JURNAL MASTER PENJAS & OLAHRAGA
Volume 7 | Issue 1 | April 2026 | pp. 944-953
p-ISSN: 2725-5660 | e-ISSN: 2722-1202
https://jmpo.stkippasundan.ac.id/index.php/jmpo

Biomechanical Analysis of Jump Smash in Badminton Athletes

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Abstrac: This study aimed to analyze the biomechanics of jump smash techniques in badminton athletes at PB Polda Sumbar. A descriptive quantitative method with a biomechanical analysis approach was used. The participants were badminton athletes selected purposively based on their active involvement in training sessions. Data were collected through observation and video recordings of jump smash movements. The analysis focused on body posture, joint angles, movement coordination, and landing balance. The results showed that effective jump smash performance was influenced by proper body coordination, optimal knee flexion during take-off, arm swing speed, and body balance during landing. Athletes with better biomechanical movement patterns produced stronger and more accurate smashes. In conclusion, proper biomechanical techniques play an important role in improving jump smash effectiveness and overall badminton athlete performance.

Keyword: Badminton, Biomechanics, Jump Smash, Athletes, Movement Analysis

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ISSN 2721-5660 (Cetak)
ISSN 2722-1202 (Online)

How to cite this article (APA):
Rafi, M., Alimuddin, Chaeroni, A., & Mukhtarsyaf, F. (2026). Biomechanical Analysis of Jump Smash in Badminton Athletes. *Jurnal Master Penjas & Olahraga*, *7*(1), 944–953. https://doi.org/10.37742/jmpo.v7i1.203

Article History:

Submitted : April, 2026	Revised : Mei, 2026	Accepted : Mei, 2026	Publish : Mei, 2026

INTRODUCTION

Sport is an activity that involves physical, mental, and social aspects carried out systematically to improve the quality of human life. Based on Law Number 11 of 2022 concerning Sports, sports activities play an important role not only in maintaining physical fitness but also in developing discipline, sportsmanship, responsibility, and social values in society. In addition, sports contribute to national development through the improvement of human resources and the achievement of athletic performance at both national and international levels (Winartin et al., 2023).

One of the most popular and rapidly developing sports in Indonesia is badminton. Badminton has become one of Indonesia's most successful sports at the international level, as evidenced by achievements in competitions such as the Olympic Games, Thomas Cup, Uber Cup, and All England Championships. These achievements indicate that Indonesia has a strong badminton coaching system supported by clubs and training centers that continuously develop athletes' technical, physical, and tactical abilities from an early age (Nurrahman, 2023).

Badminton is a racket sport played using a shuttlecock and can be performed in singles or doubles matches. The game requires speed, agility, coordination, strength, endurance, and technical precision (Susiono et al., 2024). Players must be able to move quickly across the court while performing various strokes accurately and efficiently. Therefore, mastering basic techniques is essential for achieving optimal performance in badminton competitions (Adi et al., 2024).

Basic badminton techniques include grip, footwork, service, lob, dropshot, drive, and smash. Among these techniques, the smash is considered one of the most important attacking strokes because it provides a high opportunity to score points directly (Rifai et al., 2020). One variation of the smash frequently used by athletes is the jump smash. The jump smash is performed by jumping before hitting the shuttlecock, allowing athletes to create a steeper angle and greater hitting power. This movement requires proper coordination between leg power, hip and shoulder rotation, arm swing, and wrist action to generate maximum force and accuracy (Mahindra et al., 2026).

From a biomechanical perspective, the jump smash consists of several movement phases, including the preparation phase, take-off phase, airborne phase, shuttlecock contact phase, and landing phase. During the preparation phase, athletes position their bodies to maintain balance before generating force through leg extension during take-off. While airborne, body rotation contributes to increasing arm swing momentum, resulting in greater shuttlecock speed. The shuttlecock should ideally be contacted at the highest point of the jump to create a sharper attack angle. Finally, proper landing technique is essential to maintain balance and reduce injury risk (Listina et al., 2021).

