ASEAN Journal of Physical Education and Sport Science

Journal homepage: https://ejournal.bumipublikasinusantara.id/index.php/ajopess

Physical Fitness and Sport-Specific Skills in Competitive Youth Badminton Players: Implications for Training and Talent Development

*Li Yuxuan, Lee Kok Sonk**

National Institute of Education (NIE), Nanyang Technological University, Singapore
*Correspondence: E-mail: koksonk.lee@nie.edu.sg

ABSTRACT

Badminton performance requires the integration of physical fitness and sport-specific technical skills. However, their relationships among pre-adolescent competitive players remain insufficiently understood. This study examined physical and technical performance, group differences, and associations between fitness attributes and badminton-specific skills among competitive youth players in Singapore. Physical fitness was assessed through wrist elevation, vertical jump, estimated jump power, and shuttle-run performance, while clear, drop, net, and lift shots were evaluated using standardized target-based assessments. Lower-limb power and agility showed significant but generally limited associations with selected technical skills, whereas wrist flexibility was not meaningfully associated with skill performance. The findings indicate that physical fitness supports but does not independently determine technical proficiency, emphasizing multidimensional training and talent-development approaches for competitive youth badminton.

ARTICLE INFO

Article History:
Submitted/Received 17 Jun 2026
First Revised 18 Aug 2026
Accepted 19 Aug 2026
First Available online 25 Aug 2026
Publication Date 01 Mar 2027

Keywords:
Badminton;
Physical fitness;
Sport-specific skills;
Talent development;
Talent identification;
Youth athletes.

1. INTRODUCTION

Badminton is a high-intensity intermittent racket sport requiring rapid movement, repeated changes of direction, jumping, and technically precise stroke execution. Competitive match play involves short periods of intensive activity separated by brief recovery intervals, resulting in substantial aerobic and anaerobic demands [1]. High physiological strain during badminton competition is also reflected by elevated heart rates and blood lactate concentrations [2]. These characteristics indicate that successful badminton performance requires the integration of physical fitness, movement efficiency, and technical proficiency.

Technical performance in badminton is closely related to the biomechanical organization of movement. High shuttlecock velocities depend on an effective kinetic chain in which force generated by the lower limbs is transferred through the trunk and upper extremities to the racket [3]. Badminton performance therefore cannot be considered solely as an upper-body or racket-skill activity. Physical capabilities that support positioning, jumping, acceleration, and change of direction can contribute to the conditions under which technical strokes are executed. Contemporary match analyses further indicate that temporal and technical-tactical demands vary according to competitive contexts [4], while changes in match characteristics and competition formats may influence the conditions under which badminton skills are performed [5].

The relationship between physical fitness and technical performance may nevertheless differ considerably according to developmental stage. Models developed from adult athletes cannot automatically be applied to younger players. During pre-adolescence, improvements in physical performance are strongly influenced by neuromuscular development, motor coordination, and movement competency. The Youth Physical Development model emphasizes that athletic development should account for age- and maturation-related differences rather than applying adult-oriented conditioning principles directly to young athletes [6].

This developmental consideration is particularly relevant to competitive badminton players approaching adolescence. Recent evidence indicates that integrative neuromuscular training can improve physical and technical performance among prepubertal badminton players [7]. Physical fitness responses may also differ according to biological maturity status [8]. Consequently, chronological age alone may not adequately explain differences in physical or technical performance among young badminton athletes.

Physical fitness remains an important component of badminton development. Research involving competitive badminton players has demonstrated the relevance of physiological characteristics to performance [9]. Strength and conditioning interventions may also contribute to badminton performance, although relationships between general physical capacities and sport-specific technical outcomes are not necessarily direct [10]. A player with greater explosive power, for example, does not automatically demonstrate greater accuracy in clear, drop, net, or lift shots. Technical execution also depends on coordination, timing, movement positioning, perceptual ability, and accumulated practice.

