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Physics in Badminton: How Prospective Coaches Perceive and Apply Torque Concepts

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Abstract

Background: Training methodologies in badminton often focus on technique and endurance, yet the integration of scientific principles, such as torque, remains underutilized. As a critical factor influencing shot power, speed, and accuracy, a deeper understanding of torque can optimize training effectiveness and systematically enhance athlete performance.
Aims: This research aims to analyze prospective badminton coaches' understanding and application of physics concepts, particularly torque, in training methodologies.
Methods: This research employed the qualitative descriptive method involving 24 prospective badminton coaches (17 males and 7 females, aged 18-22) in Bandung, Indonesia. A survey was conducted to assess their understanding of physics and its application in training. Data collected through the questionnaire was analyzed using NVivo software, which facilitated thematic analysis and coding of qualitative responses.
Results: The findings indicate that, while most of the respondents are familiar with physics terms, only a few recognize torque as a relevant concept in the badminton context. A deeper understanding of torque can help coaches optimize playing techniques by improving racket rotation efficiency, thereby enhancing hitting power with minimal energy expenditure.
Conclusion: This research demonstrates that integrating physics concepts, particularly torque on the racket, into badminton training provides a valuable perspective for improving training quality. The findings suggest that badminton coach training programs should integrate physics concepts to enhance training effectiveness and efficiency while systematically improving athlete performance based on scientific evidence.

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INTRODUCTION

The development of science and technology has significantly impacted various aspects of badminton training, particularly in enhancing both equipment and technique (González-Peño et al., 2024; Lin et al., 2021; Phomsoupha & Laffaye, 2015; Purnomo et al., 2023; Tiberi et al., 2024; Zulkarnain et al., 2024). Competitive success in badminton is closely linked to technological advancements. Utilizing scientific research has been shown to optimize and accelerate the training process (Bourdon et al., 2017; Kostiukevych et al., 2018). Integrating physics principles into training, especially in refining key aspects such as shot accuracy, speed, and power, is essential for coaches

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aiming to maximize athlete performance. The incorporation of fundamental physics concepts into coaching methodologies can improve training efficiency and support evidence-based practices and player development.

While scientific advancements have played a crucial role in improving training methods, many Indonesian badminton coaches transition from professional athletes, emphasizing early training and competition (Maksum & Indahwati, 2023). This emphasis, however, often limits their opportunities for in-depth formal education in sports science, including physics principles applicable to badminton. Despite this limitation, Indonesian coaches have achieved significant international success by relying on their practical expertise in elite-level training. Recognizing the importance of scientific knowledge in coaching, the Indonesian Badminton Association (PBSI) has introduced a sports science analytics platform to support evidence-based training and improve coaching methodologies, bridging the gap between traditional coaching approaches and scientific advancements.

One of the key technical aspects of badminton that can benefit from scientific integration is the hitting technique, which involves various physical and biomechanical factors, particularly the torque applied to the racket when executing a smash (Setijono et al., 2023; Soemardiawan et al., 2019). Although professional players have successfully mastered these techniques, the comprehensive understanding of the underlying physics principles remains limited among coaches, particularly prospective coaches (Chin, 2023; Raibowo et al., 2024). Addressing this knowledge gap is critical in ensuring that training methods are rooted in scientific principles, ultimately improving performance outcomes.

A deeper understanding of physics, particularly torque (Noor et al., 2021), is essential because torque plays a major role in influencing the force, speed, and accuracy of a shot. The application of torque to the racket handle directly affects the distribution of force and, consequently, the quality of the resulting shot (Suwannachote et al., 2023; Zhao et al., 2025). Research in other sports, such as tennis and baseball, demonstrates that torque significantly influences the power, speed, and precision of shots. For instance, in tennis, applying torque during a serve or groundstroke significantly increases ball velocity and spin, enhancing shot power (Landlinger et al., 2012). Similarly, in baseball, torque generated by wrist and forearm movements contributes to more powerful and accurate hits (Wong et al., 2021). In badminton, racket handling and wrist movements play a similarly critical role, suggesting that a deeper understanding of torque could help refine stroke techniques and enhance player performance.

