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Optimizing Physical Conditioning Programs for Badminton Athletes: A Comprehensive Review of Training Strategies - A Systematic Review

Optimización de programas de acondicionamiento físico para atletas de bádminton: una revisión completa de las estrategias de entrenamiento: una revisión sistemática

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Abstract. Study Background and Objectives: The performance of international badminton athletes is shaped by a blend of physical, psychological, technical, and tactical factors. This study seeks to systematically analyze these essential elements, driven by the imperative to comprehend critical factors for crafting optimized training programs to achieve peak performance efficiently and effectively.Materials and Methods: This study used a systematic approach to review various literature sources, journal articles, and empirical studies related to the achievements of badminton athletes at the international level. Strict inclusion and exclusion criteria were applied to ensure that only high-quality studies were included in the analysis. The data collected was then comprehensively analyzed to identify critical factors that consistently influence badminton athlete performance. Results: This systematic analysis reveals that the main factors influencing badminton athletes' achievements at the international level involve a combination of physical, psychological, technical, and tactical aspects. Physical strength, mental resilience, technical expertise, and a deep tactical understanding proved essential in achieving success in the sport. A deep understanding of match dynamics, emotional management, and adaptation to the opponent's tactics were also found to be keys to success. Conclusion: The results of this analysis provide a holistic view of the factors that significantly influence the performance of badminton athletes at the international level. The practical implications include the development of more focused and adaptive training programs, as well as more intensive psychological approaches. These conclusions provide an essential contribution for coaches, researchers, and decision-makers in badminton to improve athletes' potential and results at the international level.
Keywords: Physical Conditioning, Badminton Athletes, Training Program, Conditioning Strategy, Systematic Review.

Resumen. Antecedentes y objetivos del estudio: El rendimiento de los atletas internacionales de bádminton está determinado por una combinación de factores físicos, psicológicos, técnicos y tácticos. Este estudio pretende analizar sistemáticamente estos elementos esenciales, impulsado por el imperativo de comprender los factores críticos para la elaboración de programas de entrenamiento optimizados para lograr el máximo rendimiento de manera eficiente y eficaz.Materiales y Métodos: Este estudio utilizó un enfoque sistemático para revisar diversas fuentes bibliográficas, artículos de revistas y estudios empíricos relacionados con los logros de los atletas de bádminton a nivel internacional. Se aplicaron criterios estrictos de inclusión y exclusión para garantizar que sólo se incluyeran en el análisis estudios de alta calidad. A continuación, se analizaron exhaustivamente los datos recopilados para identificar los factores críticos que influyen de forma sistemática en el rendimiento de los atletas de bádminton. Resultados: Este análisis sistemático revela que los principales factores que influyen en los logros de los atletas de bádminton a nivel internacional implican una combinación de aspectos físicos, psicológicos, técnicos y tácticos. La fuerza física, la resistencia mental, la pericia técnica y una profunda comprensión táctica resultaron esenciales para alcanzar el éxito en este deporte. El conocimiento profundo de la dinámica de los partidos, la gestión emocional y la adaptación a las tácticas del adversario también resultaron ser claves para el éxito. Conclusiones: Los resultados de este análisis proporcionan una visión holística de los factores que influyen significativamente en el rendimiento de los atletas de bádminton a nivel internacional. Las implicaciones prácticas incluyen el desarrollo de programas de entrenamiento más centrados y adaptables, así como enfoques psicológicos más intensivos. Estas conclusiones suponen una contribución esencial para los entrenadores, investigadores y responsables de la toma de decisiones en bádminton para mejorar el potencial y los resultados de los atletas a nivel internacional.
Palabras clave: Acondicionamiento físico, atletas de bádminton, programa de entrenamiento, estrategia de acondicionamiento, revisión sistemática.

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Introduction

Badminton, as a racquet sport that requires a combination of technical, tactical, and physical fitness skills, has become the focus of global attention in sports. The success of a badminton athlete is determined not only by his technical expertise in hitting the shuttlecock but also by his optimal physical condition. Physical conditioning is a critical element in preparing athletes, playing an essential role in improving their performance on the court. Therefore, a comprehensive review of effective training strategies to optimize the physical conditioning program of badminton athletes is an urgent need in the world of sports research. According to (Lam et al., 2020; Medina Corrales et al., 2020), the success of a badminton athlete depends not only on the technical aspects of their game but also on optimal physical condition. Thus, the importance of physical conditioning in the training of badminton athletes is becoming increasingly evident and requires a deep understanding of effective training strategies.