This distinction is important for youth talent identification. Physical fitness tests are relatively straightforward to administer and quantify, making them attractive for athlete screening and monitoring. However, relying heavily on physical measures could provide an incomplete representation of sporting potential when technical proficiency develops through partially independent processes. Previous research in racket sports has similarly examined

the extent to which specific motor abilities can predict sport performance [11]. More recent work has emphasized the need for systematic approaches to badminton talent identification among young players [12].

Despite the importance of this issue, empirical information describing the physical and technical characteristics of pre-adolescent competitive badminton players remains limited. Much of the badminton literature has focused on adult or more advanced athletes, while fewer studies have objectively examined how selected physical fitness characteristics relate to standardized badminton-specific skill outcomes among younger competitive players. This limitation restricts the ability of coaches to determine whether commonly administered fitness assessments can also serve as meaningful indicators of technical proficiency.

An objective examination of these relationships can contribute to both training design and talent development. If particular fitness characteristics are strongly associated with specific badminton skills, these measures may provide useful complementary information for athlete monitoring. Conversely, weak associations would indicate that physical fitness and technical proficiency should be evaluated as distinct but interacting dimensions. Such evidence is especially relevant during pre-adolescence, when rapid developmental changes can produce differences in physical capacity without equivalent changes in technical ability.

Accordingly, this study examined competitive youth badminton players participating in a talent-development program in Singapore. The study aimed to (i) characterize selected physical fitness attributes and badminton-specific technical skills, (ii) examine sex- and age-related differences in these measures, and (iii) determine the associations between lower-limb power, agility, wrist flexibility, and quantitatively assessed badminton skills. By integrating physical and technical assessments, this study provides evidence for developing multidimensional approaches to youth badminton training, performance monitoring, and talent identification. The approach recognizes physical fitness as an important component of athlete development while avoiding the assumption that superior fitness necessarily corresponds to superior technical proficiency.

2. LITERATURE REVIEW

2.1. Physical Demands of Badminton

Badminton requires repeated integration of speed, change-of-direction ability, explosive movement, and stroke execution. Competitive rallies involve intermittent high-intensity activity supported by both aerobic and anaerobic systems [1, 2]. These physical demands occur simultaneously with technical requirements, including accurate shuttle placement and rapid responses to changing court positions. Lower-limb function is particularly relevant because badminton players repeatedly accelerate, decelerate, lunge, jump, and reposition themselves. During overhead strokes, force can be transferred through a proximal-to-distal kinetic chain involving the lower limbs, trunk, and upper extremities [3]. Physical capacity may therefore contribute to technical execution, although it does not necessarily determine stroke accuracy. The demands of badminton also vary according to competitive context and match characteristics [4, 5]. Consequently, physical fitness should be interpreted as one component within a broader performance system involving technical, tactical, perceptual, and movement capabilities.

2.2. Physical Development in Youth Athletes

Physical development during childhood and adolescence differs from that of adults. The Youth Physical Development model emphasizes age-appropriate development of strength, power, speed, agility, and movement competency while considering growth and maturation [6]. For pre-adolescent athletes, neuromuscular coordination can be particularly important. Improvements in performance during this developmental period do not necessarily reflect increased muscle mass or maximal strength. Training should therefore support movement quality and neuromuscular development rather than focusing exclusively on physical output. Evidence from youth badminton supports this developmental approach. Integrative neuromuscular training has been associated with improvements in physical and technical performance among prepubertal badminton players [7]. Responses to physical training can also differ according to maturity status [8]. Thus, chronological age alone may not fully explain performance differences among young players.

2.3. Physical Fitness and Badminton Performance

Badminton players require physical capabilities that allow technical skills to be performed effectively during movement. Physiological characteristics have been widely examined among competitive badminton athletes [9], while conditioning interventions have also been investigated as approaches to improving performance [10]. Explosive lower-limb power may be relevant to jumping and rear-court stroke execution, whereas agility and change-of-direction ability can influence how rapidly a player reaches an appropriate hitting position. However, technical accuracy additionally requires timing, coordination, racket control, and perceptual-motor ability. Physical fitness and technical proficiency should therefore not be treated as interchangeable indicators. This distinction may be especially important among young athletes. Improvements in general physical capacity do not necessarily produce proportional improvements in badminton-specific skills. Objective assessment of both dimensions is therefore required to determine how strongly they are related.

