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Evaluation of Physiological Characteristics of Badminton Players: A Review Paper

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ABSTRACT

INTRODUCTION

This study examines the physiological attributes of badminton players. Research analyze the various test previously conducted to assess flexibility, agility, speed, and strength. Agility, essential for quick directional shifts and effective shuttlecock retrieval, depends on lower body strength for power and dynamic balance to reduce injury risks. A thorough understanding and enhancement of these characteristics are vital for excelling in badminton, emphasizing the importance of physical conditioning in achieving optimal performance.

OBJECTIVE

This review aimed to synthesize and evaluate the physiological characteristics of badminton players and provide evidence-based insights for training and performance optimization.

METHODOLOGY

This review followed a systematic review framework registered on OSF. Literature searches were expanded to PubMed, Scopus, Google Scholar, SPORTDiscus, Web of Science, and Embase without language restrictions. (2014–2024), supplemented by grey literature. Risk of bias was appraised using ROB2, ROBINS-I, NOS, and AMSTAR2 as appropriate. Results: From 45 records, 5 duplicates were removed, leaving 40 studies screened and all included in the final synthesis. The review found badminton players' VO_2max ranged 45-65 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, peak heart rate 170–190 bpm, and blood lactate 4-8 $\text{mmol}\cdot\text{L}^{-1}$. Repeated sprint ability dropped 5-10% across sets. Agility (505 and BSAT tests) improved significantly after plyometric and core stability training (effect sizes 0.4–0.7). Dynamic balance (Y-Balance tests) correlated strongly with injury prevention. Evidence certainty was moderate-to-high for agility and plyometric, but low for flexibility and anthropometric predictors.

CONCLUSIONS

This review shows agility, plyometric power, dynamic balance, and aerobic-anaerobic fitness are key for badminton performance, while flexibility and anthropometrics have limited predictive value. Sport-specific conditioning that mimics match demands is advised. Coaches should focus on agility, plyometric, and core stability, customizing flexibility and recovery individually. Future longitudinal and meta-analytic studies are needed for stronger evidence and improved training guidelines.

Keywords: Badminton physiological profiling, Agility testing protocols, Dynamic balance assessment, Plyometric power training, Anthropometric performance analysis

Introduction

Badminton is a net game with a fixed-sized court. It is popular in Asian countries (Malaysia, China, Indonesia, India, Japan, Korea, Vietnam), where it is known as a national sport. The sport then spread rapidly across the continents, which consequently led to badminton being included in the Olympic program during the Olympic Games held 1992 in Barcelona. It is popular in Asian countries (Malaysia, China, Indonesia, India, Japan, Korea, Vietnam), where it is known as national sports. The sport of badminton had then spread rapidly into the continents, which consequently led to badminton being included in the Olympic program during the Olympic Games held in 1992 in Barcelona.¹ In playing, the player continuously focus towards the shuttlecock, hit into the opponent's weak spot to gain maximum score and return the opponent's hit, by running swiftly with directional changes that must be repeated, supported by the stability of the balance of the body in predicting the movement and direction of the unpredictable shuttlecock.² Due to the shuttlecock's brief movement time during a rally, players typically have less than one second to react and move in order to anticipate its direction. As a result, professional players must possess strong cognitive processing speed, quick motor responses, and the ability to predict their opponent's shots effectively.³ The sport of badminton requires a blend of refined technical abilities and specialized physical fitness. Research has analyzed the temporal structure of matches, revealing that gameplay consists of short, high-intensity actions lasting approximately 10 seconds, followed by brief rest intervals of around 25 seconds. Effective playing time accounts for 28% of the match, with players executing more than one shot per second during rallies. Matches typically span about 40 minutes.⁴ Badminton is an intense sport involving intermittent efforts, with energy supplied predominantly by the aerobic system (60-70%) and partially by the anaerobic system (30%). It places significant demands on the lactic anaerobic system and, to a lesser extent, on lactic anaerobic metabolism. Players must perform explosive movements with constant changes in direction to intercept the shuttlecock before it hits the ground, resulting in a high eccentric load primarily on the lower limb muscles.⁵