The importance of this study arises from the changing dynamics of badminton matches, which increasingly demand athletes to be in excellent physical condition during intense battles. Along with developing game strategies and opponent tactics, badminton athletes need to ensure that their physical conditioning program can meet the specific demands of this sport. A comprehensive systematic review will provide deep insights into the training strategies that

can be optimized to achieve the best physical condition in badminton athletes. The research results by (Safaric & Bird, 2011; Young & Farrow, 2006; Sobko et. all, 2022), indicate that developing strategies and tactics in badminton can put additional pressure on athletes' physical condition. Therefore, the need for a thorough study of training strategies to optimize the physical conditioning of badminton athletes is becoming increasingly important.

This study aimed to identify the most effective training strategies for optimizing the physical conditioning program of badminton athletes. By exploring existing knowledge and analyzing current findings, this study aims to provide practical guidance for coaches, physiotherapists, and policymakers in designing physical conditioning programs that suit the needs of badminton athletes that a better understanding of effective training strategies can contribute significantly to creating more focused and efficient physical conditioning programs. The study's focus variables, namely strength, endurance, speed, and agility, have great significance in improving the performance of badminton athletes. Muscular strength is critical to producing robust and controlled strokes, while physical endurance is needed for long and intense matches. Speed in reaction and movement allows athletes to respond quickly to dynamic game situations. Meanwhile, agility is essential in maintaining the balance and flexibility of the athlete's movements.

Scientific support suggests that developing these variables can positively affect an athlete's performance in racquet sports. Through an in-depth understanding of effective training strategies for each variable, this study is expected to provide practical guidance for coaches and athletes in designing optimal physical conditioning programs. As such, this research not only enhances our understanding of the importance of strength, endurance, speed, and agility in the context of badminton but also provides a framework that can be effectively applied to improve athletes' performance on the court.

In conducting this study, we applied a systematic data selection and analysis methodology. This process involved determining strict inclusion and exclusion criteria to ensure the completeness and relevance of retrieved information sources. Thus, this study aims to provide an objective and comprehensive analysis of training strategies in the context of physical conditioning of badminton athletes. According to (Tawfik et al., 2019), applying systematic methodology in systematic reviews is a crucial step to ensure the validity and reliability of research findings. In this study, badminton athletes are the group whose physical condition will be analyzed, and how physical conditioning programs can be optimized to improve their performance. Therefore, the discussion in the introduction includes understanding the importance of optimal biological conditions for badminton athletes and the need to develop effective training strategies to achieve this goal.

Through this study, we hope to contribute to the scientific literature on sports training, particularly in the context of the physical conditioning of badminton athletes. With a better understanding of effective training strategies, badminton athletes' physical conditioning programs can be optimized to improve their on-court performance. Based on previous research by (Connor et al., 2022), contributions to the scientific literature in the development of exercise strategies can positively impact improving athlete performance across a range of sports (Kukrić et. all, 2021; Nagorna et. all, 2023; Qadir et. all, 2023).

With this background, the next step is to detail the physical conditioning factors that are the focus of this study. The next chapter will discuss strength, endurance, speed, and agility in detail and how exercises in these aspects can be optimized to meet the specific needs of badminton athletes.

Methodology

Selection of Inclusion and Exclusion Criteria

In this phase, the research will establish inclusion and exclusion criteria to ensure the selection of studies that match the research focus. These criteria include publication type, year range, and research methods for optimizing badminton athletes' physical conditioning programs.

Table 1.
Inclusion and Exclusion Criteria

Criteria	Description
Inclusion	The research article focuses on physical conditioning for badminton athletes.
	The study was conducted on professional or advanced badminton athletes.
	Publication in the most recent year range (2013-2023).
	Research methods involve systematic reviews, meta-analyses, or relevant empirical studies.
Exclusion	Articles that are not related to physical conditioning or badminton athletes.
	Study on a population of non-badminton or beginner-level athletes.
	Publications outside the specified year range.
	Research that does not meet methodological quality standards.

Identification of Information Sources

In the source identification stage, the research will adopt a thorough approach to ensure the completeness and representativeness of the literature accessed. Literature searches will be conducted through reputable scientific databases such as PubMed, Scopus, and international sports journals. Keywords relevant to optimizing physical conditioning programs for badminton athletes will be used to obtain the most relevant articles. The selection of reputable databases ensures access to current and quality research. In addition, the study will also consider literature from books, theses, and other scientific documents to ensure a diversity of information sources. These steps will provide a solid foundation to develop a comprehensive understanding of training strategies and physical conditioning in badminton athletes.

Data Selection and Analysis Process

The selection process and data analysis were critical stages in this study. Article selection was done systematically by considering the predetermined inclusion and exclusion criteria. Articles that met the quality and relevance standards were then selected for analysis. After data

collection, analysis was conducted using the systematic review method. This includes synthesizing findings from multiple sources, comparing research methodologies, and identifying patterns or trends that emerge consistently. At this stage, researchers will also evaluate each selected study's strengths and weaknesses. Careful data analysis will allow accurate conclusions and provide a solid foundation for recommendations regarding optimizing badminton athletes' physical conditioning programs.