The effectiveness of a jump smash is influenced not only by technical mastery but also by physical conditions such as leg explosive power, arm strength, coordination, agility, and body flexibility. Athletes with good explosive leg power can achieve higher jumps, resulting in more effective attacking angles. In addition, arm and wrist strength contribute significantly to shuttlecock speed, while coordinated body movements improve movement efficiency and reduce unnecessary energy expenditure (Latuheru et al., 2024).

Based on preliminary observations conducted at PB Polda Sumbar, several athletes still demonstrated weaknesses in performing accurate jump smashes. Some athletes had difficulty directing the shuttlecock effectively toward target areas, while others showed poor coordination between footwork, body positioning, and racket swing. Biomechanically, these problems indicate inefficiencies in balance control, momentum transfer, and timing during movement execution. Errors during take-off, arm swing, or shuttlecock contact phases reduced the effectiveness of the smash and affected overall performance (Anugrah et al., 2022).

Observations also revealed technical errors such as insufficient leg drive during take-off, unstable body posture while airborne, and improper timing when contacting the shuttlecock. In addition, suboptimal hip and shoulder rotation reduced smash power and shuttlecock velocity. These findings suggest that athletes' understanding and application of biomechanical principles still need improvement to produce more effective and efficient movement patterns (Nurrahman, 2023).

Another factor affecting jump smash performance is the training method applied during coaching sessions. Based on observations, the training methods used at PB Polda Sumbar were relatively monotonous and lacked variation, causing athletes to experience boredom during practice. Limited variation in training may hinder motor skill development and movement understanding. Therefore, biomechanically based training approaches such as explosive power exercises, coordination drills, video analysis, and motion analysis technology are necessary to improve athletes' jump smash performance and technical understanding (Kuswanti et al., 2024).

Previous studies have discussed the biomechanics of badminton smash techniques from various perspectives. Nabhan et al. (2024) examined landing strategies in badminton footwork training and found that proper landing mechanics contribute significantly to balance control and injury prevention during jump smash movements. Meanwhile, Liu et al. (2024) explained that biomechanical coordination between body segments plays an important role in improving movement efficiency and performance in racket sports. In addition, Artazila (2024) analyzed smash movements in badminton athletes and reported that shoulder rotation, arm swing speed, and jump height strongly influence smash power and shuttlecock velocity. However, most previous studies focused primarily on elite athletes or specific movement components without comprehensively analyzing the entire biomechanical phases of jump smash execution, including preparation, take-off, shuttlecock contact, and landing phases in young badminton athletes. Furthermore, limited studies have specifically examined the biomechanical characteristics of athletes at PB Polda Sumbar using motion analysis software. Therefore, this study offers novelty by providing a comprehensive biomechanical analysis of jump smash techniques in PB Polda Sumbar athletes using Kinovea software to evaluate movement coordination, joint angles, jump height, and landing balance across all movement phases. Based on these considerations, this study aims to analyze the biomechanics of jump smash techniques in badminton athletes at PB Polda Sumbar.

METHOD

This study employed a descriptive quantitative research design aimed at analyzing the biomechanics of jump smash techniques in badminton athletes at PB Polda Sumbar. The descriptive method was used to describe and evaluate athletes' movement patterns based on biomechanical principles without providing experimental treatment. The study focused on identifying the quality of movement execution during the jump smash technique through numerical and observational analysis (Judijanto et al., 2025). The research was conducted at PB Polda Sumbar, located on Jl. Jend. Sudirman, Jati Baru, East Padang District, Padang City, West Sumatra, Indonesia. Data collection was carried out on Tuesday, November 25, 2025.

The population of this study consisted of all active badminton athletes at PB Polda Sumbar who regularly participated in training programs. The total population included 26 athletes divided into several age categories, namely early-age athletes, beginner athletes, and junior athletes. The sampling technique used in this study was purposive sampling. This technique was selected to ensure that the participants met specific criteria relevant to the objectives of the research. The sample consisted of 12 early-age athletes aged 8–11 years who actively participated in regular training at least three times per week, had at least one year of badminton training experience, possessed basic jump smash skills, and were physically healthy without injury during the research process (Cahyani & Surayanah, 2026).

