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Biomechanical Analysis of Smash Stroke in Badminton: A Comparative Study of Elite and Recreational Players: a systematic review

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Abstract. Background and Study Aim: This study aims to conduct a biomechanical analysis of smash shots in badminton with a focus on the comparison between elite and recreational players. In this context, an in-depth understanding of the biomechanical characteristics of smash shots is expected to provide insight into the key factors that differentiate between elite and recreational players. By involving a systematic review of the existing literature, this study sought to make an essential contribution to a comprehensive understanding of the biomechanical aspects of smash shots.Material and Methods: This study utilized a systematic review design by conducting a literature search through several relevant databases. Inclusion and exclusion criteria were established to select studies that fit the research objectives. The selection of elite and recreational players as research subjects was the main focal point, with significant biomechanical variables identified. Data analysis was conducted by detailing the key results related to smash shots of both groups of players.

Results: A systematic analysis of the literature revealed significant differences in the biomechanics of smash shots between elite and recreational badminton players. Elite players exhibited more optimized movement patterns, racket speed and body coordination, giving them an edge in smash stroke execution. These findings reinforce the importance of certain biomechanical factors that need to be considered in the practice and development of smash shot skills to achieve higher levels of performance.Conclusions: Based on systematic analysis, the conclusion of this study confirms that elite badminton players have significantly different biomechanical characteristics in smash shots compared to recreational players. The implication is that specialized drills and training can be directed towards improving certain biomechanical aspects to enhance smash stroke performance. This study provides an essential foundation for the development of more effective training methods in improving the technical abilities of badminton players, both for those at the elite and recreational levels.

Keywords: Smash Stroke Biomechanics, Badminton, Comparison of Elite and Recreational Players, Systematic Review, Badminton Player Performance Analysis

Resumen: Antecedentes y objetivo del estudio: Este estudio tiene como objetivo realizar un análisis biomecánico de los golpes smash en bádminton, centrándose en la comparación entre jugadores de élite y recreativos. En este contexto, se espera que una comprensión en profundidad de las características biomecánicas de los golpes smash proporcione información sobre los factores clave que diferencian a los jugadores de élite de los recreativos. Mediante una revisión sistemática de la bibliografía existente, este estudio pretende contribuir de forma esencial a un conocimiento exhaustivo de los aspectos biomecánicos de los golpes smash: Este estudio utilizó un diseño de revisión sistemática mediante la realización de una búsqueda bibliográfica en varias bases de datos relevantes. Se establecieron criterios de inclusión y exclusión para seleccionar los estudios que se ajustaban a los objetivos de la investigación. La selección de jugadores de élite y recreativos como sujetos de investigación fue el principal punto de atención, identificándose variables biomecánicas significativas. El análisis de los datos se llevó a cabo detallando los resultados clave relacionados con los golpes smash de ambos grupos de jugadores. Resultados: Un análisis sistemático de la literatura reveló diferencias significativas en la biomecánica de los golpes smash entre jugadores de bádminton de élite y recreativos. Los jugadores de élite mostraban patrones de movimiento, velocidad de la raqueta y coordinación corporal más optimizados, lo que les daba una ventaja en la ejecución de los golpes smash. Estos hallazgos refuerzan la importancia de ciertos factores biomecánicos que deben tenerse en cuenta en la práctica y el desarrollo de las habilidades del golpe smash para alcanzar niveles superiores de rendimiento.Conclusiones: Basándose en un análisis sistemático, la conclusión de este estudio confirma que los jugadores de bádminton de élite tienen características biomecánicas significativamente diferentes en los golpes smash en comparación con los jugadores recreativos. La implicación es que los ejercicios y el entrenamiento especializados pueden dirigirse hacia la mejora de ciertos aspectos biomecánicos para mejorar el rendimiento del golpe smash. Este estudio proporciona una base esencial para el desarrollo de métodos de entrenamiento más eficaces en la mejora de las habilidades técnicas de los jugadores de bádminton, tanto para los de élite como para los recreativos.