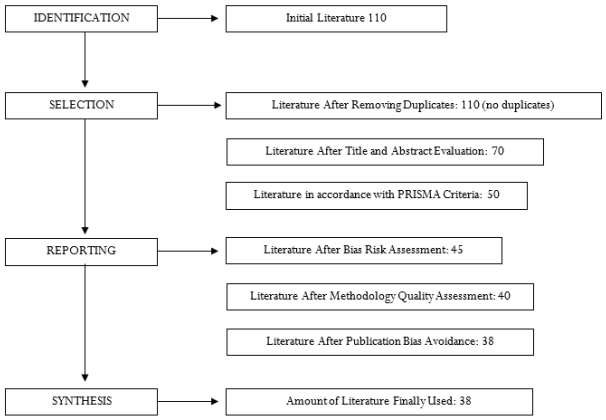

Figure 1. Article selection with PRISMA method.

Quality of Study Assessment

Assessing study quality is a critical aspect of this research method. The evaluation ensures that the studies used have high reliability and relevance. The quality assessment includes several dimensions:

The study's internal validity will be evaluated to ensure that the research design and the conduct of experiments or observations conform to scientific standards.

The reliability of the data will be in focus, ensuring that the results produced are reliable and reproducible.

The relevance of the research methodology to the context of this study will be assessed so that the selected studies effectively inform about badminton athletes' training and physical conditioning strategies.

By detailing and engaging in a rigorous assessment process, this research will produce solid and reliable findings to support recommendations for optimal training program development.

Literature review

Physical Conditioning Factors

Strength and Endurance

Weight Training to Increase Strength in Badminton Athletes

Strength training is a crucial element in the physical conditioning program of badminton athletes, aiming to improve the propulsion and agility of the muscles involved in critical movements in this sport.

The importance of weight training in this context can be seen from research showing that the development of muscular strength can contribute significantly to improving the performance of badminton athletes (Sun & Shao, 2023). Through proper weight training, athletes can improve their firepower, hitting power, and body stability, highly relevant factors in badminton matches.

Not only is the type of weight training chosen important, but also the frequency and intensity of training. Research by (dos Santos et al., 2023; Schoenfeld et al., 2017), showed that weight training with high power and appropriate frequency can effectively increase muscle strength in a relatively short period. Therefore, in optimizing a physical conditioning program, it is necessary to consider the type of weight training and how the intensity and frequency are arranged.

In addition, weight training focused on muscle groups directly involved in critical badminton movements can provide maximum benefits. Research by (Bashir et al., 2022), emphasized the importance of leg strength training in improving athletes' ability to jump and move quickly on the field. Therefore, weight training programs need to be designed with the specific needs of the muscles used in badminton movements in mind.

Furthermore, it is also important to include weight training that involves functional movements that mimic match situations (Causevic et. all, 2023; Kozin & Matlaiev, 2023). Practical weight training that simulates match movements can improve muscle strength and coordination more effectively. Therefore, weight training programs must be conceptualized by considering badminton movements' functional and contextual aspects.

By detailing these factors, optimizing a physical conditioning program for badminton athletes requires a careful approach to weight training. By selecting appropriate exercise types, appropriately managing intensity and frequency, and incorporating functional weight training, athletes can significantly increase muscular strength, supporting improved performance on the badminton court. This study illustrates how weight training can be crucial in an effective physical conditioning strategy for badminton athletes.

Cardiovascular Exercises to Increase Endurance

Cardiovascular training plays a crucial role in improving the endurance of badminton athletes. Proper cardiovascular training can significantly enhance cardiorespiratory capacity, which is essential for athletes' performance during badminton matches.

The importance of cardiovascular training in improving the endurance of badminton athletes must be addressed. According to (Franklin et al., 2022: Sobko et. all, 2022), cardiovascular exercise helps improve cardiorespiratory capacity, which is directly related to the body's ability to sustain high work intensity over extended periods. Therefore, properly integrating cardiovascular exercises in a physical conditioning program can be vital to improving athletes' endurance.

A key consideration in designing cardiovascular exercise for badminton athletes involves selecting the appropriate type of exercise. Studies by (Gillen et al., 2016; Nunes et al., 2018), emphasized the importance of interval training

in improving athletes' endurance. Interval training, which involves a series of high-intensity periods followed by recovery periods, effectively improves cardiorespiratory capacity and endurance.

In addition to the type of exercise, the frequency and intensity of cardiovascular exercise are also determining factors. The appropriate frequency of cardiovascular exercise in a week may vary depending on the athlete's specific goals and training phase (Kozin et. all, 2023). As for training intensity, training at a moderately high intensity, but according to the athlete's particular needs, can result in significant improvements in cardiorespiratory capacity.