The instrument used in this study was video recording equipment combined with biomechanical motion analysis software. The main instrument for movement analysis was Kinovea software version 0.9.5.0, which was used to analyze the jump smash movement frame by frame. Video recordings were obtained using one Canon EOS 60D DSLR camera and two smartphone cameras with Full HD 1080p 60fps resolution. The DSLR camera had specifications including an 18 MP CMOS sensor, 1920 × 1080 video resolution, and MOV video format. Kinovea software was utilized because it provides flexible and accurate motion analysis features, including angle measurement, object tracking, movement playback, and coordinate extraction.

The software allowed the researcher to analyze kinematic variables such as knee joint angle, elbow angle, shoulder angle, jump height, body position, and landing balance during jump smash execution.

The data collection procedure began with recording athletes performing jump smash movements on the badminton court. Camera placement was adjusted according to the main movement plane to obtain optimal motion analysis results. One camera was positioned on the sagittal plane at a distance of approximately 5–7 meters from the athlete and perpendicular to the direction of movement. Another camera was positioned on the frontal plane approximately 6–8 meters from the athlete to capture body alignment and movement symmetry.

After recording, the video files were transferred to a laptop in MOV or MP4 format and analyzed using Kinovea software. The researcher observed the movement sequence frame by frame to identify biomechanical characteristics during the preparation phase, take-off phase, airborne phase, shuttlecock contact phase, and landing phase. Several markers and measurement tools available in the software were used to calculate movement angles and evaluate technical execution. Data analysis in this study used a biomechanical analysis approach. The recorded jump smash movements were analyzed descriptively to evaluate movement efficiency and technique quality. The analysis focused on joint angles, body coordination, jump height, timing accuracy, and landing stability. The results of the movement analysis were then interpreted narratively to describe the biomechanical performance of the athletes during jump smash execution.

RESULT

The results of this study were obtained through biomechanical analysis of jump smash movements performed by 12 badminton athletes from PB Polda Sumbar using Kinovea software. Each athlete performed three jump smash trials, and all movements were recorded using video cameras for detailed biomechanical analysis. The recorded videos were analyzed frame-by-frame to observe body movement patterns and determine the quality of movement execution during jump smash performance. The biomechanical analysis focused on three major movement phases, namely the preparation and take-off phase, the shuttlecock contact phase, and the landing phase. Several biomechanical indicators were measured, including shoulder angle, elbow angle, knee angle, ankle angle, jump height, and body balance during movement execution.

The results revealed that each athlete demonstrated different biomechanical characteristics in performing the jump smash technique. Some athletes showed effective movement coordination and stable body mechanics, while others still demonstrated technical weaknesses related to body alignment, movement synchronization, explosive power, and landing stability. These differences indicate that the quality of jump smash performance is strongly influenced by biomechanical factors and individual movement coordination.

The preparation and take-off phase is considered the foundation of the jump smash movement because this phase determines the quality of the jump and body balance before the athlete performs the smash. During this phase, athletes prepare their body position by flexing the knees, positioning the upper body, and coordinating arm swings to generate explosive force from the lower extremities. Figure 1 illustrates the body position of athletes during the preparation and take-off phase.

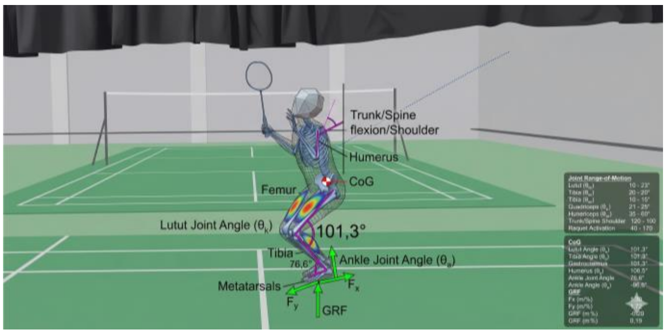

Figure 1. Preparation and Take-Off Phase of Jump Smash Movement

The biomechanical analysis results for the accurate target category during the preparation and take-off phase are presented in Table 1.

