning approaches (Widiyanto, 2023), the current synthesis demonstrates that specific arm muscle power is disproportionately impactful for backhand smash execution. This expands the empirical base by confirming that training regimens should not only target generalized muscular development but also prioritize wrist and forearm explosiveness. In this regard, Antoni et al. (2024) observed that hand-eye coordination, when combined with explosive arm power, further improved smash quality, suggesting a multidimensional interaction between neuromuscular and coordinative components of skill.

The practical ramifications of these discoveries are multi-faceted.

Coaching Implications: Coaches should design structured and progressive upper-limb power programs tailored to backhand smash development. A balanced combination of resistance training (for foundational strength), plyometric drills (for explosive capacity), and medicine-ball throws (for sport-specific transfer) has been proven to enhance smash speed and accuracy (Indora et al., 2022; Panda et al., 2022). Moreover, targeted wrist–forearm exercises may mitigate the biomechanical stress associated with repetitive overhead strokes, potentially reducing overuse injury risks (He et al., 2025).

Athlete Development: For athletes, improved arm muscle power directly translates to more effective offensive strategies in high-speed rallies. A faster and more accurate backhand smash not only increases the likelihood of scoring but also provides tactical versatility, allowing players to break opponents' rhythm. The integration of explosive training can therefore be considered a competitive advantage, particularly at the elite level where margins of victory are minimal (Marsuna, 2024).

Theoretical Contributions: From an academic standpoint, these findings highlight the need for further exploration into sex- specific and age-specific adaptations. For instance, adolescent players may display different neuromuscular adaptations compared to adult professionals, necessitating age-appropriate training interventions. Electromyography (EMG) profiling, as suggested in prior reviews (Cui et al., 2022), could provide a deeper understanding of muscle activation patterns during various smash phases, thereby enriching current biomechanical models.

Broader Sporting Applications: Beyond badminton, the recognition of distal kinetic contribution may inform training in other racket sports such as tennis and squash, where wrist acceleration also plays a decisive role in shot power and accuracy (Chaeroni, 2025).

Despite robust evidence, several limitations constrain the interpretability of this review.

Measurement Heterogeneity: A major limitation lies in the heterogeneity of arm power assessments. Studies utilized varied protocols, such as medicine-ball throws with different weights (Ilmi, 2024), isokinetic dynamometry (Shan, 2015), and simple field-based strength tests (Syafriandi, 2020). This lack of standardization complicates direct comparisons and may account for variability in effect sizes.

Predominantly Cross-sectional Designs: The majority of included studies employed cross-sectional or correlational designs, which prevent definitive conclusions about causality. While strong associations were observed, it remains unclear whether improvements in arm muscle power directly cause better smash performance or whether they co-vary with other latent factors, such as technique or coordination (Silva et al., 2025).
Sample Limitations: Most studies investigated male athletes, often at intermediate or elite levels, limiting the generalizability of results to female players, juniors, or recreational athletes. For example, He et al. (2025) focused on female athletes but primarily in relation to injury risk during landing mechanics, not power-performance relationships. This gap highlights the need for more inclusive samples to ensure external validity.
Lack of Longitudinal Evidence: Very few studies adopted longitudinal approaches that track changes in arm muscle power and smash performance over extended periods. Without such evidence, the sustainability of training-induced improvements remains uncertain (Silva et al., 2025).

Given these limitations, future research should prioritize: 1. Standardization of power assessment protocols (e.g., uniform medicine-ball weights, validated isokinetic testing). 2. Longitudinal intervention studies linking training adaptations to real-world match performance. 3. Diversified participant samples spanning different sexes, age groups, and competitive levels. 4. Integration of advanced biomechanical techniques, such as EMG and motion capture, to provide fine-grained insights into muscle activation and joint kinematics. By addressing these gaps, subsequent research can provide stronger causal evidence and practical guidelines, enhancing both the scientific robustness and applied relevance of training recommendations.

CONCLUSION

Arm muscle power exerts a clear, positive, and often dominant influence on badminton backhand smash effectiveness. Coaches are advised to implement structured upper-limb power programs, emphasize wrist- forearm conditioning, and regularly monitor biomechanical execution. Researchers should pursue standardized, longitudinal studies to deepen causal understanding and inform precision training.

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CONFLICT OF INTERESTS

The authors declare no competing financial or personal interests.

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