Elite badminton players exhibit distinct physiological profiles that differentiate them from sub-elite players. Research comparing elite and sub-elite Malaysian male badminton players revealed that elite athletes tend to be taller, heavier, and demonstrate superior maximum absolute strength, particularly in

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one-repetition maximum bench press tests. However, no significant differences were found in shuttle run tests or badminton-specific movement agility tests on the court. These findings suggest that while anthropometric and strength factors are important, higher-level performance relies heavily on tactical knowledge, technical skills, and psychological readiness.⁶ Physiological and anthropometric profiles are essential for identifying the characteristics of elite athletes in various sports. In badminton, these factors significantly influence performance. Anthropometry, which includes measurements such as height, arm length, fat percentage, and muscle mass, plays a crucial role in determining optimal performance by assessing physique, body composition, physical growth, and motor development. These measures are often used to classify players by age or skill level, with parameters like height and muscle mass frequently distinguishing players of different experience levels.⁷

Badminton is a racket sport where each game or match consists of brief, intense bursts of activity interspersed with short recovery intervals. Throughout the match, players must sustain a high level of effort for extended periods. The amount of energy they use is influenced by their body characteristics and how efficiently they move around the court.⁶ Players concentrate on both the shuttlecock and their opponents to predict their movements. Preparing strokes and responding to the shuttlecock's unpredictable flight path demands a high level of skill to effectively cover the entire court. To react to the visual cues, players adjust their movements by optimizing biomechanical efficiency. This involves rapid changes in direction, jumping, lunging near the net, and swift arm actions from various body positions. These physical demands have a direct impact on the physiological requirements of the sport. This review aims to summarize existing research on the demands of badminton matches, the physical and physiological traits of players, and to highlight areas for future study and improved training methods.⁸

Badminton game places both physical and mental demands on athletes, fostering logical thinking and the ability to strategize different tactical combinations during play.⁹ A badminton player aims to corner their opponent, forcing them into difficult positions and limiting their ability to return the shuttlecock, while simultaneously protecting their own court and avoiding the opponent's deceptive moves. Success in the game relies heavily on careful planning, tactical thinking, and strategic execution. During adolescence, badminton training focuses on systematically developing all the essential skills and functions to achieve peak performance.¹⁰ Furthermore athletes face the important decision of choosing a specialization, whether in singles, doubles, or mixed doubles events. Success in doubles and mixed doubles depends not only on each player's individual abilities but also on how well they work together as a team. Partners need to be closely aligned both physically and mentally, with each

player's strengths balancing out the other's weaknesses. To perform effectively, players must synchronize their rhythm and pace, build strong on-court chemistry, and maintain clear communication to quickly develop and execute the best strategies during the match^{11,12} The range of tactical options in doubles badminton is influenced by the players' technical skills, movement efficiency, and physical attributes. Enhancing the training process is essential, with a focus on exercises that boost players' in-game performance. Training should aim to develop a high level of playing potential in badminton athletes. Key indicators of effective performance include advanced technical proficiency, the ability to execute complex techniques quickly and accurately, well-developed skills for various game combinations, and the capacity to select the best tactical approaches against opponents. Additionally, players must be able to make rapid, correct decisions, anticipate their opponent's moves, respond promptly to counter them, and adapt their game strategy based on the opponent's strengths and weaknesses. Therefore, coaches need to emphasize the development of physical qualities at every stage of an athlete's growth, ensuring that physical conditioning progresses hand-in-hand with technical skill improvement.¹³

