Jurnal Pendidikan Jasmani (JPJ)
Vol. 6, No.3, April 2026
ISSN: 2723-2816 (Online)

Biomechanical Analysis of Smash Movement in Badminton Athletes: A Case Study

M Arrival Mahindra[1], Riska Mulya[2], Radja Bumi Dirgantara[3], A'mal Nazhif Daulay[4], Tifan Fradous Sihombing[5], Mahmudin Matondang[6]

[1,2,3,4,5,6] Sports Coaching Education, Faculty of Sport Science, State University of Medan, Jl. William Iskandar Ps. V, Kenangan Baru, Percut Sei Tuan District, Deli Serdang Regency, North Sumatra 20221

Abstract
This study aims to analyze the biomechanical aspects of the smash movement of a university-level badminton athlete using a case study methodology. The smash is one of the most important strokes in badminton, as it primarily functions as an attacking stroke that is expected to directly generate points. The effectiveness of the smash is greatly influenced by coordination between body segments, movement speed, and joint angles used in each phase of the movement. The subject of this study was a university student badminton athlete with four years of training experience. Data was obtained through high-speed video recording (120 fps) and analyzed using Kinovea software to measure joint angles, swing speed, and the shuttlecock's trajectory. The results showed that in the preparation phase, the knee angle was around 110°, which functions as a potential energy support, while the elbow angle was around 80° in preparation for the arm swing. In the swing phase, shoulder rotation reaches high speeds that contribute to the acceleration of the stroke. Upon contact with the shuttlecock, the wrist angle opens approximately 25° to increase power. However, weaknesses were found in the follow-through phase where the foot position is less balanced, reducing the accuracy of the stroke. The results of this study emphasize the importance of body segment coordination and core stability training in supporting smash effectiveness.

Keywords: *Biomechanics, Smash, Badminton, Case Study*

Correspondence author: M Arrival Mahindra, Universitas Negeri Medan, Indonesia.
Email: Muhammadrrival1@gmail.com

INTRODUCTION

Badminton is a popular sport in Indonesia and has produced numerous achievements at the global level. In badminton, there are various basic techniques that an athlete must master, from the serve, lob, dropshot, drive, to the smash. Among these techniques, the smash is considered the primary weapon in offensive strategy due to its speed, power, and high potential for immediate points. Success in a smash is determined not only by muscle strength but also by the efficiency of body movements in accordance with biomechanical principles .

Sports biomechanics studies the human body as a moving mechanical system, emphasizing the analysis of force, speed, and trajectory. In the context of a smash, the movement begins with the preparation phase, swing, contact with the shuttlecock, and the follow-through phase. Each phase requires optimal coordination between the legs, trunk, shoulders, arms, and wrists. A small error in any one body segment can affect the outcome of the shot, whether in terms of speed, power, or accuracy.

Biomechanical studies of the badminton smash are important because they provide scientific information about how energy is transferred from larger to smaller body parts. With this understanding, coaches and athletes can design more specific training, focusing not only on increasing muscle strength but also on efficient movement techniques. Furthermore, biomechanical studies also play a role in preventing injuries caused by incorrect or repetitive movements .

Based on this, this study was conducted to analyze the smash movement of a student badminton athlete using a case study approach. The analysis focused on joint angles, movement speed, and body coordination during each phase of the smash. It is hoped that the results of this study will make a tangible contribution to the development of more effective training techniques to improve smash quality while maintaining athlete safety.

METHOD

This research uses a case study approach, focusing on the biomechanical analysis of the smash movement of a university-level badminton athlete. This case study was chosen because it allows researchers to examine the phenomenon in greater depth and detail within a single subject, allowing for a more comprehensive observation and analysis of every detail of the movement (Nela, 2023).

The research subject was a university-level badminton athlete with approximately four years of training experience. Subject selection was based on the criteria of understanding basic badminton techniques, having experience competing at the university level, and being willing to have their movements recorded during the study(Ma, Geok Soh, et al., 2024). By focusing on a single individual, this study allows for a more detailed description of each phase of the smash movement .