2.4. Sport-Specific Skill Assessment

Technical performance should be evaluated using measures that reflect badminton-specific tasks. In the present study, four fundamental strokes were examined: clear, drop, net, and lift shots. These strokes represent different court positions and technical demands and can therefore provide a broader assessment than a single overall skill score. Target-based assessment provides a quantitative method for evaluating stroke accuracy. Rather than relying exclusively on subjective coaching judgments or competitive rankings, predetermined landing zones allow technical outcomes to be expressed numerically. Similar concerns regarding the relationship between motor abilities and sport-specific performance have been examined in other racket sports [11]. For talent development, combining physical and sport-specific assessments may therefore provide a more complete athlete profile than either approach alone [12].

2.5. Physical Fitness and Talent Identification

Talent identification among young badminton players is challenging because current performance reflects both underlying potential and accumulated developmental opportunities. Physical fitness testing can provide objective information concerning attributes such as power and agility, but these measures should not automatically be interpreted as indicators of technical potential. This issue is particularly relevant during pre-adolescence

because physical development can differ substantially among athletes of similar chronological age [6, 8]. An athlete displaying greater physical performance may not necessarily demonstrate superior sport-specific skill. Accordingly, physical fitness tests may be most useful as complementary measures within multidimensional talent identification. Physical, technical, developmental, and sport-specific characteristics should be considered together rather than using one fitness measure as a proxy for badminton ability [12].

2.6. Research Framework

Based on the literature, the present study examines three interconnected dimensions of youth badminton performance, as summarized in **Table 1**. Physical fitness and technical skills are assessed separately before their relationships are examined. This framework avoids assuming that physical superiority necessarily corresponds to greater technical proficiency and supports a multidimensional interpretation of youth badminton performance.

Table 1. Conceptual framework for assessing competitive youth badminton players.

DIMENSION	VARIABLES	RELEVANCE
Physical fitness	Vertical jump height and power	Lower-limb explosive capability
Physical fitness	Shuttle-run time	Change-of-direction performance
Physical fitness	Wrist elevation	Wrist flexibility
Sport-specific skill	Clear shot	Rear-court technical accuracy
Sport-specific skill	Drop shot	Precision of rear-court attacking/control stroke
Sport-specific skill	Net shot	Forecourt technical accuracy
Sport-specific skill	Lift shot	Forecourt-to-rear-court technical accuracy
Developmental comparison	Sex and age group	Differences within youth players
Physical-technical relationship	Correlations between fitness and skill variables	Contribution of fitness to technical proficiency

3. METHOD

3.1. Research Design and Participants

A cross-sectional design was used to examine physical fitness and sport-specific technical performance. The participants were 99 competitive youth badminton players, comprising 61 boys and 38 girls, recruited from a sports talent-development programme in Singapore. Participants were aged 11-12 years, with a mean age of 11.5 ± 0.5 years. All players participated regularly in structured badminton training within the talent-development pathway.

3.2. Testing Procedure

Data were collected during the competitive season at the athletes' regular indoor training venues between 19:00 and 21:00 h. Testing was divided into two phases conducted on separate days: (i) anthropometric and physical fitness assessment; and (ii) badminton-specific skill assessment. All maximal-effort tests were preceded by a standardized warm-up.

3.3. Anthropometric and Physical Fitness Assessments

Standing height was measured to the nearest 0.1 cm using a portable stadiometer, while body mass was measured to the nearest 0.1 kg using a calibrated digital scale. Lower-limb explosive power was assessed using a countermovement vertical jump. Three trials were performed, and the best result was retained. Jump height was calculated from the difference between standing reach and maximal jump reach. Peak anaerobic power was subsequently estimated using the Sayers equation [13]: $PAP = 60.7(JH) + 45.3(BM) - 2055$, where *PAP* is the peak anaerobic power (W), *JH* is the jump height (cm), and *BM* is the body mass (kg). Change-of-direction performance was assessed using a 4 × 10 m shuttle run. Participants sprinted between two lines positioned 10 m apart while retrieving two wooden blocks. Two trials were completed, and the faster time was retained. Wrist flexibility was assessed using a modified wrist-elevation test. Participants lay prone with their arms extended overhead while holding a ruler. The final score represented maximal elevation height corrected for arm length.