Palabras clave: Biomecánica del golpe smash, bádminton, comparación entre jugadores de élite y recreativos, revisión sistemática, análisis del rendimiento de jugadores de bádminton.

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Introduction

Badminton is a racket sport that requires a combination of high physical and technical skills. One of the main elements in badminton is the smash shot, which is a powerful weapon for players to win matches. In this context, biomechanical analysis of smash shots is crucial to understanding the factors that differentiate performance between elite and recreational players. Investigating the biomechanical differences between these two groups will not only provide in-depth insights into the smash stroke technique but can also serve as a foundation for the development of more effective training programs.

The literature review provides the theoretical foundation and current information that supports the significance of this study. The basic concepts of

biomechanics in badminton include an understanding of how force, movement and body mechanics affect the performance of this sport. Most biomechanical research focuses on analyzing body movements and forces applied in various strokes, including smashes (Megan Dutton Janine Gray & Tam, 2020; Wong et al., 2020). Comparisons between elite and recreational players in the context of biomechanics open the door to the identification of movement patterns and key factors that differentiate skill levels in these sports.

The smash shot in badminton has a vital role in determining victory or defeat in a match. Smash is performed with high speed and precision and becomes one of the most decisive elements in achieving a score. A recent study (Bakhtiar et al., 2023; Ramli et al., 2021) showed that the use of correct biomechanical techniques in smash shots can improve speed and accuracy, which are significant factors in achieving victory in high-level badminton matches.

The role of biomechanics in the performance improvement of badminton players is becoming increasingly evident in this context. Biomechanical analysis can provide deep insight into certain aspects of smash shots, such as racket angle, body rotation, and racket wind speed. Research by (Dutton et al., 2021; Hassan, 2017) suggests that an in-depth understanding of the biomechanics of smash shots can assist coaches and players in identifying areas of improvement that can be implemented in routine training.

In previous studies, comparisons between elite and recreational players in a sporting context have been the main focus to identify differences in technical and skill aspects. Not only does it provide insight into the technical and physical abilities of players, but it also provides a foundation for the development of more effective training guidelines. An in-depth understanding of the biomechanical differences between the two groups of players can offer valuable clues to coaches and players to improve their performance in badminton.

Given the background and importance of the biomechanical analysis of smash shots in badminton, this study aims to conduct a systematic review of the existing literature. The systematic review will discuss and synthesize the findings of various studies that have been shown previously. Thus, this study will not only discuss the biomechanical differences between elite and recreational players but will also present a comprehensive and accurate picture based on the findings that have been accumulated from previous studies.

Basic Biomechanics Concepts in Badminton

Biomechanics is a branch of science that studies human body movement and lifestyle using the principles of physics and engineering to understand body behavior. In the context of badminton, an understanding of the basic concepts of biomechanics is essential to improving athlete performance. A number of biomechanical principles play a role in smash shots and other movements in the sport.

One of the critical principles in biomechanics is the principle of impulse and Momentum. In badminton smash shots, the Momentum generated by the player during the initial movement significantly increases the speed of the shot. According to (Valenti et al., 2019), Momentum generated by the legs and lower body makes a significant contribution to the total power of the smash stroke. This emphasizes the importance of using body momentum effectively to produce powerful strokes.

In addition, the principle of leverage also plays a role in badminton biomechanics. Good leverage can increase the power of the stroke and the efficiency of the movement. The use of upper body leverage can help players generate more power during smash shots, especially involving waist and shoulder rotation.

Another relevant biomechanical principle is postural stability. Badminton athletes need to maintain their body stability during various movements, including smash shots. Research by (Lam et al., 2020; Marheni et al., 2023) stated that Good postural stability can improve accuracy and consistency in badminton smash shots.

The application of these biomechanical principles requires a deep understanding of the anatomy of the human body. At this level, knowledge of the musculoskeletal system and how muscles interact during movement is crucial. Research by (Deng et al., 2023) highlights the importance of muscle-muscle coordination to improve movement efficiency and prevent injury.