Data collection was conducted through video recording using a high-speed camera capable of recording up to 120 frames per second. The recordings were taken from two perspectives: from the side and from the front, to obtain a comprehensive picture of body angles, movement speed, and coordination between body segments(Yumin Zeng & Yu Sun, 2024). The video recordings were then analyzed using motion analysis software (Kinovea), which allows for the measurement of joint angles, shoulder rotation, arm swing speed, and wrist movement.

The research procedure involved asking subjects to execute ten standard smashes on a badminton court under controlled playing conditions. Each movement was then recorded, the most representative selected, and analyzed based on the four main phases of the movement: the preparation phase, the swing phase, the impact phase, and the follow-through phase.

Data analysis was conducted descriptively, combining quantitative measurements and qualitative observations. Quantitative results, including joint angles, speed, and trajectory, were analyzed to determine the regularity of biomechanical patterns (Ramasamy et al., 2023). Meanwhile, qualitative results were obtained through visual observations of body coordination, positional stability, and compliance with sports biomechanical principles. The combination of these two approaches is expected to provide a more comprehensive picture of how the smash movement is executed and the factors that influence its effectiveness (Matsunaga & Kaneoka, 2018).

With this methodology, the research seeks to provide both scientific and practical understanding, ensuring that the results are not only useful as academic data but also serve as a practical reference for coaches and athletes in developing more efficient and injury-free smash techniques.

RESULTS AND DISCUSSION

Result

After analyzing ten smash attempts performed by a case study subject, a university-level badminton athlete with approximately four years of training experience, a number of biomechanical metrics were obtained that were fairly consistent across the trials. The average knee angle in the preparation phase was approximately 110° ± 6°, indicating that the athlete flexed the knee sufficiently deeply to generate initial power from the leg. The elbow angle in the pre-swing averaged 80° ± 5°, indicating that the player positioned his arm in extreme preparation while maintaining optimal arm length without overflexion that could decrease velocity. Upon reaching the contact phase with the shuttlecock, the wrist angle opened approximately 25° ± 3°, indicating wrist snap or opening of the wrist as part of the energy transfer to the racket tip. The average shoulder rotational speed at the top of the swing was approximately 325°/s ± 15°/s, which was then transmitted to the racket and tip trajectory, where the estimated linear speed of the racket tip at contact was 21 m/s ± 2.5 m/s. Furthermore, the vertical displacement of the center of mass (CoM) from the setup phase to the top of the swing was recorded at approximately 10 cm ± 2 cm, indicating that the athlete utilized the upward thrust to increase the energy of the vertical movement. The time elapsed from the start of the swing phase to contact averaged 0.18 s ± 0.02 s, indicating that the swing phase was relatively fast. Finally, qualitative post-landing observations indicated that in some trials there was a slight imbalance: the athlete tended to lean forward or shift his footing, although this instability was minor and did not always affect the overall movement. This can be seen in the following table.

Table 1. Average Biomechanical Parameters of Smash Movement in Badminton Athletes

Variable	Mean ± SD
Knee angle (preparatory phase)	110° ± 6°
Right angle (start of swing)	80° ± 5°
Wrist angle (at contact)	25° ± 3°
Shoulder rotation velocity (peak)	325°/s ± 15°/s
Linear velocity of the racket tip at contact (estimation)	21 m/s ± 2.5 m/s
CoM vertical displacement (preparation → peak)	10 cm ± 2 cm
Swing phase time (preparation→contact)	0.18 s ± 0.02 s

Discussion

The measured angle and velocity values support a pattern of energy transfer from the lower to the upper body. The preparation phase, with an optimal knee angle, allows for elastic energy storage in the leg muscles, followed by hip and trunk rotation, which then transfers energy to the shoulders and arms. These findings align with (Cui et al., 2022) study describing overhead strokes; they emphasized that skilled players exhibit a distinct sequence of body segment activation to achieve high racket speeds. (Li et al., 2023)

An elbow angle of approximately 80° allows the arm to be in a ready position to accelerate forward with an optimal swing length. A wrist angle of approximately 25° at contact indicates that wrist snap plays a significant role in generating racket tip speed. A study by (Li et al., 2023) comparing novice and skilled players found that skilled players had more consistent wrist angle settings and generated higher shuttlecock speeds than novice players (Artazila & S, 2024).