Despite their significance, the application of physics principles in badminton training remains underdeveloped, particularly among prospective coaches, who often prioritize practical techniques over integrating scientific concepts (Lin et al., 2024). In fact, a deep understanding of scientific concepts is essential for enhancing various aspects (Fratiwi et al., 2024; Kaniawati et al., 2019; Nurdini et al., 2020). Previous research has examined various technical and biomechanical aspects of badminton. For instance, functional training has been implemented to enhance injury prevention, preparation, and rapid contraction in badminton instruction (Zhou et al., 2022). Additionally, biomechanical principles highlight the importance of rotational movements in the shoulder and radioulnar joints in executing powerful shots (Putra & Lumintuarso, 2020).

Furthermore, mathematical modeling based on the Brachistochrone problem suggests that a cycloid trajectory allows for the shortest shuttlecock smash time, offering a reference for optimizing shot execution (Putra et al., 2024). Studies in other racket sports, such as tennis and squash, further emphasize the critical role of torque application in achieving fast and accurate shots. In squash, players use torque to generate speed and control, especially when executing smashes that require precise force application for both power and accuracy (Fabris et al., 2022).

Given these insights, this research contributes a novel perspective by emphasizing how prospective coaches can apply their knowledge of torque to enhance badminton hitting techniques. While previous research has largely focused on biomechanical aspects and kinematic stroke analysis, this research explores the influence of torque in racket handling and its implications for training methodology. Without proper training in torque application, coaches may inadvertently teach suboptimal techniques, resulting in reduced power, accuracy, and speed of shots, ultimately affecting the athlete's performance. By fostering a deeper understanding of torque, coaches can design more personalized training methods that cater to individual players' needs, leading to improved on-court performance and more efficient training strategies.

Moreover, this research underscores the importance of incorporating physics principles into badminton coaching to develop scientific-based training methods. The integration of physics concepts into training can improve the quality of technical instruction, making performance improvements more measurable and systematic. By bridging the gap between theoretical knowledge and practical application, this research aims to contribute to the development of evidence-based training methods, enabling coaches to transfer knowledge and techniques to players more effectively. Ultimately, this research seeks to offer new insights into the role of torque in badminton training, enhancing prospective coaches' understanding of physics principles and their application in optimizing stroke techniques to maximize player performance. This research aims to analyze prospective badminton coaches' understanding and application of physics concepts, particularly torque, in training methodologies to enhance stroke techniques, shot accuracy, and player performance.

METHOD

Research Design

This research employed a qualitative descriptive method to analyze the perspectives of prospective badminton coaches on integrating physics concepts, particularly torque, into training methodologies. This method was chosen to provide a clear and detailed description of the respondents' understanding and their views on how to apply physics concepts to improve badminton training. However, the qualitative nature of this research means that the findings are interpretative.

Participant

Respondents for this research were selected using a purposive sampling technique (Diani et al., 2023) to ensure they have direct relevance to the research focus. The sample comprised 24 pre-coaching students (17 males and 7 females, aged 18–22) from a university in Bandung, West Java, who were preparing to become badminton coaches or had a strong interest in the field. Although the sample size was limited and geographically restricted, efforts were made to include individuals with varying levels of coaching experience and academic backgrounds to capture a diverse range of perspectives. Specifically, participants were selected from different stages of their coaching education, including those who had just begun their training and those who had already gained practical coaching experience through internships or assistant coaching roles. Additionally, the sample included students from different academic programs related to sports science and physical education, ensuring representation from various theoretical and practical backgrounds in badminton coaching.

Instrument

This research used a survey with an open-ended questionnaire to gather data. The six core questions focused on respondents' understanding of physics in badminton, their reasons for recognizing or ignoring these concepts, and the physics terms they knew, as shown in Table 1. To ensure reliability and validity, the questionnaire was tested using the Rasch Model. The analysis showed a raw variance of 62.1%, classifying it as 'excellent' based on the 60% validity benchmark. A Cronbach Alpha of 0.85 confirmed high internal consistency, ensuring the questionnaire accurately measured the intended constructs.