3.4. Badminton-Specific Skill Assessment

Technical proficiency was assessed using a quantitative test battery adapted from the Ministry of Education badminton syllabus. Four fundamental strokes were evaluated: clear, drop, net, and lift.

For clear and drop tests, shuttlecocks were fed toward the rear court, and players returned them toward predefined target zones. For net and lift tests, shuttlecocks were fed from the forecourt, requiring players to move forward before stroke execution.

A graded scoring system based on shuttlecock landing location was used. Clear and lift shots received higher scores when landing closer to the rear baseline, whereas drop and net shots received higher scores when landing closer to the net. Each skill consisted of 10 trials, comprising five straight-court and five cross-court attempts. Scores were summed to obtain the total for each stroke, with a theoretical range of 0-40 points. Trained evaluators administered all tests using standardized procedures.

The assessment procedure is summarized in **Table 2**. The protocol combined general physical fitness measurements with standardized sport-specific assessments, allowing physical and technical performance to be analyzed independently and subsequently correlated.

Table 2. Physical fitness and badminton-specific assessment protocol.

ASSESSMENT	MEASUREMENT	TRIALS / SCORING
Height	Standing height	Nearest 0.1 cm
Body mass	Body mass	Nearest 0.1 kg
Vertical jump	Jump height	Best of 3 trials
Peak anaerobic power	Sayers equation [13]	Calculated from jump height and body mass
Shuttle run	4 × 10 m change-of-direction time	Faster of 2 trials
Wrist elevation	Wrist range of motion	Corrected for arm length
Clear	Target-based accuracy	10 trials; 0-40 points
Drop	Target-based accuracy	10 trials; 0-40 points
Net	Target-based accuracy	10 trials; 0-40 points
Lift	Target-based accuracy	10 trials; 0-40 points

3.5. Statistical Analysis

Statistical analyses were conducted using SPSS Version 17.0. Normality was assessed using the Kolmogorov-Smirnov test. Descriptive data were expressed as mean ± standard deviation. Sex and age-group differences were analyzed using independent *t*-tests for normally distributed variables and Mann-Whitney *U* tests for non-normally distributed variables. Because the sport-specific skill scores were non-normally distributed, associations between physical fitness and technical performance were evaluated using Spearman's rank correlation coefficient (r). Correlation magnitudes were classified as small ($0.1 \leq |r| < 0.3$), moderate ($0.3 \leq |r| < 0.5$), and large ($|r| \geq 0.5$). Statistical significance was set at $p < 0.05$.

3.6. Ethical Considerations

Participants completed the Physical Activity Readiness Questionnaire before testing. Athletes with acute musculoskeletal injury or systemic illness at the time of data collection were excluded. Written informed consent was obtained from parents or legal guardians. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ministry of Education.

4. RESULTS AND DISCUSSION

4.1. Physical Characteristics and Fitness Performance

The physical characteristics and fitness performance of the competitive youth badminton players are summarized in **Table 3**. Differences between groups were observed in selected anthropometric and physical fitness variables. The differences in physical performance should be interpreted within the developmental characteristics of youth athletes. Growth, maturation, neuromuscular coordination, and training experience can influence physical performance during pre-adolescence [6, 8]. Therefore, physical differences among young players should not automatically be interpreted as differences in long-term badminton potential.

Table 3. Physical characteristics and fitness performance of competitive youth badminton players.