In cardiovascular exercise, variability is also a key factor to consider. Studies by (Ochentel et al., 2018), highlight the importance of exercise variety to prevent burnout and help maintain athlete motivation. Therefore, developing a cardiovascular exercise program that includes various activities can increase athlete engagement and optimize exercise outcomes.

Overall, practical cardiovascular training to improve the endurance of badminton athletes involves selecting the appropriate type of exercise, the right frequency and intensity, and variability to maintain athlete motivation. Detailing and investigating these aspects can optimize physical conditioning programs to achieve maximum endurance improvements in badminton athletes.

Speed and Agility

Speed Training for Athlete Reaction Improvement

Speed training is a crucial component in the physical conditioning of badminton athletes, directly affecting an athlete's ability to respond quickly to an opponent's movements. Optimal reaction speed is essential to an athlete's success in responding to rapidly changing situations during a match. Therefore, an in-depth understanding of speed training and its implementation in the physical conditioning program of badminton athletes is essential.

Several studies have highlighted the importance of speed training in improving an athlete's reaction to an external stimulus. According to Research (Sukmooncharen et al., 2023), speed training focusing on visual stimulation can significantly improve athletes' reaction time, an essential parameter in badminton. This training approach includes using visio-motor devices and simulated match situations to speed up athletes' response time.

In addition, a Research study (Castañeda-Lechuga et al., 2020; Hülsdünker et al., 2019), showed that speed drills specific to badminton movements can improve athletes' ability to adjust body position and prepare shots more efficiently. These exercises include routines incorporating footwork and direction changes often occurring in badminton matches.

Various speed drills are needed to optimize a physical conditioning program to engage different aspects of the athlete's reactions. A combination of visual and motor speed exercises can improve the coordination between an athlete's visual perception and motor response, helping them to respond more accurately to changing situations during a match.

It is also important to note that the intensity of speed training should be tailored to the athlete's fitness level and specific physical condition. According to Research (González et al., 2022; Malone et al., 2018), speed training that is too intense can increase the risk of injury. Hence, adjustments to the training program must be made according to the athlete's condition.

Combining these findings, implementing diverse and specific speed training can significantly improve the reactions of badminton athletes. Considering the supporting research results, coaches and physical conditioning practitioners can design more effective and safe training programs, helping athletes achieve their highest level of performance in badminton matches.

Agility Training to Improve Body Movement

Agility training is a critical element of the physical conditioning of badminton athletes because it combines the flexibility and agility required to respond to sudden changes in a match. In this context, agility training refers to improving joint flexibility and the athlete's ability to move efficiently and quickly along the court. These exercises are vital in improving a badminton athlete's body movements, which are crucial for dominating the game and responding to the opponent's attacks.

Targeted agility training can focus on improving muscle and joint flexibility required for typical movements in badminton. A study by (Al Attar et al., 2022), highlighted the importance of agility training in preventing injuries in athletes. They emphasized that these drills can help increase joint range of motion and reduce stress on muscles and ligaments, improving the efficiency of athletes' movements.

Agility training drills can also be focused on developing agility and speed of movement. According to (Chaudhary et al., 2021), agility drills that include directional displacement and sudden changes in direction can improve an athlete's ability to respond quickly to changing situations in a match. This includes zig-zag and agility ladder drills that strengthen athletes' coordination and movement speed.

The importance of agility drills to improve body movement in badminton can also be understood biomechanically. Studies by (Thieschäfer & Büsch, 2022), show that agility training can influence postural control and movement coordination, directly impacting athletes' ability to organize and direct their bodies more efficiently during matches.

In a practical context, the integration of agility training in physical conditioning programs can be done through diverse approaches, including yoga, pilates, and dynamic static exercises. A review by (Kurt & Firtin, 2016), highlighted the benefits of active static training in improving flexibility and agility. They suggested that this approach can be valuable to athletes' physical conditioning programs, helping them achieve the skill required to optimize body movement in badminton.

Agility training plays a vital role in developing

flexibility, agility, and movement coordination to improve the body movements of badminton athletes. Scientific support from these studies provides a foundation for designing effective training programs that suit the needs of badminton athletes. Therefore, the implementation of focused and measurable agility training can have a positive impact on athletes' performance in badminton matches.

Latest Training Strategies in Badminton

Analysis of Techniques and Tactics in Badminton Matches

In developing badminton athletes, the evaluation of critical techniques plays a central role. Overhead shots, drop shots, and smashes are technical aspects that are the main focus. (Barsuglia et al., 2018), Underscoring the importance of proper technique development, it noted that adequate mastery of overhead shots and smash techniques can be the difference between successful and unsuccessful athletes. Careful technical evaluation lays the foundation for identifying areas of improvement that can enhance an athlete's performance.