Table 1. Questionnaire on Physics Integration in Badminton Coaching

No.	Question	Aspect Measured
1.	Do you think it is important for a coach to understand physics concepts in badminton?	Perceived importance of physics in coaching
2.	Why do you think understanding physics concepts is important in badminton?	Reasons for the importance of physics in badminton
3.	What physics terms do you currently know?	Prior knowledge of physics terms
4.	How do the physics terms you know relate to badminton?	Understanding of the relationship between physics and badminton

No.	Question	Aspect Measured
5.	In physics, there is a concept called torque. If you were a coach, how would you integrate torque into athlete training in badminton?	Practical application of torque in training
6.	What are your ideas for developing a training program that helps players understand and apply physics effectively in badminton?	Training program development based on physics principles

In addition to the questionnaire, interviews were conducted to further explore respondents' perspectives on the application of physics in badminton coaching, particularly related to the integration of concepts such as torque. These interviews aimed to understand the extent to which prospective badminton coaches have applied physics in their training and how they perceive the potential for integrating physics to enhance athlete performance.

Analysis Plan

The qualitative data obtained from open-ended questionnaires and semi-structured interviews were analyzed using NVivo Plus 12.0 software. The analysis was carried out in three systematic stages: open coding, axial coding, and selective coding. In the open coding stage, the raw data were carefully examined to identify recurring keywords and initial concepts related to participants' understanding and application of physics in badminton coaching. Several emerging codes were identified, including "Physics terms related to badminton," "Approaches and learning strategies," "Training program development," and "Benefits of physics in badminton."

Subsequently, the axial coding phase was conducted to refine these initial codes into broader categories, enabling a deeper exploration of relationships between concepts. For example, responses related to students' perceptions of physics terms in badminton were grouped under "Physics Terms Related to Badminton." In contrast, responses concerning the application of physics in training program development were categorized under "Plan for Developing a Training Program by Integrating Physics Concepts." Furthermore, responses identifying the benefits of physics in badminton performance and coaching were categorized as "Benefits of the Relationship Between Physics and Badminton." This phase allowed for a clearer understanding of how knowledge gaps impact training methodologies and how physics principles can be effectively incorporated into coaching strategies.

In the final stage, selective coding, the core themes were identified in alignment with the research objectives, providing a structured framework for understanding how prospective coaches recognized, applied, and benefited from physics principles in badminton coaching. Based on the analysis, three dominant parent nodes were identified, with the alignment of key terms categorized under corresponding child nodes, as presented in Table 2.

Table 2. NVivo Parent and Child Nodes Categorization in the Thematic Analysis

Parent Nodes	Child Nodes
Physics Terms Related to Badminton	Momentum, Acceleration, Force, Kinetic Energy, Torque, etc.
Plan for Developing a Training Program by Integrating Physics Concepts	• Learning Methods (e.g., providing seminars, organizing workshops, and creating educational sessions). • Learning Media (e.g., video analysis, motion simulations, radar gun usage, and animated videos). • Approaches and Learning Strategies (e.g., contextual teaching, theoretical explanations, and collaboration with physics experts).
Benefits of the Relationship Between Physics and Badminton	Helping Coaches Design Training Programs, Improving Players' Decision-Making, Enhancing

Parent Nodes	Child Nodes
	Wrist Rotation Techniques, Supporting Shuttlecock Trajectory Optimization, etc.

RESULTS AND DISCUSSION

Results

The data from the open-ended questionnaires were analyzed using NVivo Plus 12.0 software to explore prospective badminton coaches' views on integrating physics concepts, particularly torque, into training. This qualitative analysis involved organizing responses, identifying patterns, and extracting key themes to gain insights into their understanding of physics principles and their application in badminton, as shown in Figure 1.

The survey revealed different student views on the role of physics terms in badminton and their benefits. While most students are familiar with terms like acceleration, speed, and gravitational force, only a few recognize torque as relevant, even though it plays a key role in movements like the wrist during a shot. One respondent (Resp 23) didn’t consider this concept at all, which suggests that there’s a need to highlight the importance of physics more in badminton training.