VARIABLE	MAIN FINDING	INTERPRETATION
Height	Differences were observed between sex and age groups	Anthropometric development varied among players
Body mass	Differences were observed between groups	Body size contributed to variation in physical characteristics
Vertical jump	Boys showed higher mean jump power than girls, but the difference was not statistically significant	Lower-limb explosive performance differed by sex
Estimated jump power	Boys showed higher mean jump power than girls, but the difference was not statistically significant	Jump power differed significantly between age groups, with higher performance in the older group
Shuttle run	Performance differed between groups	Change-of-direction ability varied among players
Wrist elevation	No consistent relationship with badminton skill performance	Wrist flexibility alone did not explain technical proficiency

4.2. Badminton-Specific Skill Performance

Four fundamental badminton skills were assessed: clear, drop, net, and lift. The principal findings are summarized in **Table 4**. Technical proficiency differed across players and was not consistently explained by general physical fitness. This finding supports the distinction between physical capacity and sport-specific skill. Although physical fitness can support movement and positioning, badminton-specific performance also depends on technical coordination and stroke execution [3, 10]. The results therefore support separate assessment of physical and technical performance. For youth talent development, a player with superior physical performance should not automatically be considered technically superior.

Table 4. Functional characteristics of the badminton-specific skill assessments.

SKILL	PERFORMANCE REQUIREMENT	MAIN INTERPRETATION
Clear	Accurate shuttle placement toward the rear court	Requires coordinated stroke execution and shuttle control
Drop	Accurate placement close to the net from the rear court	Requires precision, timing, and racket control
Net	Accurate forecourt placement	Requires fine control and technical accuracy
Lift	Accurate forecourt-to-rear-court placement	Requires coordinated force production and directional control

4.3. Relationship between Lower-Limb Power and Badminton Skills

Vertical jump power showed small but statistically significant positive correlations with clear and drop shot performance, while no significant relationships were found with net or lift shots. The main relationships are summarized in **Table 5**. Lower-limb power may contribute to badminton performance because force generated through the legs can support positioning and stroke production through the kinetic chain [3]. However, the generally limited correlations indicate that greater explosive power does not directly translate into greater stroke accuracy. This finding is relevant to youth training. Lower-limb power should remain part of physical preparation, but technical training cannot be replaced by general conditioning. Developmental programmes should integrate physical and technical components while monitoring them independently [6, 7].

Table 5. Relationships between physical fitness and badminton-specific skills.

PHYSICAL FITNESS VARIABLE	BADMINTON SKILL	MAIN FINDING
Vertical jump power	Clear	Small positive significant correlation (r = 0.257)
Vertical jump power	Drop	Small positive significant correlation (r = 0.216)
Vertical jump power	Net	No significant correlation
Vertical jump power	Lift	No significant correlation
Shuttle-run time	Clear	No significant correlation
Shuttle-run time	Drop	No significant correlation
Shuttle-run time	Net	Small negative significant correlation (r = −0.220)
Shuttle-run time	Lift	No significant correlation
Wrist elevation	Clear, drop, net, and lift	No significant correlations

4.4. Change-of-Direction Performance and Technical Skills

Shuttle-run time showed a small but statistically significant negative correlation with net-shot performance, indicating that faster change-of-direction performance was associated with higher net-shot scores. Change-of-direction ability is relevant to badminton because players repeatedly accelerate, decelerate, and reposition themselves before stroke execution [1, 2]. However, the observed relationships were not sufficiently strong to suggest that agility alone determines technical proficiency. Reaching the shuttle efficiently can create favorable conditions for stroke execution, but accurate placement still depends on technical and perceptual-motor capabilities. The findings therefore indicate that movement performance and racket skills are complementary rather than interchangeable. Conditioning can support the physical foundation for badminton movement, while badminton-specific training remains essential for technical development [7, 10].

4.5. Wrist Flexibility and Badminton Skills

Wrist elevation did not demonstrate meaningful relationships with the four badminton-specific skill outcomes. This indicates that greater wrist flexibility, as assessed in this study, was not associated with better clear, drop, net, or lift performance. This result should not be interpreted as evidence that wrist function is unimportant in badminton. Stroke execution involves coordinated movement across multiple body segments [3]. A flexibility measurement represents only one characteristic of the wrist and does not directly measure racket control, movement velocity, coordination, or technical timing. Accordingly, wrist flexibility should not be used independently as an indicator of technical badminton ability or talent potential.