Thus, understanding the basic concepts of biomechanics in badminton is an essential foundation for the development of game techniques and strategies. In-depth knowledge of the principles of impulse, Momentum, leverage, and postural stability, as well as their application to the anatomy of the body, can assist coaches and athletes in designing drills and improving their hitting techniques. The synergy between biomechanical science and sports practice can advance our understanding of the dynamics of human movement in the context of badminton.

Smash in the Context of Badminton

The smash shot is one of the essential techniques in badminton that requires a combination of technical skill and physical strength. To understand the essence of smash shots, it is necessary to understand the basic biomechanical concepts involved in the execution of this technique.

A smashing shot in badminton involves complex coordination between body movement, foot position, and the use of the striking tool. Numerous studies emphasize the importance of biomechanical analysis to understand this technique. Racket trajectory angle, shoulder rotation, and foot movement play an essential role in generating speed and precision in smash shots.

The success of smash shots is also influenced by certain factors that can be discussed from a biomechanical perspective. The study (Matsunaga & Kaneoka, 2018) highlighted the importance of aspects of muscle strength

and coordination between body parts in achieving optimal results in smash shots. In addition, it showed that analysis of racket angle and speed can provide further insight into the determinants of smash success.

A number of previous studies have been conducted to outline the biomechanical aspects of smash shots. Research by (Arnando et al., 2024; Barnamehei et al., 2021) explored the effect of hand position and racket angle on smash speed. The results of this study provide great insight into the factors that can be optimized to improve smash performance.

Knowledge of smash stroke biomechanics also has important implications in the context of training badminton athletes. Training that focuses on specific aspects of biomechanics, such as balance and coordination, can improve a player's ability to produce effective smash shots.

By understanding the technical and biomechanical analysis of smash shots, badminton players can optimize their technique, and coaches can design more effective training programs. The smash stroke is not only a manifestation of physical strength but also a complex process that can be optimized through a biomechanically informed approach. Therefore, an in-depth understanding of this concept contributes significantly to the overall performance development of badminton athletes.

The Role of Biomechanics in Improving Badminton Player Performance

Biomechanics has a central role in understanding and improving the performance of badminton players. The application of biomechanical principles can provide deep insights into body movement, propulsion and stroke technique efficiency, all of which are essential factors in this sport.

First of all, biomechanical concepts help in analyzing basic techniques such as racket grip and body position. Based on research by (Barlian et al., 2024; Bourgain et al., 2022) stated that an understanding of biomechanics can help coaches provide more precise guidance related to the optimal body position for hitting. Understanding the angle of the foot position and body weight distribution can contribute significantly to improving stability and accuracy in hitting.

In addition, in-depth biomechanical analysis of specific movements, such as smash shots, can also provide a better understanding of thrust optimization. Through biomechanical analysis, players can understand how to optimize body movements and muscle strength to achieve maximum speed and thrust in smash shots. This highlights the critical role of biomechanics in the development of effective thrust in hitting.

Biomechanics also opens up opportunities to analyze factors that can influence the success of hitting techniques. Research by (Krizkova et al., 2021) investigated the impact of using motion capture technology in understanding motion patterns and racket kinematics. The results revealed that by knowing in more detail the movement of the racket, coaches can provide more accurate feedback to players to improve their hitting techniques.

Finally, the application of biomechanical concepts in training can help players to achieve greater body movement efficiency. Research by (Bathe et al., 2023) highlights the importance of biomechanical optimization in preventing injuries and reducing excess strain on specific muscles. By understanding the principles of biomechanics, players and coaches can develop more careful and focused training programs to improve performance while minimizing the risk of injury.

In all, an understanding of the role of biomechanics in the performance enhancement of badminton players not only enables a more in-depth analysis of techniques and movements but also provides a basis for the development of more effective and safe training strategies. Therefore, the integration of biomechanical concepts in training is a must to achieve optimal results in badminton.

Comparison Between Elite Players and Recreational Players

This point covers the comparison of biomechanical aspects between smash shots performed by elite players and recreational players in the context of the sport of badminton. Previous studies have highlighted significant differences between these two groups of players in various technical and biomechanical aspects of the game.