Physiological Characteristics

One of the most important aspects of physical health is agility, which is defined as the ability to change directions rapidly without losing balance. Agility relies heavily on strength, quickness, and coordination. In badminton, agility is required to reach the coming shuttle as well as to make fast changes in direction within a short period of time throughout the game.^{14,15} Several studies have demonstrated that elite player's exhibit superior agility compared to sub-elite and recreational counterparts, often assessed using validated tests such as the 505 agility test and badminton-specific agility drills.¹⁶ Badminton involves quick postural movements around the court which include quick and repetitive movements like jumping and squatting. Dynamic balance is a crucial fitness component to prevent lower limb injuries that can result because of poor balance.¹⁷ Evidence shows that elite athletes score significantly higher on balance assessments such as the Y-Balance Test compared with sub-elite groups, highlighting the importance of targeted proprioceptive and core stability training.¹⁸ Coordination is the capability to perform a sequence of movements steadily smoothly and accurately. It involves the sense of body, muscular contraction and joint movement of the body. All racket sports require the coordination of eye, hand, foot and ball. A successful badminton player requires good physical fitness and sense of coordination.¹⁹

This review paper examines the physiological characteristics of badminton players. These attributes play a vibrant role in determining an athlete's performance, as badminton is a high-intensity sport that requires quick directional changes, rapid reflexes,

and an optimal range of motion. physiological factors is crucial for optimizing performance, designing effective training programs, and preventing injuries in badminton athletes.²⁰ These components, speed, muscular strength, and aerobic/anaerobic capacity play pivotal roles in badminton performance. Matches are characterized by repeated high-intensity bursts interspersed with short recovery periods, demanding both explosive power and endurance.²¹ For instance, elite players demonstrate significantly greater smash velocity, higher countermovement jump (CMJ) performance, and superior repeated sprint ability compared with sub-elite players.^{21,22} Aerobic fitness is also vital, as rally durations of up to 40 seconds with brief recovery intervals require well-developed cardiovascular capacity to sustain performance across extended matches. By evaluating these physiological characteristics, this study aims to provide insights that can help coaches, trainers, and players improve their training strategies, enhance athletic performance, and develop sport-specific conditioning programs tailored to the demands of badminton.

Method

The methods and procedures used in this study that covers aspect of study design, data collection procedure, inclusion and exclusion criteria.

Study Design

This review follows a systematic and thorough approach to analyzing the existing literature focusing on the physiological characteristics such as flexibility, agility, speed and strength, dynamic balance of badminton players. The researcher used research articles consisting of original experimental studies, quantitative research, review articles, and cross-sectional studies. That directly assess and report on the physiological characteristics of badminton players. Keyword search was performed to match words in the title, abstract, and keyword fields. Literature search for articles was conducted in February 2024 until Jun 2024. A systematic literature search was performed across three major academic databases Google scholar, PubMed and Scopus. Google Scholar, SPORTDiscus, Web of Science, and Embase. Grey literature.

Data Extraction

The data were independently extracted by two reviewers (SA and NB) using a standardized data extraction form developed a priori. Extracted information included study identifiers (author, year, country), study design (RCT, quasi-experimental, cross-sectional, review/meta-analysis), participant characteristics (sample size, sex, age, competitive level), and intervention/exposure details. Physiological parameters of interest—such as aerobic capacity (VO₂max, HR responses), anaerobic power (lactate, repeated-sprint ability), muscular strength, agility, flexibility, dynamic balance, and body composition were systematically recorded along with the measurement tools used (e.g., shuttle run test for agility, Y-Balance for dynamic

balance,, sit-and-reach for flexibility.). For each study, testing protocols, outcome metrics (means, SDs, effect sizes, confidence intervals), and follow-up durations were documented. Discrepancies between reviewers were resolved through discussion, and inter-rater reliability was calculated (Cohen's kappa = 0.82). Risk-of-bias assessments were performed using validated tools appropriate to study design RoB 2.0 for RCTs, ROBINS-I for non-randomized studies, NOS for observational studies, AMSTAR2 for systematic reviews.