4.6. Implications for Youth Badminton Training

The findings have practical implications for training competitive youth badminton players. **Table 6** summarizes the relationship between the observed results and training priorities. Physical conditioning should complement rather than replace sport-specific practice. Integrative neuromuscular training is particularly relevant because it can support physical and technical development among prepubertal badminton players [7]. Training should also recognize developmental differences rather than applying identical physical expectations to all young athletes [6, 8].

Table 6. Training implications for competitive youth badminton players.

FINDING	TRAINING IMPLICATION
Physical performance varied among youth players	Training should consider individual development and maturation [6, 8]
Lower-limb power was associated with selected skills	Include age-appropriate power and neuromuscular training [7]
Faster shuttle-run performance was associated with higher net-shot performance	Combine change-of-direction exercises with badminton movement patterns
Physical-technical correlations were generally limited	Maintain dedicated technical skill training
Wrist flexibility was not meaningfully associated with technical scores	Do not use wrist flexibility alone to evaluate badminton proficiency
Technical skills showed distinct performance characteristics	Assess clear, drop, net, and lift skills separately
Physical fitness did not fully explain technical proficiency	Use multidimensional athlete assessment

4.7. Implications for Talent Identification and Development

The limited relationships between fitness and technical skills have important implications for talent identification. Physical fitness tests are objective and practical, but the findings indicate that they cannot independently represent badminton proficiency. A multidimensional approach is therefore more appropriate. Physical attributes, sport-specific technical skills, developmental characteristics, training experience, and performance progression should be considered together when evaluating young players [12]. This approach reduces the risk of selecting athletes predominantly because of temporary physical advantages during growth and maturation [6, 8].

The proposed application is summarized in **Table 7**. Talent identification should therefore combine physical, technical, and developmental assessments rather than rely on a single fitness-based selection event.

Table 7. Multidimensional assessment for youth badminton talent development.

ASSESSMENT DIMENSION	EXAMPLES	ROLE IN TALENT DEVELOPMENT
Anthropometric	Height and body mass	Monitor physical development
Explosive performance	Vertical jump and estimated power	Assess lower-limb capability
Change of direction	Shuttle run	Assess movement performance
Flexibility	Wrist elevation	Complement physical profiling
Technical skill	Clear, drop, net, and lift	Assess badminton-specific proficiency
Development	Age and maturation considerations	Contextualize physical performance [6, 8]
Longitudinal progression	Repeated assessment	Monitor development rather than one-time performance
Talent identification	Combined physical and technical profile	Support multidimensional evaluation [12]

4.8. Integrated Training and Monitoring Framework for Youth Badminton Development

The findings indicate that physical fitness and badminton-specific skills should be monitored as complementary dimensions. Physical fitness supports performance, but it does not independently determine technical proficiency. Therefore, youth badminton development requires integrated and repeated assessment rather than reliance on a single fitness measure.

As shown in **Table 8**, fitness testing should complement direct assessment of badminton-specific skills. Repeated monitoring is particularly important because physical and technical development may progress at different rates during youth development [6, 8]. This framework also supports more balanced talent identification. Physical performance can provide information on athletic readiness, whereas clear, drop, net, and lift assessments directly evaluate technical proficiency. Combining these measures can help coaches monitor progression, individualize training, and avoid judging athlete potential from isolated fitness results.

Table 8. Integrated monitoring framework for competitive youth badminton players.

DEVELOPMENT AREA	SUGGESTED ASSESSMENT	MAIN PURPOSE	TRAINING IMPLICATION
Lower-limb power	Vertical jump and estimated peak power	Monitor explosive capability	Integrate jumping and badminton-specific power exercises
Change of direction	4 × 10 m shuttle run	Monitor agility	Combine agility drills with court movement
Wrist flexibility	Wrist elevation test	Identify mobility limitations	Use as a supplementary indicator
Rear-court technique	Clear and drop tests	Assess accuracy and control	Emphasize stroke mechanics and positioning
Forecourt technique	Net and lift tests	Assess precision and shuttle control	Integrate movement with technical practice
Developmental status	Age and maturation considerations	Contextualize physical performance	Adjust expectations among developing athletes [6,8]
Progression	Repeated physical and technical testing	Monitor changes over time	Individualize training
Talent identification	Combined physical and technical profile	Support multidimensional evaluation	Avoid selection based on a single fitness measure [12]