According to the interview responses, most prospective coaches have a basic understanding of how physics applies to badminton but face challenges in applying these concepts in their coaching. Many respondents acknowledged terms such as speed, force, and acceleration but expressed difficulty in incorporating them into their training routines. One respondent (Resp 12) shared, "*We focus more on the player's technique and agility. We do not often refer to physics, but we know that speed and force affect the shuttlecock’s trajectory*.” Although they are aware of the impact of physics on the shuttlecock's flight, this coach has not fully applied it in a structured training strategy. For example, they did not explore the influence of the vector in the smash movement, such as the optimal angle for a smash, typically between 15° and 20° from the horizontal, which could significantly improve shot accuracy and power. Another respondent (Resp 5) mentioned, “*I use terms like speed and force in training, but torque and rotational motion are not things we actively consider in practice, even though they play a role in shots like the smash*.” This suggests that while they acknowledge the impact of speed and force on the shuttlecock's trajectory, they have yet to fully grasp the application of torque and wrist rotation in a smash, which can affect the acceleration and power of the shot.

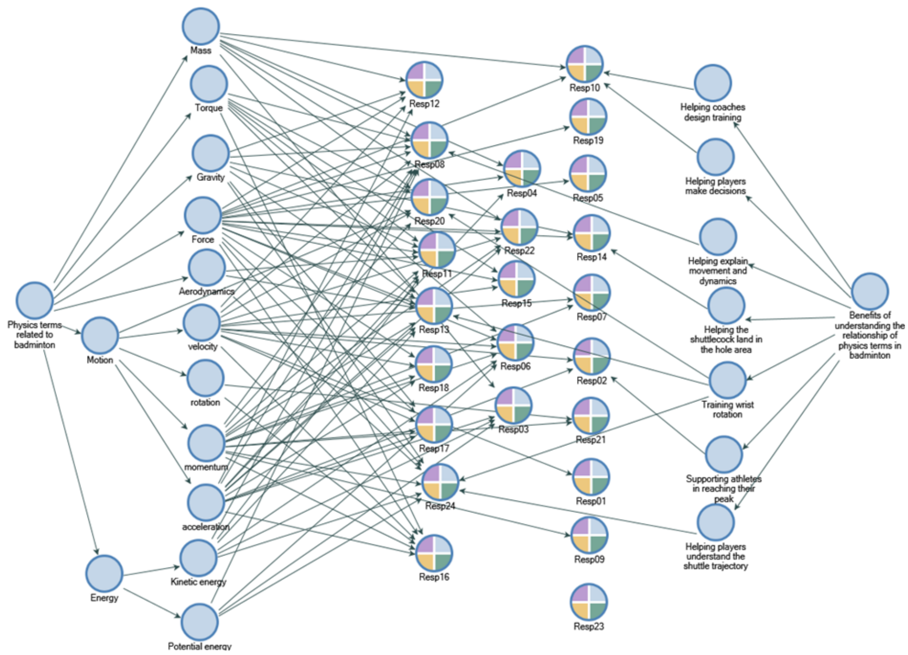

Figure 1. Students' Knowledge of Physics Terms and Their Benefits in Badminton Training

Figure 1 also shows that students recognize several benefits of integrating physics concepts into badminton training. These include explaining movement dynamics, understanding shuttlecock trajectories, and aiding coaches in program design. The concept also supports wrist rotation efficiency and decision-making during gameplay. While most students have a basic understanding of physics terms, there is potential to enhance their knowledge, especially regarding less familiar concepts like torque, and to emphasize their practical application in training.