Table 1. Biomechanical Analysis Results in the Preparation and Take-Off Phase

Athlete	Shoulder Angle	Elbow Angle	Knee Angle	Ankle Angle
ZZ	68.5°	42.2°	101.3°	76.6°
Average	68.5°	42.2°	101.3°	76.6°

Table 1 shows that athlete ZZ demonstrated the best biomechanical movement during the preparation and take-off phase. The athlete produced a knee angle of 101.3°, indicating optimal knee flexion to generate explosive leg power during take-off. Proper knee flexion allowed the athlete to maximize lower body force production before jumping. In addition, the shoulder angle of 68.5° and elbow angle of 42.2° indicate coordinated arm swing movement, which contributed to body momentum and jump stability.

The results also showed that proper coordination between the upper and lower body segments plays a significant role in producing effective jump smash performance. Athletes who demonstrated appropriate knee flexion and synchronized arm movement tended to produce more stable jumps and better body balance before entering the airborne phase. On the other hand, athletes with poor body coordination showed unstable body positions and reduced jump effectiveness.

The shuttlecock contact phase was identified as the core movement phase in jump smash execution because this phase determines the power, speed, and accuracy of the smash. During this phase, athletes contact the shuttlecock at the highest point of the jump while coordinating body rotation, arm swing, shoulder movement, elbow extension, and wrist action. Figure 2 presents the body position during the shuttlecock contact phase.

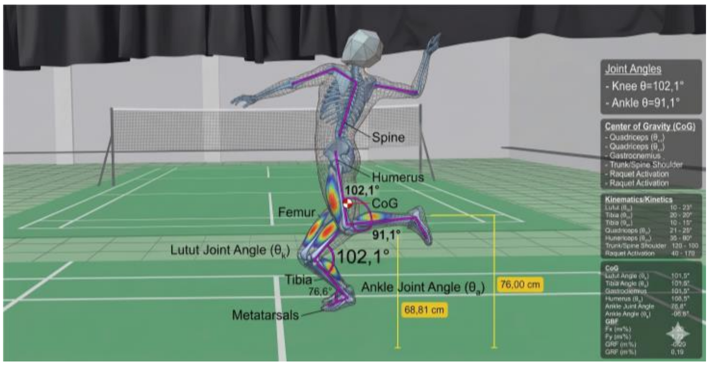

Figure 2. Shuttlecock Contact Phase of Jump Smash Movement

The biomechanical analysis results during the shuttlecock contact phase are presented in Table 2.

Table 2. Biomechanical Analysis Results in the Shuttlecock Contact Phase

Athlete	Knee Angle	Elbow Angle	Shoulder Angle	Jump Height
AT	167.3°	92.7°	67.4°	7.25 cm
DT	72.6°	45.3°	69.1°	27.09 cm
GF	111.3°	52.8°	72.4°	19.44 cm
ZZ	102.1°	96°	91.1°	68.81 cm
AN	145°	112.5°	162.8°	28.64 cm
Average	128.79°	74.91°	84.30°	27.82 cm

Based on Table 2, athlete ZZ produced the highest jump height at 68.81 cm, indicating excellent explosive leg power and effective take-off mechanics. Higher jump performance allowed the athlete to contact the shuttlecock from a higher point, resulting in a steeper smash trajectory and increased attack effectiveness. Meanwhile, athlete AN produced the largest shoulder angle at 162.8°, indicating strong upper-body rotation and effective arm swing coordination during smash execution.

The results also revealed variations in elbow angle and shoulder movement among athletes. Athletes who showed better shoulder rotation and elbow extension tended to generate stronger and faster smashes. Proper body rotation contributes to efficient transfer of force from the lower body to the upper body and ultimately to the racket and shuttlecock. In contrast, athletes with limited shoulder rotation or poor elbow coordination produced weaker smash movements and reduced shuttlecock accuracy.

In addition, jump height was found to play an important role in determining smash effectiveness. Athletes who achieved higher jumps were able to generate sharper attack angles, making the shuttlecock more difficult for opponents to return. However, high jump performance alone was not sufficient to produce accurate smashes. Several athletes who demonstrated high jump performance still produced inaccurate smashes due to poor body coordination and unstable movement control during shuttlecock contact.

The landing phase is the final movement phase of jump smash execution and is important for maintaining body stability and reducing injury risk after landing. During this phase, athletes must control body balance and absorb impact force properly to return quickly to the ready position. Figure 3 illustrates athletes' body positions during the landing phase.