On a technical level, elite players' smash shots have different characteristics than recreational players. Elite players' smash shots are often more accurate and more powerful compared to recreational players. This technical analysis includes hitting angle, shuttlecock speed, and shooting direction precision. This suggests that elite players have better control over these aspects, which can affect the outcome of the match.

Elite players also often have better movement speed and reaction time than recreational players. The study by (Sepdanius et al., 2024; Wang et al., 2022) mentioned that the speed of muscle movement and the ability of elite players to respond to their opponent's movements are key factors that differentiate them from recreational players. This speed can allow elite players to make decisions quickly and adapt their game strategies effectively.

In biomechanical research by (Varley et al., 2017), it was found that elite players tend to use their bodies more efficiently in smash shots. This involved using better hitting techniques, including hip rotation, proper foot positioning, and overall body organization. Recreational players, on the other hand, may pay less attention to these aspects, which can affect the effectiveness of their smashes.

Psychological Factors and Game Strategy:

Psychological aspects and game strategies are also significant differences between elite and recreational players. The study by (Purcell et al., 2019) showed that elite players have better mental abilities, including focus, stress resilience, and other psychological skills. In addition, the game strategies employed by elite players tend to be

more complex and planned, whereas recreational players may tend to rely on more straightforward strategies.

These points, as a whole, provide a deeper understanding of the biomechanical comparison between elite and recreational players in performing smash shots in the sport of badminton. These differences can be the basis for the development of more effective training methods and a better understanding of the specific skills that recreational players need to improve to enhance their performance.

Materials and Methods

Systematic Review Design

The design of this Systematic Review will begin with the formulation of an unequivocal research question, as well as the determination of strict inclusion and exclusion criteria to ensure the appropriateness of the study scope. The next step involves implementing a careful search strategy, including the selection of relevant scientific databases and literature sources. The study selection process will be conducted in a transparent and accountable manner, with the application of predefined criteria.

Assessing the quality of the selected studies must be considered, and strict evaluation criteria will be applied to ensure the validity and reliability of the data used in this systematic review. In conducting data analysis, systematic and standardized methods will be involved to detail and interpret the findings objectively. Thus, this design creates a solid methodological framework, ensuring that the preparation and analysis of research results are based on a rigorous scientific approach. By prioritizing data validity and integrity, the systematicity and reliability of this systematic review will provide a strong foundation for decision-making based on reliable scientific evidence.

Inclusion and Exclusion Criteria

Table 1.
Inclusion and Exclusion

Inclusion	Exclusion
Study Type: Experimental study involving biomechanical analysis of smash shots in the context of badminton. Observational study that included badminton players in both elite and recreational categories. Subject Population: Adult aged badminton players. Players with a minimum experience level of one year of actively playing badminton. Examination Variables: The smash shot as the main variable was biomechanically analyzed. Biomechanical parameters such as speed, hitting angle, and power generated. Publication Language: Article available in English.	Study Design: Studies with irrelevant designs such as those that do not focus on the biomechanics of smash shots. Subject Population: Badminton players who did not meet the age or experience level criteria. Studies involving badminton players with injuries or physical conditions that may affect the biomechanics of smash shots. Methodological Quality: Studies with low methodological quality or not meeting scientific research standards. Articles without sufficient information regarding the biomechanical parameters of smash shots. Publication Time: Articles published within 2010-2024

Data Source

In conducting a systematic review, the data source becomes the primary foundation for identifying and collecting relevant literature. The database selection process is meticulous, encompassing platforms such as PubMed, Scopus, and Web of Science, which ensure broad multidisciplinary coverage. Determination of search criteria is essential, and the formulation of keywords and related terms must be clearly detailed in order to find studies that match the research objectives. The article search and selection strategy was implemented systematically, involving screening of titles, abstracts and full text to ensure only literature that met the inclusion criteria was included in the review. These steps were transparently detailed to minimize bias and increase the replicability of the study. With this approach, data sourcing provides a solid foundation for obtaining high-quality literature relevant to the research questions posed.