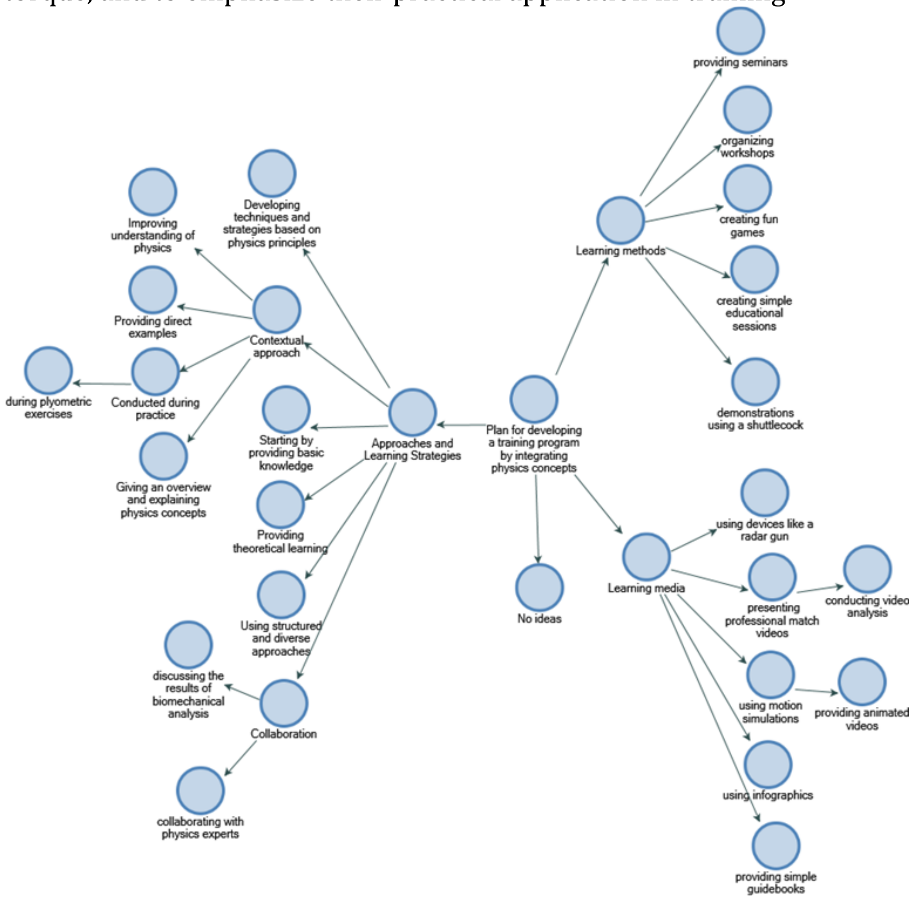

Figure 2. Students' Perspectives on the Plan for Developing Badminton Training Based on the Integration of Physics Concepts

The analysis from Figure 2 highlights students' views on integrating physics into badminton training, emphasizing a contextual approach. They suggest building a strong foundation in physics theory before applying it practically and incorporating hands-on examples, like biomechanics in plyometric exercises, to bridge theory and practice. Collaboration with physicists is also seen as crucial to ensure scientific data and valid analysis back training.

Students suggest interactive methods like seminars, workshops, and demonstrations with simple tools, such as shuttlecocks, to teach physics concepts like trajectory, force, and momentum. They also propose innovative learning media, including professional match videos for motion analysis, simulations for abstract concepts, radar guns for shoot speed, and infographics for visualization. However, the "No ideas" node reflects gaps in development, signaling a need for further exploration.

Several respondents emphasized the need for more training on concepts like torque and wrist rotation to improve the effectiveness of shots such as smashes. They argued that a deeper understanding of these principles could help coaches refine players' techniques and enhance overall training outcomes. One respondent (Resp 8) mentioned, *"Understanding torque and wrist rotation would definitely help improve our coaching, especially for smashes. It's an area that's mostly overlooked right now."*

Discussion

The integration of physics concepts, particularly torque, into badminton training, has gained significant attention, yet it remains underutilized despite its critical role in enhancing player performance. The results of the open-ended questionnaires and interviews with prospective badminton coaches highlight the general awareness of basic physics concepts such as speed, force, and acceleration but reveal a notable gap in the understanding and application of torque, particularly in wrist rotation and racket handling during a smash.

One key issue is that coaching curricula focus more on technical skills than the underlying scientific principles, such as physics. Additionally, limited exposure to biomechanics in coaching education may prevent a deeper understanding of torque and wrist rotation in smash techniques. As a result, coaching has transformed and been influenced by the emergence of new scientific knowledge. However, in this shift towards 'pure' science, the pedagogical aspects of coaching, the awareness and understanding of how to teach effectively, have often been overlooked (Van et al., 2017). Studies have also shown that coaches often rely on personal experience and traditional methods rather than science-based approaches to improve athlete performance (Chaeroni et al., 2024).