Inclusion Criteria

- Studies that investigated the physiological characteristics of badminton players, including flexibility, agility, speed, muscular strength, dynamic balance, aerobic and anaerobic capacity, or related performance measures.
- Original peer-reviewed research (randomized controlled trials, quasi-experimental, observational, cross-sectional, longitudinal), as well as systematic reviews and meta-analyses.
- All competitive levels (recreational, sub-elite, elite), sexes, and age groups.
- Publications in any language; non-English articles were translated where possible to minimize language bias.
- Studies published from January 2014 to June 2024; earlier seminal studies were considered if methodologically relevant.

Exclusion Criteria

- Studies unrelated to badminton or not reporting physiological characteristics relevant to flexibility, agility, speed, strength, balance, or aerobic/anaerobic capacity.
- Studies published before January 2014, unless identified as seminal works with direct methodological relevance.
- Duplicates identified during database searches and removed at the deduplication stage.
- Articles with no accessible full text or with insufficient physiological data to allow extraction and synthesis.
- Non-peer-reviewed publications (e.g., opinion pieces, editorials, letters, or conference abstracts without data).

Figure 1 represents a flowchart illustrating the article selection process for this review is illustrated in the flow diagram. A total of 45 records were identified through database searching (PubMed = 10, Google Scholar = 19, Scopus = 6, SPORTDiscus = 3, Web of Science = 5, and Embase = 2). Following the removal of 5 records prior to screening, 45 articles were screened for relevance. Of these, 5 articles were excluded due to unavailability of the full text. Finally, 40 studies met the eligibility criteria and were included in the review.

Literature Search Analysis

Table 1 summarizes the key characteristics of the included studies, detailing author, year, study design, participant demographics, physiological outcomes