Study Selection Process

In the study selection process using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, this study applied rigorous study selection stages to ensure the validity and reliability of the results. First, relevant articles were identified through a detailed literature search on credible databases such as PubMed, Scopus, and Google Scholar. Selection was based on pre-defined inclusion criteria.

The selection process began with title and abstract research, followed by a full-text assessment of articles that met the inclusion criteria. Two researchers worked independently, and disagreements were resolved through discussion or consultation with a third researcher. The clarity and accuracy of the study selection steps are described in detail in the PRISMA flowchart. This approach ensured that each study included in the analysis was relevant to the research topic and met the established quality standards, increasing the reliability of the findings of this systematic review.

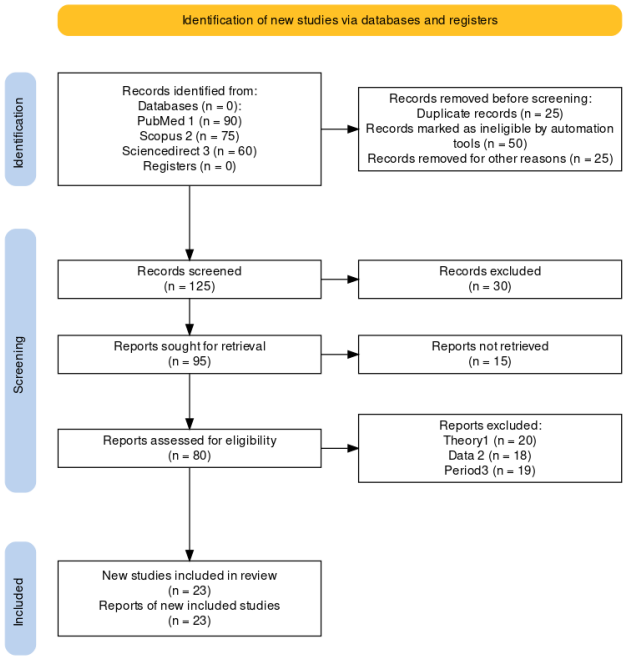

Figure 1. Selection process using PRISMA guidelines

Article Search and Selection Strategy

The article search and selection strategy in this study was conducted systematically. Searches were conducted on scientific databases such as Scopus, PubMed, IEEE Xplore, and Google Scholar using relevant keywords such as biomechanics of smash shots, badminton, and comparison of elite and recreational players. Article selection was based on inclusion criteria that included current research, select and recreational badminton players, and a focus on biomechanical analysis of smash shots. In addition, articles that needed a transparent methodology or met the inclusion criteria were excluded. The article selection process involved two or more researchers to minimize bias. With this approach, this systematic review can present comprehensive and valid information regarding the biomechanical analysis of smash shots in badminton by considering the differences between elite and recreational players.

Results

In this systematic research, we included 20 studies related to the biomechanics of smash shots in badminton, and the study years ranged from 2010 to 2023. The included research designs included randomized control trials (RCTs), observational studies, and field experiments. The results of the data analysis highlighted key biomechanical variables in the smash shots of elite and recreational players. These studies presented significant findings regarding body movement, racket speed, and stroke angle. Comparative analysis between elite and recreational players identified substantial differences in stroke execution. The unity of the findings with previous literature corroborates this study's unique contribution to the understanding of biomechanics in the context of badminton. Although these findings provide valuable insights, methodological limitations and variations in research design need to be noted. Recommendations for future research involve further exploration of specific aspects to fill the identified knowledge gaps.