This trend is also evident in Indonesia, as mentioned in the introduction. While scientific advancements have played a crucial role in improving training methods, many Indonesian badminton coaches transition from professional athletes, emphasizing early training and competition (Maksum & Indahwati, 2023). This emphasis, however, often limits their opportunities for in-depth formal education in sports science, including physics principles applicable to badminton. Despite this limitation, Indonesian coaches have achieved significant international success by relying on their practical expertise in elite-level training. Recognizing the importance of scientific knowledge in coaching, the Indonesian Badminton Association (PBSI) has introduced a sports science analytics platform to support evidence-based training and improve coaching methodologies, bridging the gap between traditional coaching approaches and scientific advancements.

Building on these findings, responses indicated that while many acknowledged the importance of physics concepts in training, the majority lacked concrete guidelines for applying these principles in practice sessions. This emphasizes the need for developing training modules that explicitly integrate physics principles, including torque, into existing coaching techniques.

Several other studies have also indicated that coaches across various sports disciplines have yet to fully integrate physics concepts, particularly torque, into their training techniques. For instance, research by Koike & Hashiguchi (2014) highlights that many coaches lack a sufficient understanding of racket torque mechanics, which is crucial for enhancing stroke speed and power, particularly in badminton smash techniques. They emphasize that although coaches recognize the importance of muscle strength and body coordination, they tend to overlook how the wrist and arm generate torque in maximizing racket movement.

A study by Awatani et al. (2018) also found that coaches often focus primarily on general physical training, such as strength and endurance, without considering the role of physics in technical skills. They suggest that introducing physics concepts, such as torque, into training sessions can help athletes optimize their energy efficiency and improve performance. Similarly, Ramasamy et al. (2023) argue that coaches in racket sports tend to exclude physics analysis from their approach to stroke techniques. They assert that a better understanding of torque and its influence on racket movement can provide valuable insights for teaching more efficient techniques, which, in turn, can enhance shot power and accuracy.

Despite these findings, the integration of physics-based principles in sports training remains limited, highlighting the need for a more structured approach to incorporating scientific concepts into coaching methodologies. From a physics perspective, one of the main concepts relevant in training for various sports involving arm movement is torque.

A torque is a rotational force applied to an object around a specific axis. Mathematically, torque (τ) can be formulated as:

$$\tau = r \cdot F \cdot \sin\theta \dots\dots\dots (1)$$

The torque is calculated by multiplying the distance $\boldsymbol{r}$, which is the distance between the axis of rotation and the point where the force is applied (also known as the torque arm), by the magnitude of the applied force $\boldsymbol{F}$. Additionally, the angle $\boldsymbol{\theta}$ between the direction of the force and the torque arm plays a crucial role in determining the effectiveness of the force in producing torque.

Various sports have been studied for their mechanics, similar to the overarm throw seen in badminton, including baseball (Rusdiana et al., 2021). These studies focus on muscle activity, joint torque, and kinematics, but the cause-and-effect relationships remain unclear despite their importance. Understanding the link between kinetics (e.g., muscle force) and kinematics (e.g., joint rotation) is challenging in multi-joint movements. This is because torque at one joint causes angular acceleration at all joints in the system due to dynamic coupling (Hirashima et al., 2008).

To address this issue, research has introduced a dynamic approach, as described in the article by Hirashima et al. (2008), which presents the equations of motion for multi-joint systems as follows:

$$I(\theta)\ddot{\theta} = \sum_{i=1}^{m} \tau_i + V\left(\theta, \dot{\theta}\right) + g(\theta) \dots\dots\dots (2)$$

The torque vector is generated by the force exerted by the *i*-th muscle. The acceleration induced by the muscle force can be calculated by multiplying the inverse of the system's inertia matrix by the torque vector produced by the muscle force, expressed as $I(\theta)^{-1}\tau_i$. This forward dynamics analysis reveals how muscle forces contribute to joint acceleration and has been used to study muscle forces in body acceleration during walking.