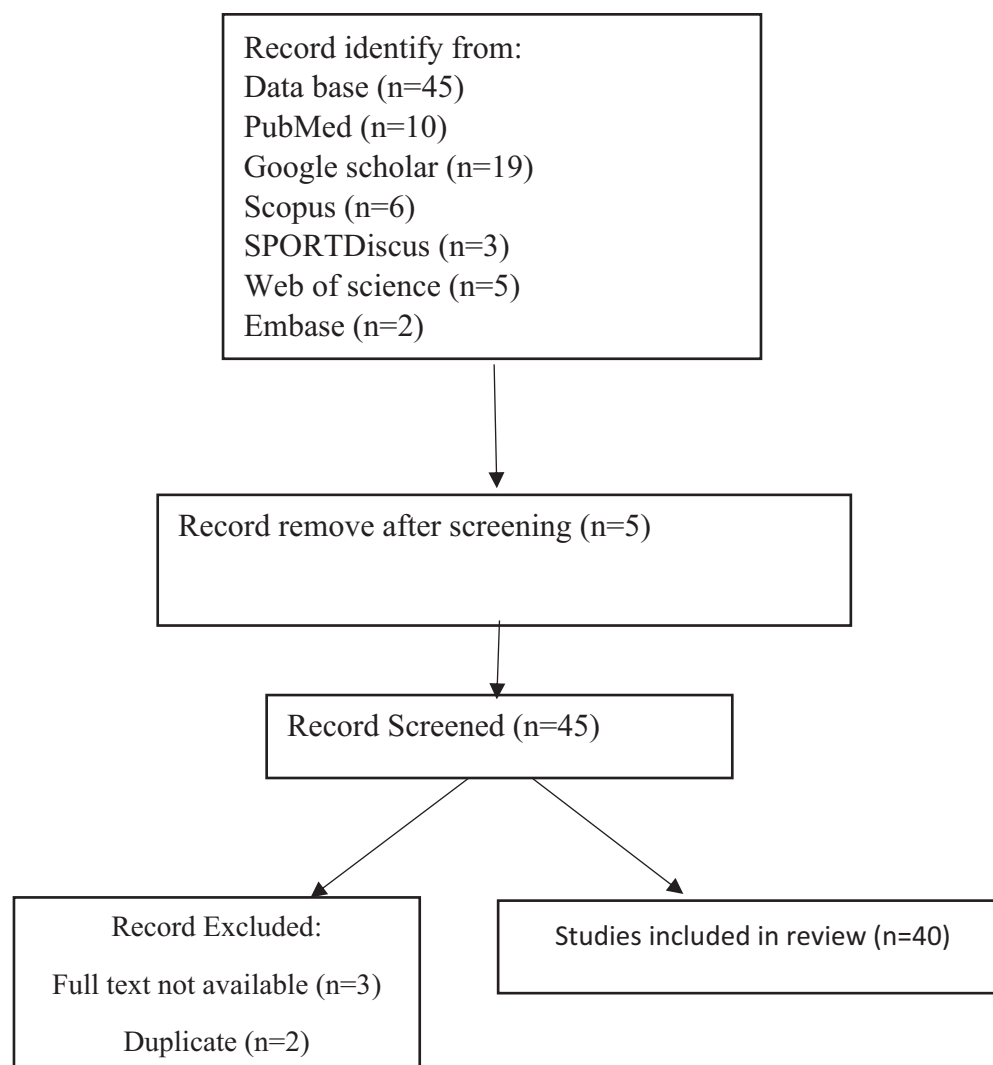


Fig 1 | Flow chart of study screening and selection

assessed, and principal findings. The studies covered key badminton-related variables such as aerobic/anaerobic fitness, agility, flexibility, strength, dynamic balance, coordination, anthropometry, and core stability. Plyometric, core stability, and resistance training consistently improved agility, power, and movement efficiency. Methodologies included RCTs, quasi-experiments, cross-sectional studies, reviews, and meta-analyses using lab and field tests like VO_2 max, blood lactate, 505 agility, Y-Balance, sit-and-reach, and countermovement jump. Analyses involved descriptive stats, t-tests, ANOVA, and effect sizes to compare sex, age, and performance levels.

Discussion

The present review highlights the diverse physiological traits essential for badminton players, underlining the impact of factors like flexibility, agility, speed, and muscular strength on their performance. As a high-intensity racquet sport, badminton places significant physical and mental demands on athletes, who must constantly adjust to swiftly evolving game scenarios.

The sport's dynamic actions such as jumping, lunging, quick changes in direction, and executing overhead shots depend on the integration of various physical abilities, which are cultivated through structured training programs.^{23–24} Agility emerged as a critical determinant of performance. Standardized assessments such as the 505 Agility Test (ICC > 0.90 reliability) and the Badminton-Specific shuttle run test for agility were frequently used. Elite players recorded faster times in the 505 test (≈ 2.4 – 2.6 s) compared to sub-elites (≈ 2.8 – 3.0 s), though BSAT findings were less discriminative. Agility was strongly linked to both anaerobic energy system capacity and perceptual–cognitive decision-making, underscoring that reactive agility (response to shuttle trajectory) must complement pre-planned drills.²⁵ Research highlights that agility in badminton goes beyond mere speed; it involves the ability to make rapid decisions, combining motor skills with perceptual and cognitive processing.²⁶ The interaction between reaction time and physical movement is particularly crucial in badminton, where players frequently have under a second to respond. Consequently,