Figure 3. Landing Phase of Jump Smash Movement

Table 3. Biomechanical Analysis Results in the Landing Phase

Athlete	Shoulder Angle	Knee Angle
AT	152.6°	145.3°
DT	71.1°	150.3°
AN	63.7°	147.5°
Average	83.72°	144.8°

Table 3 shows that athletes generally demonstrated relatively stable landing positions. The average knee angle of 144.8° indicates that most athletes landed with slightly flexed knee positions, which helped absorb impact force and reduce stress on the joints. Proper knee flexion during landing is important to minimize injury risk and maintain body balance.

The results also showed that athletes who maintained stable shoulder positioning during landing were able to recover more quickly and continue movement efficiently. In contrast, athletes who landed with unstable body posture experienced balance difficulties and delayed recovery movement. Proper landing mechanics are essential not only for injury prevention but also for maintaining movement continuity during badminton rallies.

Overall, the findings demonstrated that jump smash performance is influenced by multiple biomechanical factors, including body coordination, explosive leg power, shoulder rotation, jump height, movement synchronization, and landing stability. Athletes who demonstrated effective movement coordination throughout all phases of jump smash tended to produce stronger, faster, and more accurate smashes compared to athletes with less coordinated movement patterns.

DISCUSSION

This study aimed to analyze the biomechanics of jump smash movements in badminton athletes at PB Polda Sumbar using Kinovea software. The findings showed that athletes demonstrated varying levels of biomechanical performance across the preparation and take-off phase, shuttlecock contact phase, and landing phase. These differences were influenced by movement coordination, explosive leg power, body balance, joint angles, jump height, and technical execution during jump smash performance.

The preparation and take-off phase plays a fundamental role in generating explosive power and producing optimal jump height during jump smash execution. Athletes who demonstrated appropriate knee flexion and coordinated arm swings tended to achieve better jump stability and stronger smash performance. Effective take-off mechanics allow athletes to transfer force efficiently from the lower body to the upper body, resulting in more effective airborne movement. According to Anugrah et al. (2022), proper coordination between the lower extremities and upper body segments significantly contributes to jump smash effectiveness because explosive movement begins during the take-off phase.

The findings showed that athletes with optimal knee flexion produced better jump mechanics and body balance. Knee flexion allows the quadriceps and hamstring muscles to store elastic energy before explosive extension occurs during take-off. Athletes who produced knee angles that were too small or too large showed reduced jump effectiveness and unstable body balance. This finding supports biomechanical principles suggesting that proper lower body positioning is essential for maximizing vertical jump performance in badminton movements.

The shuttlecock contact phase was identified as the most important phase in jump smash execution because this phase determines smash power, speed, and accuracy. Athletes with greater jump height and effective shoulder rotation tended to produce stronger and sharper smashes. The results support the theory proposed by Isra & Asnaldi (2020), which explains that jump height and body rotation are key biomechanical components influencing jump smash performance. Athletes who contacted the shuttlecock at the highest point produced steeper smash trajectories, making the shuttlecock more difficult for opponents to return.

The findings also demonstrated that shoulder rotation and elbow extension contribute significantly to racket acceleration during smash execution. Athletes with better shoulder rotation generated greater arm swing momentum and higher shuttlecock velocity. Efficient transfer of force from the lower body through the trunk and upper extremities allowed athletes to maximize smash power. Conversely, athletes who showed limited body rotation or poor arm coordination produced less effective smash movements.

In addition, jump height alone was not sufficient to produce accurate jump smashes. Some athletes demonstrated high jump performance but failed to produce accurate shuttlecock placement because of poor body coordination and unstable body control during contact. This finding indicates that successful jump smash performance requires synchronization between jump mechanics, shoulder rotation, elbow extension, wrist movement, and body balance.

The landing phase was also identified as an important biomechanical component of jump smash execution. Athletes who landed with slightly flexed knee positions demonstrated better body stability and reduced impact force on the joints. Hung et al. (2020) stated that proper landing mechanics are important for distributing impact force evenly across the lower extremities and reducing stress on the knee and ankle joints. Athletes who landed with excessively straight or excessively bent knees experienced poorer balance and increased injury risk.