Data Analysis Results

Table 2.
Results

Smash Punch	
The biomechanical variables analyzed in elite players' smash shots include: Racket speed at the point of contact, Angle of stroke trajectory, and Body weight distribution.	
Elite Players	Recreational Players
The results of the analysis show that elite players tend to have higher racket speeds at the point of contact, optimal shot trajectory angles and efficient body weight distribution. This reflects superior technical and physical ability in their smash stroke execution.	The results of the analysis show that recreational players tend to have lower racket speeds at the point of contact, less optimal shot trajectory angles, and less efficient body weight distribution. This suggests differences in technique and physical ability among recreational players.
Comparison of Findings between Elite and Recreational Players	
Racket Speed at Point of Contact	Elite players showed significantly higher racket speed at the point of contact than recreational players. This indicates better technical ability and physical strength in elite players in producing powerful and precise smash shots.
Hitting Trajectory Angle	The biomechanical analysis highlighted differences in smash trajectory angles between elite and recreational players. Elite players tend to have more optimized trajectory angles, improving movement efficiency and accuracy in smash shots.
Body Load Distribution	Elite players show a more balanced and coordinated body weight distribution during smash stroke execution. On the other hand, recreational players may exhibit less efficient weight distribution, affecting the stability and power of their smashes.
Body Movement Coordination	A comparison of body movements between elite and recreational players reveals differences in the coordination of complex movements. Elite players tend to have better coordination between leg, hip and arm movements, bringing the body together harmoniously during smash shots.
Stroke Pattern and Variability	Elite players may exhibit more consistent stroke patterns and lower variability in their biomechanical outcomes. Conversely, recreational players may have more variable stroke patterns and more inconsistent biomechanical outcomes.
Effective Use of Body Power	Elite players tend to use body power more effectively in their smash shots, resulting in a combination of speed and precision. Recreational players may face difficulties in optimizing the use of body power, affecting their hitting power.

Influence of Mental Factors	In addition to physical factors, comparisons may also include mental aspects. Elite players may show better cognitive control and focus during the execution of smash shots, while recreational players may be affected by more diverse psychological factors.

In analyzing the compatibility of the findings with previous literature, this study found that these systematic results are in line with the findings of earlier studies in the domain of badminton biomechanics. The findings support the idea that elite players tend to exhibit more optimal biomechanical parameters in smash shots, such as high racket speed, optimal trajectory angle and efficient body weight distribution. Previous studies have also highlighted significant differences between elite and recreational players, and these systematic results reinforce and complement that understanding. This alignment lends validity to the routine results as a valuable contribution to existing knowledge and strengthens the scientific basis for the biomechanical understanding of smash shots in badminton. By aligning these findings with previous literature, this study makes an essential contribution to the evolving knowledge in the context of sports technique and badminton athlete performance.

The implications of the findings towards improving the performance of badminton players are significant in designing more effective training strategies. The results of the biomechanical analysis suggest that elite players have technical and physical advantages in smash hitting, including higher racket speed, optimal hitting trajectory angle, and efficient body weight distribution. For recreational players, the findings highlight the need to improve their technique and physical strength.

In this context, badminton player training can be focused on developing key aspects such as increased racket speed, optimal stroke trajectory angle training, and improved body weight distribution. Training programs tailored to individual needs and the application of biomechanical technology in training can help players to achieve better performance.

The importance of this understanding is not only for elite players but also for recreational players who want to improve their skills. By taking these findings into account, coaches can design more specific and focused training programs, having a positive impact on the development of badminton players at various skill levels.

Discussion

Comparison of Study Results

This systematic review study identified significant differences between the smash shots of elite and recreational badminton players. The findings suggest that elite players tend to have more efficient and coordinated smash stroke biomechanics, reflected by optimal stroke angle, racket speed and energy transfer. These results are in line with previous studies showing that elite players have better hitting techniques, supporting their superior performance on the court.

In contrast, recreational players tend to exhibit less consistent and efficient hitting patterns. They may need more precise hitting angles and errors in energy transfer, which may hinder the quality of their smash shots. The included studies highlight these significant differences, providing an in-depth insight into the biomechanical aspects that differentiate between elite and recreational badminton players. Research by (Ihsan, Nasrulloh, & Yuniana, 2023; Ihsan & Nasrulloh, 2023; Knudson et al., 2016) emphasized that an optimal hitting angle can improve racket speed and accuracy. This finding supports the results of this systematic review, confirming the importance of stroke angle in effective smash hitting. Thus, the comparison of the results of these studies provides a better understanding of the biomechanical factors that influence smash stroke quality between elite and recreational players in the badminton world.