High shoulder rotation (~325°/s) and estimated racquet tip speed (~21 m/s) indicate that the athletes in this study were capable of producing quite aggressive shots. An average swing time (from start to contact) of 0.18 seconds indicates an efficient and fast swing phase, which is important in smashes. This aligns with literature showing that swing speed and timing significantly influence smash success (Tajik et al., 2025).

A CoM displacement of approximately 10 cm indicates that the athlete is using an upward thrust (jump or semi-jump) to increase the vertical component of the smash motion. This has the potential to increase the power of the shot and the angle of the shuttlecock, particularly in the jump smash. Studies such as those comparing smash landings and landing biomechanics (He et al., 2025) (Yeap et al., 2025)indicate that using vertical power can increase output but also increases the demands on post-landing stability.

Post-landing observations show that some smashes result in slight forward body movement or shifting of the foot when footwork/landing is suboptimal. Although this instability is small, its effects are significant in terms of shuttlecock directional accuracy and contact angle consistency. Recent literature on landing biomechanics and injury prevention suggests that neuromuscular control and core stability training are crucial. (Edmizal et al., 2024)

These results clearly demonstrate that, in addition to strength and speed, aspects such as body segment coordination (timing), post-landing stability, and neuromuscular control are essential components of training. Exercises aimed at strengthening the core, improving landing technique, and improving follow-through can help reduce shot variability and the risk of injury (Pengked et al., 2025).

Although the data obtained are quite informative, this study has limitations: the sample size was limited to a single individual, the analysis was 2D, and the speed estimation did not use direct measurement tools (radar or specialized sensors). Therefore, the results should be interpreted with caution and not directly generalized. Future research is recommended to involve more athletes, use 3D motion capture, force plates, and direct speed measurement tools (Ma, Soh, et al., 2024).

CONCLUSION

Based on the results of a biomechanical analysis of the smash movement in university-level badminton athletes, it can be concluded that the effectiveness of a smash is significantly influenced by body segment coordination, efficient kinetic patterns, and optimal joint angles. Data shows that in the preparation phase, a knee angle of around 110° plays a crucial role in generating initial power from the leg to initiate the kinetic chain. Furthermore, in the swing phase, rapid shoulder rotation (approximately 325°/s) and an elbow angle of 80° allow for optimal acceleration toward the point of contact. The combination of torso rotation, arm swing, and wrist opening of approximately 25° are the primary factors contributing to racket tip speeds reaching 21 m/s.

A vertical displacement of the center of mass of approximately 10 cm indicates that the upward thrust element contributes to increased hitting force and increased the shuttlecock's impact angle. However, post-landing stability remains an area of concern, as slight imbalances have the potential to reduce movement efficiency and increase the risk of injury if not properly controlled.

Overall, the results of this case study reinforce the view that smash performance depends not only on muscle strength but also on efficient motor coordination and biomechanical alignment. Training that emphasizes synchronization between body segments, core stability, and neuromuscular control during landing is highly recommended to improve performance while minimizing the risk of injury.

This research is expected to serve as a reference for coaches, athletes, and academics in designing more effective and measurable biomechanics-based training programs. Further studies involving more subjects and utilizing 3D motion analysis technology are recommended to generalize the results and provide a deeper understanding of the characteristics of the smash movement in modern badminton.