In addition to technique, applying effective tactical strategies plays a crucial role in the success of badminton athletes. Research by (Putri & Musdi, 2020), highlights the importance of developing a deep tactical understanding, including appropriate game selection and reactions to opponents. Adaptive tactical strategies can provide a significant strategic advantage, such as changing game patterns according to the opponent's weaknesses.

The utilization of video analysis is becoming increasingly important in the understanding of opponent movements. Research by (Plakias et al., 2023), shows that the integration of video analysis allows coaches and athletes to identify the opponent's playing patterns, opening up opportunities for rapid tactical adjustments. This technology strengthens the understanding of the opponent's strengths and weaknesses, supporting more effective strategy planning.

The use of data analysis in badminton matches is also a significant focus. The study by (Ferraz et al., 2023), noted that integrating data, including match statistics and practice results, can help coaches and athletes identify performance trends. The data can be used to identify areas that require further attention and optimize training strategies.

By approaching the analysis of in-match techniques and tactics based on these supporting sources, badminton coaches and athletes can develop more brilliant training strategies responsive to specific needs in the world of competition.

Integration of Mental Training in Conditioning Programs

Mental training plays a crucial role in improving the performance of badminton athletes. Cognitive analysis can help athletes develop mental agility and focus on effective match tactics. Mental training is often integrated with physical conditioning programs to achieve optimal results (Andreato et al., 2022; Kozin et. all, 2023).

Relaxation techniques are an essential part of mental training. A study by (Hamdani et al., 2022), showed that relaxation techniques such as deep breathing and visualization can help athletes manage stress and anxiety levels before and during matches. Integrating these relaxation techniques in conditioning programs can help athletes maintain optimal physical and mental conditions.

Mental training also includes using visualization to improve athletes' concentration and confidence. According to (Stephen et al., 2022), visualization helps athletes to experience match situations in their minds, reinforcing skill development and increasing confidence. By integrating visualization exercises in conditioning programs, athletes can improve their mental aspects and effectively prepare themselves for challenges on the field.

The importance of emotional control in competition must be considered. Mental training that includes emotion management can help athletes better deal with pressure and challenges. A study by (Jekauc et al., 2021), showed that emotion management techniques, such as self-reflection and positive reframes, can help athletes deal with competitive tension. The integration of these exercises in conditioning programs ensures that athletes have the physical strength and emotional balance that is essential in intense match situations.

Applying the latest technology can also increase the effectiveness of mental training. Athletes can monitor and manage their mental training using specialized apps or software. Technology-based meditation applications can help athletes achieve optimal levels of relaxation. Research by (Vveinhardt & Kaspare, 2022), highlighted the positive impact of meditation apps on athletes' mental well-being and performance. The integration of this technology in conditioning programs marks a progression towards a holistic approach to improving the performance of badminton athletes.

In conclusion, integrating mental training in conditioning programs is critical to optimizing the performance of badminton athletes. Relaxation techniques, visualization, emotion management, and the utilization of technology are essential elements that can improve the mental aspects of athletes, making them integral components in preparation for competitive excellence. By incorporating mental and physical training, conditioning programs can become more thorough and effective in producing resilient athletes who are ready to compete on the badminton world stage.

Application of Latest Technology in Badminton Training

Applying the latest technology in badminton training has been vital in advancing and improving athlete performance. With the rapid development of technology, coaches, and athletes have easier access to various tools and systems that can increase training effectiveness and improve certain aspects of their training strategies.

A critical aspect of the latest technology in badminton training is video analysis. Video analysis allows coaches to observe the athlete's movements and techniques, identify

strengths and weaknesses, and detail the opponent's strategy. According to (Silva et al., 2022), video analysis provides a rich visual representation of an athlete's performance. It can be a very effective tool for identifying areas of improvement in technique and tactics.

Besides video analytics, sensors and tracking devices also play a crucial role in applying the latest technology. Sensors can be attached to an athlete's body to measure various parameters such as speed, acceleration, and angle of movement. This gives the coach objective data on the athlete's performance during training and matches. Sensors and tracking devices help the coach monitor the athlete's progress in real-time, enabling quick adjustments in the training program to achieve optimal results.

Virtual reality (VR) and augmented reality (AR) technologies have also been applied in badminton training. Using VR or AR, athletes can experience realistic match situations without being on the court. This helps practice quick reactions and decision-making in cases that can determine victory or defeat. Virtual and augmented reality technologies can provide an immersive and immersive training experience, creating training conditions similar to actual matches.

The utilization of data analytics is also an integral part of the application of the latest technology. By collecting and analyzing training and match data, coaches can identify trends, patterns, and areas of weakness that need improvement. Furthermore, according to (Corbu & Edelhauser, 2021), data analysis is an essential instrument for designing responsive training programs, allowing for rapid adaptation to athlete development and changes in opponent strategy.