In badminton, coaches must recognize that torque plays a crucial role in the force applied to the racket, especially in techniques like smashes. The smash requires fast, precise rotational movements to deliver an effective strike (Rusdiana et al., 2020). The more torque generated by the player's wrist and arm through rotation, the greater the force transferred to the shuttlecock, which is key to improving both shot speed and accuracy.

Torque plays a crucial role in the smash technique. Greater torque increases the rotational acceleration of the racket head, leading to higher momentum at contact with the shuttlecock, which boosts stroke speed and striking power (Rusdiana et al., 2023). Additionally, controlled torque application helps maintain shot focus, reducing the chances of missing the target. Therefore, torque enhances both the power and accuracy of the strike.

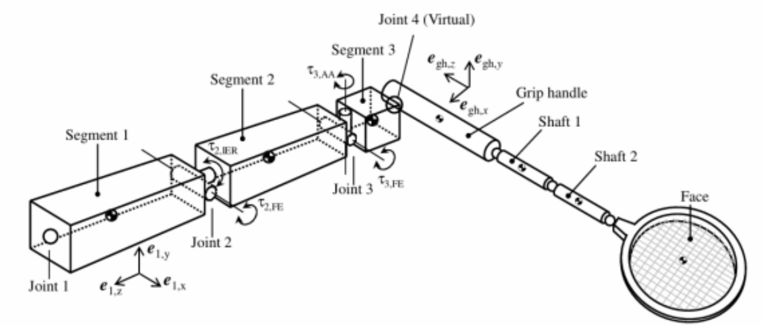

Figure 3. Torque Analysis in Every Joint (Koike & Hashiguchi, 2014)

An analysis of torque in a racket can be conducted using the equations of motion for systems that incorporate various forces and moments. This system includes the upper body segments and the racket, which are connected by joints, along with external forces that affect the torque on the racket. The pertinent equation of motion, as presented by Koike & Hashiguchi (2014), is as follows:

$$M\dot{V} = PF + P_{ext}F_{ext} + QN + H + G \dots\dots\dots (3)$$

This equation represents the balance of forces and moments acting on the human body and racket during dynamic movement, derived from classical dynamics principles. It incorporates internal and external forces that interact to produce system acceleration. The left side of the equation, $\boldsymbol{M\dot{V}}$, describes the inertial response of the system to an applied force, where $\boldsymbol{M}$ is a mass matrix that includes the player's body and the racket. At the same time, $\dot{\boldsymbol{V}}$ represents system acceleration, demonstrating how the total force and torque influence motion. On the right, $\boldsymbol{PF}$ represents muscle-generated internal forces driving body and racket movement. External forces ($\boldsymbol{P_{ext}F_{ext}}$) include wind and surface effects altering trajectory. $\boldsymbol{QN}$ denotes torque from the grip or body-racket connection, affecting shot speed and direction. $\boldsymbol{H}$ reflects racket torque, including shaft recovery, while $\boldsymbol{G}$ represents constant gravitational force.

This equation serves as a comprehensive analytical tool for understanding the interplay of various forces in complex movements, such as badminton hitting techniques. Integrating internal forces, environmental influences, and racket-generated torque explains how these factors collectively contribute to system acceleration. However, applying this equation in experimental contexts requires discrete data analysis, as continuous acceleration cannot fully account for motion changes measured at specific intervals, necessitating further adjustments for practical use.

Therefore, equation (4):

$$\dot{V(k)} = \frac{V(k+1) - V(k)}{\Delta t} \ldots\ldots\ldots (4)$$

This equation (4) bridges the gap by allowing acceleration to be calculated directly from experimental data. It compares the system's speed at two consecutive discrete times, ***k*** and ***k+1***. In this way, changes in the system's speed can be computed numerically by considering the time intervals, ***Δt***, established during data collection. This approach ensures that the experiment aligns with the basic principles of the force balance equation, making it applicable to real-world motion analysis, such as studying racket motion in badminton. By calculating acceleration in discrete form, it bridges theoretical models with experimental data, improving the realism and relevance of motion analysis (Ramasamy et al., 2023; Rasolofomanana et al., 2020).