Body balance during landing is important not only for injury prevention but also for maintaining movement continuity during badminton gameplay. Athletes who maintained proper landing posture were able to return more quickly to the ready position and continue movement efficiently during rallies. In contrast, unstable landing mechanics delayed movement recovery and reduced overall game effectiveness.

Furthermore, this study demonstrated that biomechanical coordination between the lower body and upper body segments is essential throughout all phases of jump smash execution. The synchronization of leg power, hip rotation, shoulder movement, arm swing, and wrist action contributes significantly to movement efficiency and smash effectiveness. These findings are consistent with biomechanical principles proposed by Krizkova et al. (2021), which emphasize that efficient movement coordination improves athletic performance and movement accuracy in racket sports.

The results also indicate that systematic training programs focusing on explosive power, coordination, flexibility, balance, and technical biomechanics are necessary to improve jump smash performance in badminton athletes. Coaches should provide specific training exercises emphasizing lower-body power development, shoulder rotation mechanics, arm swing coordination, and landing stability. In addition, biomechanical analysis using Kinovea software can provide valuable visual feedback for athletes and coaches to identify technical weaknesses and improve movement quality during jump smash execution.

Overall, the findings of this study suggest that jump smash performance in badminton is influenced by complex biomechanical interactions involving movement coordination, explosive strength, body balance, and technical execution. Athletes who demonstrated effective biomechanics throughout all movement phases tended to produce stronger, faster, and more accurate jump smashes. Therefore, understanding biomechanical principles and applying them in training programs are essential for improving badminton performance and reducing injury risk among athletes. However, this study has several limitations. First, the sample size was relatively small and only involved athletes from PB Polda Sumbar, limiting the generalizability of the findings to broader badminton populations. Second, the study focused only on kinematic biomechanical analysis using video-based motion analysis without incorporating kinetic measurements such as muscle activity or force analysis. Third, environmental and individual physical factors such as fatigue level, training intensity, and athlete experience were not examined in detail. Therefore, future studies are recommended to involve larger and more diverse samples, apply more advanced biomechanical instruments such as motion capture systems and electromyography (EMG), and examine additional physical and physiological factors that may influence jump smash performance in badminton athletes.

CONCLUSION

Based on the results of the biomechanical analysis of jump smash movements in badminton athletes at PB Polda Sumbar, it can be concluded that the effectiveness of jump smash performance is strongly influenced by biomechanical factors during the preparation and take-off phase, shuttlecock contact phase, and landing phase. Athletes who demonstrated proper movement coordination, optimal knee flexion, effective shoulder rotation, stable body balance, and synchronized arm swing produced more powerful, accurate, and efficient jump smashes.

The findings showed that the preparation and take-off phase plays an important role in generating explosive power and jump height, while the shuttlecock contact phase determines smash speed, power, and attack angle. In addition, proper landing mechanics contribute significantly to body stability, movement recovery, and injury prevention. Athletes with better biomechanical movement patterns were able to perform more effective jump smashes compared to athletes who demonstrated poor body coordination and unstable movement control.

This study also indicates that biomechanical analysis using Kinovea software can provide valuable information regarding athletes' movement quality and technical weaknesses during jump smash execution. Therefore, coaches and athletes are encouraged to apply biomechanically based training programs focusing on explosive leg power, movement coordination, balance, flexibility, and technical accuracy to improve jump smash performance in badminton athletes.

Overall, the application of proper biomechanical principles is essential for improving jump smash effectiveness, enhancing athletic performance, and minimizing the risk of injury in badminton players.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to all parties who have contributed to the completion of this research. Special appreciation is extended to PB Polda Sumbar for granting permission and facilitating the data collection process, as well as to all badminton athletes who willingly participated in this study. The authors also acknowledge the valuable support from colleagues and academic mentors at Universitas Negeri Padang for their constructive feedback and academic guidance throughout the research process. In addition, the authors would like to thank those who assisted in the technical aspects of data collection and video analysis using Kinovea software. Finally, the authors deeply appreciate the support and encouragement from family and peers, which have been instrumental in the successful completion of this study.

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