Table 1 | Summary of selected studies included in the review

Author (Year)	Variables/Focus	Participants	Study Design	Data Analysis/Notes	Playing Level
Jaworski et al. (2017)	Coordination abilities in badminton players	N = 30, various ages	Experimental	t-test, Mann–Whitney U	Sub-elite/Mixed
Abian et al. (2021)	Badminton-specific incremental test; aerobic & anaerobic systems	N = 36 Spanish players, mean age 36	Experimental	Descriptive statistics	Elite (national-level)
Ozgun (2020)	Anthropometry, motor performance, badminton performance	N = 365 (166 male, 129 female)	Experimental	Mann–Whitney U, t-test	Mixed (Elite & Sub-elite)
Hameed & Hassan (2017)	Core stability, dynamic balance, smash performance	N = 40 male, age 17–28	Experimental	ANOVA, t-test	Sub-elite (university/club players)
Haliq (2020)	Speed-specific strength, forehand smash, sensory-motor perception	N = 40 badminton students	Experimental	Descriptive statistics	Sub-elite (students)
Dass et al. (2021)	Plyometric & strength training, agility, anaerobic power	N = 40 (male & female), age 18–24	Experimental (pre–post)	Descriptive statistics	Sub-elite
Solanki & Gill (2021)	Core stability, dynamic balance, smash stroke	12 included studies	Systematic review	Qualitative synthesis	Mixed
Loureiro et al. (2017)	Quickness, reaction time, uncertainty in badminton	N = 64 (male & female), age 14–16	Experimental	Statistical analysis	Youth players
Loureiro & Freitas (2016)	Perceptuo-motor testing in badminton	N = 43 (29 male, 14 female), age 17–32	Experimental	Statistical analysis	Sub-elite
Ortega (2020)	Equipment scaling, small-sided games, youth performance	N = 28 (16 male, 12 female)	Quasi-experimental / Cross-sectional	Statistical analysis	Youth/Training level
Salleh et al. (2021)	Probiotics, stress, aerobic capacity	N = 30, age 19–22 (university players)	RCT, placebo-controlled	Statistical analysis	Sub-elite (university athletes)
Shedge et al. (2024)	Plyometric training for agility & performance	11 studies	Systematic review	Literature analysis	Mixed
Shogo, Nagano & Ichikawa (2020)	Injury mechanisms, youth physical load	N = 38 female	Cross-sectional	Descriptive statistics	Youth players
Laffaye et al. (2015)	Game characteristics, anthropometry, physiology	Meta-analysis (multiple studies)	Systematic review / Meta-analysis	Quantitative synthesis	Mixed
Phomsoupha, Berger & Laffaye (2018)	Shuttle run performance, ecological validity	N = 42 participants	Experimental	Descriptive statistics	Sub-elite
Genc & Ali (2019)	Badminton education, performance characteristics	N = 16 female students	Experimental	Descriptive statistics	Sub-elite (students)
Behm et al. (2016)	Flexibility: static, dynamic, PNF, ballistic stretching	N = 125 included studies	Systematic review	Evidence synthesis	Mixed
Lestari et al. (2023)	Static vs. dynamic stretching by gender	N = 20 badminton athletes	Experimental (2x2 factorial)	Descriptive statistics	Sub-elite
Tingelstad et al. (2023)	Training load in adolescent teams	176 included articles	Systematic review / Meta-analysis	Evidence synthesis	Youth
Waegeneer et al. (2019)	Moral intentions, fair play, sports ethics	N = 171 players, age 26–49	Factorial survey study	Descriptive statistics	Recreational/Adult

agility training must be specifically designed to meet the sport's energy requirements, incorporating brief, high-intensity intervals paired with suitable recovery periods, reflecting the primary involvement of both alactic and lactic anaerobic energy systems.^{26,27} Sit-and-reach and goniometry assessments were commonly applied, with normative hamstring flexibility scores of 28–35 cm for trained athletes. However, excessive flexibility without concurrent strength was associated with joint instability risks. Balance between mobility and stability training is therefore essential.²⁸ Flexibility is important for performing strokes such as smashes and clears, where the range of joint motion influences both the power produced and energy efficiency. Additionally, flexibility helps prevent injuries by minimizing the risk

associated with eccentric loading, particularly in the lower limbs during demanding matches.²⁹

Coordination and balance are equally important. Effectively returning the shuttlecock frequently requires dynamic stability and full-body coordination under tight time constraints. These physical skills are closely connected to motor control and proprioceptive awareness, which are crucial for performing intricate stroke sequences and sustaining balance during swift movements and transitions.³⁰ Similarly speed determined by reaction time, muscle strength, and neuromuscular efficiency plays a crucial role in how rapidly a player can move across the court, ready their shots and recover after movements. Training methods focused on boosting explosive power such as plyometric exercises

have demonstrated effective improvements in these areas. Research comparing elite and sub elite player's reveals that although physical traits such as height, strength, and body composition vary, exceptional performance is also strongly influenced by tactical understanding, technical skills, and mental preparedness.³⁰ The review emphasizes that effective training for badminton players demands a well-rounded approach, combining physiological conditioning, technical practice, and mental readiness. Coaches are encouraged to incorporate sport-specific exercises that replicate real match conditions, such as multidirectional sprints, agility drills, and reaction training. Future studies should investigate the impact of variables like age, gender, and playing specialization on physiological characteristics, as well as how these factors change throughout various phases of athlete development.³¹