Overall, applying the latest technology in badminton training provides an excellent opportunity to improve the effectiveness and efficiency of movement. From video analysis to VR technology, coaches and athletes can leverage these innovations to optimize their training strategies, provide a competitive edge, and maintain athlete performance at the highest level. Integrating these technologies is essential in building competitive and adaptive badminton athletes internationally.

Development of an Integrated Training System

The development of Integrated Training Systems is becoming increasingly essential in sports, especially badminton, where physical strength, technical skills, and mental stability determine athlete performance. A deep understanding of these various aspects can form the basis for improving athlete performance. Therefore, Integrated Training System Development becomes a necessity to achieve optimal results. Integrating physical training with technical training plays a central role in Integrated Training System Development. Physical strength and endurance development must be aligned with improving hitting techniques and movements on the field. The right balance between physical and technical training can positively impact athlete performance. For example, increasing leg muscle strength can improve bat speed and field movement.

Integrating mental training in Integrated Training System Development is also a determining factor. Mental training can help athletes manage stress, improve focus, and build confidence. Techniques such as visualization and relaxation can help athletes deal with competitive pressure. By integrating mental training in Integrated Training System Development, athletes can optimize their performance on the field.

Applying the latest technology is also integral to Integrated Training System Development. Tracking devices and sensors can provide real-time data on athlete performance, allowing coaches to make immediate adjustments to the training program. The study by (Siekańska et al., 2021), highlights that using technology in training can improve the efficiency and effectiveness of movement, leading to improved athlete performance.

The importance of adaptation to athlete development is also a crucial point in Integrated Training System Development. Each athlete has unique needs and characteristics. As described by Bompa and Buzzichelli (2018), the individualization approach in Integrated Training System Development allows coaches to tailor training programs according to each athlete's characteristics and goals. This creates a more responsive and effective training environment.

In the context of competitive badminton, Integrated Training System Development is about optimizing the athlete's physical condition and achieving synergy between physical, technical, and mental aspects. Schmidt and Lee (2014) state that this harmony provides a solid foundation for improving athlete performance. Thus, Integrated Training System Development is a training strategy and a philosophy of holistic and sustainable athlete development.

Adaptation to Athlete Development in Badminton Training Programs

Adaptation to athlete development is a crucial aspect in the design of badminton training programs. Tailoring the training program to the athlete's characteristics, including age, skill level, and physical condition, is an essential strategy for achieving optimal performance. As a critical emphasis, this approach deeply understands each athlete's unique needs and potential.

In running a badminton training program, it is essential to consider the athlete's age. According to (Dewi et al., 2023), during the period of growth and development, physiological and psychological changes significantly affect the athlete's ability. Therefore, training programs must accommodate these changes to ensure that the exercises provided are appropriate for the athlete's physical and mental development.

Skill level is a critical factor in the customization of training programs. Athletes with varying skill levels require an appropriate approach to improve their technical and tactical skills. A successful training program must understand each athlete's skill level and provide proper challenges to improve performance.

An individualized approach is also required to tailor the

training program to each athlete's physical condition. As stated by (Bonilla et al., 2022), Individually tailored training settings can maximize physiological adaptation and reduce the risk of injury. This means involving a detailed assessment of each athlete's strengths, weaknesses and needs to design an effective training program. Individualized training approaches can result in more significant performance improvements than generalized training programs. Therefore, adaptation to athlete development is an essential foundation for achieving optimal results in badminton.

In implementing a responsive badminton training program, it is also essential to consider the psychological factors of athletes. Adaptation to changes in motivation, confidence, and other psychological needs is crucial in achieving consistent performance. As stated by (Rebecka Ekelund Stefan Holmström & Stenling, 2023), Appropriate psychological interventions can increase athletes' mental resilience and help them better deal with match pressure.

By understanding adaptations to athlete development, badminton training programs can become more holistic and practical. Proper adaptation to each athlete's age, skill level, and physical condition helps to create a solid foundation for improving the athlete's overall performance and potential. Therefore, an individualized and responsive approach is critical to a successful training program.

Responsive Training to Changes in Regulations or Technological Developments

The training of badminton athletes must be able to adapt to changes in match rules and technological advances. Responsiveness to this evolution can be critical in maintaining and improving athlete performance. This point includes training strategies designed to accommodate changes in match rules and utilize technological innovations to achieve a competitive advantage.

Over time, the rules in badminton can undergo significant changes, affecting athletes' training tactics and strategies. An in-depth understanding of the current rules is essential in developing an effective training program. Adapting to rule changes requires careful analysis and adjustments to training tactics to ensure athletes' readiness for new match scenarios.