REFERENCES

Artazila, S. Z. N., & S, A. (2024). Analysis of Badminton Techniques Smash Using a Biomechanical Approach: Systematic Literature Review. *JUMORA: Jurnal Moderasi Olahraga*, *4*(2), 232–241. https://doi.org/10.53863/mor.v4i2.1474

Cui, X., Lam, W. K., Gao, Q., Wang, X., & Zhao, T. (2022). Biomechanical Analysis on Skilled Badminton Players during Take-Off Phase in Forehand Overhead Strokes: A Pilot Study. *Biology*, *11*(10), 1401. https://doi.org/10.3390/biology11101401

Edmizal, E., Barlian, E., Komaini, A., Hauw Sin, T., Ahmed, M., Pratap Singh, A., Haryanto, J., & Arzhan Hidayat, R. (2024). Biomechanical Analysis of Smash Stroke in Badminton: A Comparative Study of Elite and Recreational Players: a systematic review. In *Retos* (Vol. 57). https://recyt.fecyt.es/index.php/retos/index

He, Z., Fang, Z., Ye, H., & Su, S. (2025). Impact of unanticipated and backhand area smash landing on the lower limb biomechanics of female badminton players. *Frontiers in Bioengineering and Biotechnology*, *13*. https://doi.org/10.3389/fbioe.2025.1609911

Li, F., Li, S., Zhang, X., & Shan, G. (2023). Biomechanical Insights for Developing Evidence-Based Training Programs: Unveiling the Kinematic Secrets of the Overhead Forehand Smash in Badminton through Novice-Skilled Player Comparison. *Applied Sciences*, *13*(22), 12488. https://doi.org/10.3390/app132212488

Ma, S., Geok Soh, K., Binti Japar, S., Xu, S., & Guo, Z. (2024). Maximizing the performance of badminton athletes through core strength training: Unlocking their full potential using machine learning (ML) modeling. *Heliyon*, *10*(15), e35145. https://doi.org/10.1016/j.heliyon.2024.e35145

Ma, S., Soh, K. G., Japar, S. B., Liu, C., Luo, S., Mai, Y., Wang, X., & Zhai, M. (2024). Effect of core strength training on the badminton player's performance: A systematic review & meta-analysis. *PLoS ONE*, *19*(6 June). https://doi.org/10.1371/journal.pone.0305116

Matsunaga, N., & Kaneoka, K. (2018). Comparison of Modular Control during Smash Shot between Advanced and Beginner Badminton Players. *Applied Bionics and Biomechanics*, *2018*, 1–6. https://doi.org/10.1155/2018/6592357

Nela, S. (2023). Implementasi Teknologi Blockchain dalam Sistem Manajemen Identitas: Studi Kasus Pengamanan Data Pasien di Klinik ABC. *Jurnal Ilmu Komputer (JILKOM)*, *1*(09).

Pengked, K., Hareebin, Y., Tawanwongsri, W., & Manunyanon, S. (2025). Badminton-related musculoskeletal injuries in senior players: Epidemiology and preventive strategies for common injuries. *Electronic Journal of General Medicine*, *22*(1), em629. https://doi.org/10.29333/ejgm/15917

Ramasamy, Y., Usman, J., Razman, R., Wei, Y. M., Towler, H., & King, M. (2023). A Systematic Review of the Biomechanical Studies on Shoulder Kinematics in Overhead Sporting Motions: Types of Analysis and Approaches. *Applied Sciences*, *13*(16), 9463. https://doi.org/10.3390/app13169463

Tajik, R., Dhahbi, W., Fadaei, H., & Mimar, R. (2025). Muscle synergy analysis during badminton forehand overhead smash: integrating electromyography and musculoskeletal modeling. *Frontiers in Sports and Active Living*, *7*. https://doi.org/10.3389/fspor.2025.1596670

Yeap, M. W., Ramasamy, Y., Usman, J., King, M., & Razman, R. (2025). Knee Abduction Angles and Landing Kinematics in Badminton Jump Smash: A Study of ACL Injury Risk Factors. *Bioengineering*, *12*(4), 343. https://doi.org/10.3390/bioengineering12040343

Yumin Zeng, & Yu Sun. (2024). Analysis on the Importance of Core Strength Training in College Badminton Teaching. *Journal of Human Movement Science*, *5*(1). https://doi.org/10.23977/jhms.2024.050102