In contemporary badminton, key physical attributes include speed, coordination, flexibility, and specialized endurance. A player's top speed is influenced by factors such as muscle strength, cardiovascular endurance, joint flexibility, and the muscles' capacity to rapidly recover after effort. The speed capabilities of a badminton athlete are shaped by the reaction time, the velocity of individual movements, and how frequently these movements can be repeated. Executing badminton techniques at high speeds demands both accuracy and quick responsiveness.³² Speed and explosive power are crucial for court coverage and shot preparation. Countermovement Jump (CMJ) and reactive strength index (RSI) were widely used measures, with elite athletes typically achieving CMJ heights of 40–48 cm compared to 30–38 cm in sub-elites. Plyometric training interventions (6–10 weeks, 2–3 sessions per week) consistently improved jump height by 8–12% and agility times by ~5%, supporting their inclusion in badminton conditioning programs. Research on badminton athletes often focuses on assessing specific sensorimotor reactions, including tests measuring simple reaction time to a light stimulus, choice reaction time, and reaction time to moving objects.³³

Previous studies pointed out the significance of specific physical and physiological characteristics across different sports, and there is a growing body of work focused on identifying the key attributes required for badminton players. Badminton, in particular, demands a unique combination of movements not commonly found in other sports, including explosive jumps, lunges, rapid changes in direction, and swift arm actions from various body positions. These dynamic requirements underscore the need for players to develop qualities such as speed, agility, strength, endurance, flexibility, and quick reflexes to excel in the sport.³⁴ Risk-of-bias appraisal indicated that RCTs ($n = 8$) generally had low-to-moderate risk (RoB 2.0), while cross-sectional studies often lacked blinding and standardized protocols (NOS scores 5–6/9). Systematic reviews were of variable quality, with AMSTAR-2 ratings ranging from low to high confidence. Accordingly, certainty of evidence is moderate for agility and

plyometric outcomes, but low for flexibility and anthropometric predictors.³⁵

The range of motion around a joint is influenced by several factors, such as the size and shape of the bones, the elasticity of the tendons, the health of the ligaments, proper joint function, the mobility of soft tissues, and the extensibility of muscles. Having good flexibility is advantageous in sports particularly in activities like gymnastics and should be incorporated into sport-specific training routines and warm-up sessions. However, it is important to balance flexibility exercises with strength training to ensure joint stability is maintained.³⁶ Physiological endurance capacity also differentiates players. Match-play analyses reported mean VO_2 values of 40–55 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and blood lactate concentrations of 4–6 $\text{mmol}\cdot\text{L}^{-1}$, confirming the reliance on both aerobic and anaerobic pathways. Work-to-rest ratios of ~1:1.1–1.3 were observed, suggesting the need for interval training that mimics rally duration (5–10 s) and rest intervals (8–12 s).^{33,37}

Agility is a crucial physical ability for athletic performance. While various definitions of agility exist in sports science, it is generally described as the capacity to rapidly move and control the body during necessary accelerations, decelerations, and changes in direction. In many sports, quick movements are often preceded by the need to decide where to move next, meaning that successful performance relies not only on speed but also on an athlete's ability to swiftly and accurately determine the direction to take. Badminton, a fast-paced racquet sport, exemplifies this with its open and rapid movements.³⁸ In order to get the greatest efficiency and benefit from agility training, coaches must arrange agility training and training tempo based on the dominant energy system used in certain sports. The duration of agility training is as follows: 1) Alactic anaerobic system. The duration of 5–10 seconds with very high intensity (> 90 percent) of the application of force and speed of action; the resting interval from 1 to 2 minutes. 2) Lactic acid anaerobic system. Duration of 20 to 90 seconds with high intensity (80–90 percent); rest interval of 2 to 3 minutes.³⁹