The equation derived by Koike and Hashiguchi (2014) explains how racket torque and other forces collaborate to generate optimal racket head speed during the smash. The torque from the racket grip, influenced by the grip position, angle, and wrist movement, plays a key role in the shot speed and power (Aslam et al., 2019; Suwannachote et al., 2023). Research shows that torque at the racket handle greatly impacts racket head speed, particularly at impact with the shuttlecock.

This emphasizes the importance of torque, influenced by upper body joints, in optimizing stroke speed. Understanding the physics of torque allows coaches to teach techniques that maximize racket rotation, enabling players to produce powerful shots with less effort.

This research offers a new perspective on integrating physics concepts, particularly torque, into badminton training, enhancing training effectiveness through a scientific and systematic approach.

Implications

This research highlights the importance of applying physics concepts, such as torque, in badminton training to improve stroke technique and enhance overall player performance. By connecting physics theory to training practice, coaches can gain a deeper understanding of movement dynamics, thereby designing more optimal training strategies. Understanding torque and its effects on racket swing, shuttlecock speed, and player biomechanics allows coaches to make data-driven adjustments to improve movement accuracy, power, and efficiency. Furthermore, this research reveals the broad potential of applying physics principles across sports, encouraging further exploration of how movement concepts can be tailored to the needs of athletes across disciplines. With a scientific approach, coaches can optimize athlete performance while reducing the risk of injury, contributing to the development of more innovative sports training methods.

Research contribution

This research bridges the gap between physics education and sports coaching, specifically in badminton, by analyzing how concepts like torque and motion dynamics can enhance coaching methods and player performance. The study highlights the need to integrate physics into coaching curricula and offers practical implementation insights, providing a framework for future research in sports science and education.

Limitations

This research focused only on prospective badminton coaches, so the findings may not apply to other sports or coaching groups. The reliance on self-reported qualitative data introduces the possibility of response bias, as participants may provide socially desirable answers rather than reflect their true understanding or practices. The absence of longitudinal data also limits insight into the long-term effects of integrating physics in coaching. Moreover, the lack of experimental validation, such as biomechanical analysis of players applying torque-optimized techniques, further restricts the study's ability to demonstrate practical outcomes. While concepts like torque and motion were discussed, practical experiments would provide stronger evidence of their impact.

Furthermore, while this research focuses on prospective coaches, research comparing approaches between novice and professional coaches is still limited. More data is needed to determine whether new coaches have a limited understanding of torque or if this is also true for experienced coaches. A comparative study of coaches with different levels of experience could provide more information about how biomechanics knowledge evolves and what factors influence its application in training.

Suggestions

Future studies should focus on experimentally validating the impact of torque-based training on badminton performance through objective assessments such as biomechanical analysis and motion tracking. While this research supported torque discussions with theoretical and mathematical formulations, the lack of empirical validation through experimental data or biomechanical simulations renders the argument theoretical. To support these findings, future research should include motion capture analysis or computer modeling to quantify the effects of torque on smash speed and accuracy. Coaching curricula should incorporate structured training modules that combine theoretical physics with practical applications, including drills that enhance racket rotation, shot power, and precision. Additionally, broader research should explore other physics concepts, such as force and momentum, in optimizing badminton techniques.

CONCLUSION

This research reveals that prospective badminton coaches generally lack awareness of torque's role in stroke techniques and player performance. While they acknowledge the relevance of physics in training, their understanding remains superficial, particularly regarding its biomechanical application. This highlights the need to strengthen physics integration in coaching education. However, this research does not provide direct evidence that teaching torque improves training outcomes, emphasizing the necessity for further experimental research to assess its tangible impact.

AUTHOR CONTRIBUTION STATEMENT

TK, NJ, and HA were responsible for the study's conceptualization and design, data collection, and initial drafting of the manuscript. NN and NH contributed to the data analysis, interpretation of the results, and critical revision of the manuscript. RR also served as the corresponding author and handled all correspondence. AS handled revisions related to the publication.

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