In addition, technological developments provide new opportunities in badminton athlete training. Using sensors and tracking devices in training programs can provide accurate data on athlete performance. Using advanced technology in training can help coaches and athletes identify areas of weakness and objectively measure progress.

Adaptation to technological change also involves the application of innovative training methods. Using simulation technologies, such as virtual or augmented reality, can allow athletes to train in situations that are close to actual matches. This is by research conducted by (Dewi et al., 2023), which showed that simulation technology can improve athletes' agility and decision-making in complex match situations.

Additionally, responsiveness to technological developments also includes adjustments to the latest training tools and equipment. More advanced equipment, such as rackets with the newest technology, can improve athletes' technical skills. In line with the findings (Ferro & Catania, 2023), equipment with the latest technology can affect control and precision in performing certain shots.

In the context of responsive training to changes in rules or technological developments, ensuring that athletes and coaches keep their knowledge up to date is crucial. Regular exercise and workshops on new regulations or the latest technology can ensure that training strategies continue evolving according to badminton demands. Thus, responsive training includes immediate adjustments in the training program and continuous knowledge improvement.

To ensure the sustainability and effectiveness of training programs, coaches and athletes must be lifelong learners, constantly updating their knowledge of badminton's latest rules and technologies. Responsiveness to changes in regulations and technology is not just a direct response to change but also a proactive attitude to continuously improve to achieve maximum performance.

Results and discussion

In the Results and Discussion section, this comprehensive review outlines the key findings of systematically evaluating training strategies and physical conditioning programs for badminton athletes. An in-depth analysis of the relevant studies allowed for identifying consistent patterns and trends that guide our understanding of the effectiveness of various approaches. The results present a comprehensive overview of strength, endurance, speed and agility, providing valuable insights for coaches and practitioners in designing integrated training programs.

However, while there have been significant advances in this literature, knowledge gaps still need to be addressed. One is the need for more consistency in the evaluation methods of physical conditioning programs. In addition, psychological aspects and the use of technology in exercise programs also require further exploration. By identifying these gaps, we can design more specific follow-up research, significantly contributing to the development of physical conditioning science for badminton athletes.

Table. 3.
Systematic Review Results and Findings

Key Findings from Systematic Review		
Findings	One of the supporting Journals of Systematic Review	Explanation
Through the evaluation of several studies, physical conditioning programs that integrate weight training to	(Schoenfeld et al., 2017), (McGuigan et al., 2013),	It should be noted that strength and endurance are critical elements in improving athlete performance. These studies also

increase strength and cardiovascular exercise to increase endurance positively impact badminton athletes.	(Bashir et al., 2022).	highlight the need to detail strength training specific to the typical movements in badminton and cardiovascular exercises that support the stamina required during matches.
Speed and agility highlight the importance of speed training to improve athletes' reactions and agility training to improve body movements.	(Thieschäfer & Büsch, 2022) (Anwer et al., 2021)	These speed drills not only speed up the athlete's reaction to changes in the match but also improve the athlete's ability to anticipate and respond to the opponent's movements. Likewise, agility training helps improve flexibility and agility, which are critical elements in badminton game strategy.
Integration of mental training in conditioning programs and application of the latest technology in training.	(Andreato et al., 2022) (Hamdani et al., 2022)	Mental exercises such as visualization and mental focus have been shown to benefit athletes, improving concentration and mental resilience during matches. Technology, such as performance monitoring and data analysis, can provide valuable insights for coaches to tailor training programs in real-time according to athletes' needs.

Implications for Physical Conditioning Programs for Badminton Athletes

Actions taken based on the findings of this systematic review can have significant implications for developing a Physical Conditioning Program for Badminton Athletes. First of all, the data analysis suggests that increasing strength through weight training positively impacts the performance of badminton athletes. Along with these findings, strength training that focuses on the key muscles used in badminton movements can improve the strength and endurance of athletes. Therefore, training programs should focus on developing muscle strength relevant to badminton activities.

Furthermore, in improving speed and agility, structured speed training and agility drills can contribute significantly to an athlete's response to match situations. Speed training that includes exercises and simulations of match situations can improve athletes' reaction and response times. Therefore, integrating speed and agility training into an integral part of the Physical Conditioning Program can provide inevitable advantages in improving badminton athletes' performance.

In addition, mental and psychological aspects also need to be considered in the training program. Relaxation and visualization techniques in training can help manage competitive stress and improve athletes' focus. Therefore, integrating mental activity into the Physical Conditioning Program may improve athletes' mental resilience and focus during matches.

By applying these findings in a Physical Conditioning Program for Badminton Athletes, coaches and practitioners can more effectively design a holistic training program encompassing the critical aspects found in this review. This can not only improve overall athlete performance but also guide the development of more effective and up-to-date training methods in the world of badminton.