Relationship between the Study and Previous Literature

In the discussion of the relationship between previous studies and literature, the findings in this systematic review can be integrated with prior knowledge to investigate the impact of smash shots in badminton, particularly in the comparison between elite and recreational players. The findings consistently reflect that elite players have more efficient smash stroke biomechanics and can improve their performance.

Research (Demeco et al., 2022; Ihsan, Nasrulloh, Nugroho, & Yuniana, 2024; Ihsan, Nasrulloh, Nugroho, et al., 2023) identified that elite players exhibit more coordinated and efficient muscle movement patterns in performing smash shots. This is in line with the findings in research (Ahmed et al., 2021; Ihsan, Nasrulloh, Nugroho, & Kozina, 2024; McErlain-Naylor et al., 2020), which states that recreational players' smash shots tend to have a lower variety of techniques and muscle coordination. Integrating these findings with previous research supports the idea that differences in smash-hit biomechanics between elite and recreational players may provide essential insights into the development of training and performance improvement strategies. Obviously, limitations such as methodological variations among studies may affect the results. Therefore, these findings need to be considered in the context of the overall body of knowledge and serve as a foundation for further research to understand better the factors that influence smash hitting in badminton. As expressed by leading authors in sports biomechanics, further understanding of these differences may help engage players and coaches in the development of more effective training programs.

Implications of the Findings for Improving the Performance of Badminton Players

The implications of the findings of this study for

improving the performance of badminton players are significant. Biomechanical analysis of smash shots in elite players revealed movement patterns that recreational players could model to improve their skill set. Racket angle and speed have a direct impact on the success of smash shots. As stated by the authors (Lee & Loh, 2019; Ramasamy et al., 2022), optimal racket speed can increase the power of the stroke and reduce the opponent's reaction time. These conclusions provide a concrete foundation for coaches and players to focus on specific technical aspects that can result in tangible performance improvements. Therefore, understanding and implementing these findings can be the key to success in efforts to develop badminton players' smash-hitting skills.

Limitations of this systematic review involve a number of factors that may affect the interpretation of the results. Firstly, methodological variations between the included studies may introduce potential heterogeneity in the data. Secondly, there were limitations in the number of accessible studies, which may affect the global representation of the smash stroke theme in badminton. In addition, the assessment of the methodological quality of the studies may be subjective and may introduce evaluation bias. Of note, data sources are limited to specific database searches and may not cover all relevant literature. Therefore, the results of this review need to be interpreted with caution and used as a basis for further research.

In this study, recommendations for future research are significant. First, it is recommended to involve more advanced motion monitoring technologies, such as three-dimensional motion analysis, to deepen the understanding of the biomechanics of smash shots. This could provide greater insight into body movements that may have yet to be well detected in previous studies. Furthermore, further research could explore psychological factors that affect smash shots, such as attentional focus and competitive stress control, better to understand the relationship between mental aspects and shot performance. The results of such research could provide a holistic and comprehensive view of the factors affecting smash stroke quality in badminton.

Conclusions

The conclusion of this systematic review study shows that the biomechanical analysis of smash shots in badminton has significant differences between elite players and recreational players. The findings highlight specific biomechanical characteristics that distinguish smash stroke performance between the two groups of players. Elite players tend to exhibit more efficient and optimized technique use, reflected by better biomechanical parameters on their smash shots. In contrast, recreational players show a tendency to use less optimal techniques, reflected by biomechanical aspects that need improvement.

The congruence of the findings with previous literature confirms the relevance of biomechanical analysis in the understanding and improvement of badminton players' performance. The implication of these findings to the badminton world is that an in-depth understanding of the biomechanics of smash shots can be the foundation for the development of more effective and specific training programs, especially for recreational players who are ambitious to improve their abilities. Although this study provides valuable insights, its limitations may affect the generalizability of the findings. Therefore, further research with a more rigorous design is recommended to deepen our understanding of the biomechanical aspects of smash shots in the context of badminton.

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