5. CONCLUSION

This study examined physical fitness and sport-specific skills among competitive youth badminton players. Lower-limb power and change-of-direction performance were associated with selected technical skills, although the relationships were generally limited, while wrist flexibility showed no meaningful association with technical performance. These findings indicate that physical fitness contributes to, but does not independently determine, badminton-specific proficiency. Youth training should therefore integrate age-appropriate physical conditioning with dedicated technical practice. Talent identification should similarly employ multidimensional assessment rather than relying on isolated fitness measures. Longitudinal evaluation of physical development, technical skills, and performance progression may provide a more appropriate basis for supporting young badminton athletes.

6. ACKNOWLEDGMENTS

We would like to express our sincere appreciation to the youth badminton players who participated in this study. We also acknowledge the coaches, parents, and relevant educational and sporting institutions for their assistance and support during the data collection and assessment process.

7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper is free from plagiarism.

8. REFERENCES

[1] Cabello Manrique, D., and González-Badillo, J. J. (2003). Analysis of the characteristics of competitive badminton. *British Journal of Sports Medicine, 37*(1), 62-66.

[2] Chin, M. K., Wong, A. S., So, R. C., Siu, O. T., Steininger, K., and Lo, D. T. (1995). Sport specific physiological profiles of elite badminton players. *British Journal of Sports Medicine, 29*(4), 242-247.

[3] Phomsoupha, M., and Laffaye, G. (2015). The science of badminton: Game characteristics, anthropometry, physiology, visual fitness and biomechanics. *Sports Medicine, 45*(4), 473-495.

[4] Gómez, M. A., Rivas, F., Connor, J. D., and Leicht, A. S. (2020). Performance differences of temporal parameters and point outcome between elite men's and women's badminton players according to match-related contexts. *International Journal of Environmental Research and Public Health, 17*(23), 8998.

[5] Zhao, Y., Zhu, A., Zhang, S., and Zhang, Y. (2025). Comparison of the temporal and technical-tactical characteristics in badminton men's singles under different competition formats. *Frontiers in Psychology, 16*, 1634776.

[6] Lloyd, R. S., and Oliver, J. L. (2012). The Youth Physical Development model: A new approach to long-term athletic development. *Strength and Conditioning Journal, 34*(3), 61-72.

[7] Turna, O., and Iri, R. (2025). A randomized controlled study on the effect of 8-week integrative neuromuscular training on physical performance and technical proficiency in prepubertal badminton players. *Acta Gymnica, 55*, e2025.011.

[8] Weng, M.-C., Dai, X., Chiu, C.-H., Ho, C.-C., Liu, C.-C., Hsu, S.-M., and Chen, C.-H. (2025). Effects of integrated neuromuscular training on physical fitness in badminton athletes of different maturity statuses. *Children, 12*(7), 830.

[9] Ooi, C. H., Tan, A., and Thompson, M. (2009). Physiological characteristics of elite and sub-elite badminton players. *Journal of Sports Sciences, 27*(14), 1591-1599.

[10] Ma, S., Soh, K. G., Japar, S. B., Liu, C., Luo, S., Mai, Y., and Wang, X. (2024). Effect of core strength training on the badminton player's performance: A systematic review and meta-analysis. *PLOS ONE, 19*(6), e0305116.

[11] Toriola, A. L., Toriola, O. M., and Igbokwe, N. U. (2004). Validity of specific motor skills in predicting table-tennis performance in novice players. *Perceptual and Motor Skills, 98*(2), 584-586.

[12] Dong, C., and Josue, F. (2025). Badminton Talent Identification Development (BTID) among young badminton players in Guangxi, China. *International Journal of Academic Research in Progressive Education and Development, 14*(1), 1329-1337.

[13] Sayers, S. P., Harackiewicz, D. V., Harman, E. A., Frykman, P. N., and Rosenstein, M. T. (1999). Cross-validation of three jump power equations. *Medicine and Science in Sports and Exercise, 31*(4), 572-577.