Knowledge Gaps and Opportunities for Further Research

Although this comprehensive review has provided deep insights into badminton athletes' training strategies and physical conditioning programs, some knowledge gaps need further exploration. Firstly, there is little consistency in evaluating the effectiveness of physical conditioning programs. Some studies focus more on strength and endurance, while aspects of speed and agility may have yet to receive enough attention. A further analysis of the integration of these elements may provide a better understanding of how to design a holistic and balanced program.

One potential research opportunity is to investigate in more depth the psychological impact of training strategies on the performance of badminton athletes. Although this review touched on integrating mental training, more research is needed to explore how to involve psychological aspects in conditioning programs. Further studies could uncover how motivation, mental focus, and stress management affect physical training outcomes. Applying sports psychology experts and using relevant evaluation methods could provide greater insight into designing programs that strengthen the body and improve athletes' mental resilience.

Furthermore, there is an opportunity to utilize the latest technology to train badminton athletes. In the face of technological advances such as performance sensors and data analysis, further research could explore how best to integrate these technologies into physical conditioning programs. By analyzing data in real-time, coaches can quickly adjust training programs according to athletes' individual needs, increasing training efficiency and potential performance improvements. By filling this knowledge gap through continued research, we can significantly contribute to the development of physical conditioning science for badminton athletes. Sources of support include recent research studies addressing uncertainties in physical training program evaluation methods and sports psychology studies demonstrating the importance of mental aspects in athlete performance achievement.

Discussion

Our analysis showed that the identified training strategies were specifically designed to meet the unique needs of badminton athletes. Weight training to increase muscle strength, especially in the lower limbs, such as the feet and thighs, increases repulsion power and movement speed. This is due to the demands of fast movements and high jumps often occurring in badminton matches.

The results showed that some training strategies were more effective than others. Speed training that incorporates quick reactions to changes in opponent tactics can provide

a significant competitive advantage. In contrast, agility drills, although important, may need to be further customized to achieve optimal results.

In looking at the findings related to psychological and mental factors, mental aspects significantly impact the performance of badminton athletes. Physical conditioning programs that include cognitive training, such as match visualization and stress management, improve athletes' focus and mental endurance.

Although the findings show positive results, some challenges and obstacles must be noted. In the implementation of specific training strategies, there were logistical and equipment constraints in some training environments. In addition, individuals with different initial fitness levels may face other challenges in adopting physical conditioning programs.

We acknowledge several limitations in the methodology of this systematic review. Limitations in the number of relevant studies may limit the generalizability of the findings. Although efforts have been made to cover relevant literature, the possibility of recent studies that have yet to be included in our analysis must also be recognized.

In looking to the future, recommendations for future research could include an in-depth study on the adaptation of training strategies for different fitness levels and ages of athletes. In addition, further research could focus on integrating current technologies, such as movement analysis and real-time performance monitoring, in developing innovative physical conditioning programs.

The results of this systematic review make an essential contribution to our understanding of how to optimize physical conditioning programs to improve the performance of badminton athletes. The findings provide a basis for developing more effective training programs that suit the specific needs of this sport.

Conclusion

In pursuit of the research objective to optimize physical conditioning programs for badminton athletes through a comprehensive review of training strategies, this systematic review provides valuable insights into our understanding of the critical aspects that need to be considered in developing training programs. To provide a comprehensive overview, this conclusion will summarize the key findings' practical and theoretical implications and provide insights into knowledge gaps and further research opportunities.

The summary of the main findings highlights the importance of physical conditioning integrated with appropriate training strategies for badminton athletes. The results include discussions on critical aspects such as strength, endurance, speed and agility. The review shows that weight training is efficacious in improving strength, while cardiovascular exercise is crucial for building the endurance required during matches. Likewise, speed and agility training proved crucial for enhancing athletes' reactions and quick and accurate body movements.

The practical implications of these findings are highly relevant for coaches, athletes and fitness practitioners. Practical recommendations include implementing training strategies that have proven effective in physical conditioning programming and emphasizing the integration of current technology and mental training in training. This can help create a holistic and adaptive training program according to the individual needs of athletes.

In terms of theoretical implications, this study contributes to our understanding of the relationship between badminton training strategies and physical conditioning. Integrating technology in training also opens the door for further research on how such innovations can enrich traditional approaches to athlete coaching.

While the results of this review provide valuable insights, there are still knowledge gaps that need to be filled for better understanding. Emphasizing those areas can be the basis for further research, creating the opportunity to develop more effective and innovative approaches to physical conditioning for badminton athletes.

Overall, this study plays a vital role in developing knowledge and practice in physical conditioning for badminton athletes. By providing a solid foundation through critical findings, practical implications, and recommendations for future research, it is expected to provide valuable guidance for coaches and practitioners in improving the performance of badminton athletes.

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