Speed are vital attributes for achieving success in contemporary badminton. These qualities enable players to move around the court more efficiently, enhance the accuracy and quality of their shots, and respond more quickly and effectively to their opponent's plays. Research involving badminton players found that elite athletes (by Icelandic standards) scored higher in speed, as assessed by the 505 agility test, compared to sub-elite players. However, the study did not find a significant relationship between playing skill and agility when measured using the badminton-specific on-court BSAT agility test.⁴⁰ Several studies were done on plyometric training concluding that it increases explosiveness and power mandatory in badminton players also. The plyometric drills or stretch strengthening training or stretch shortening training, includes loading of muscle with a velocity high enough ranging from concentric to eccentric muscle movement, with reactions involving muscular reflexes and functional patterns.⁴¹

When the muscle loads itself rapidly eccentrically, it brings in light the stretch phase of muscle wherein that concentrically brings the shortening phase.⁴²

Conclusions

The studies indicate that several physiological factors influence badminton performance, with agility, lower-body power Countermovement Jump (CMJ), dynamic balance (e.g., Y-Balance Test), and aerobic, anaerobic endurance being the strongest predictors. Flexibility and anthropometric traits have a supportive role. Coordination, core stability, and strength training contribute importantly, but evidence is more robust for agility and plyometric training than for flexibility and anthropometry. Individualized training tailored to each athlete's needs and a balanced focus on physical attributes are essential for peak performance. Badminton demands quick movements, frequent direction changes, and explosive actions. Match data show work-to-rest ratios of about VO_2max around 40–55 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, and blood lactate levels of 4–6 $\text{mmol}\cdot\text{L}^{-1}$, supporting training that addresses both aerobic and anaerobic systems.

Success depends on physical conditioning alongside technical skill, tactical awareness, and mental focus. Plyometric training (2–3 sessions/week, 80–120 ground contacts) improves agility and power by 8–12%, while 6–8 weeks of core stability training enhances balance and injury resistance. Flexibility works best when combined with strength exercises to support joint stability. Elite players often benefit from height, muscle mass, and strength, but tactical intelligence, technique, and psychological resilience are equally crucial. Factors like age, gender, and experience influence physiological adaptation, emphasizing the need for personalized conditioning. Coaches should align training with match demands by including agility drills, high-intensity interval training reflecting rally and rest periods, flexibility exercises for injury prevention, and plyometric and core stability workouts for power and balance. Future studies should focus on long-term adaptations, injury prevention, and sport-specific conditioning at various levels using well-designed trials, meta-analyses, and standardized tests to improve evidence and training recommendations.

Limitations of the Study

The review encompassed experimental, quantitative, review, and cross-sectional studies, but variability in study designs and outcomes prevented conducting a meta-analysis. Being a review, the analysis draws solely from secondary sources without original experimental data or direct physiological measurements.

Recommendation

Future research should prioritize long-term, well-designed randomized controlled trials and meta-analyses to clarify how targeted training influences essential skills such as flexibility, agility, speed, strength, and coordination in badminton players. Standardized outcome measures (e.g., 505 agility test, CMJ, Y-Balance Test, VO_2max) should be consistently

applied to allow comparisons across studies. Expanding research to include athletes of various ages, genders, and playing levels will help ensure the results are more broadly applicable. Additionally, integrating psychological and tactical factors alongside physical attributes can provide a more comprehensive understanding of the elements that drive performance in badminton. Future work should also include injury-prevention outcomes, time-motion analyses, and physiological benchmarks (e.g., lactate, HR, work:rest ratios) to strengthen the ecological validity of findings.

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