

Effects of the battle shuttlecock game on VO_2 max and lob technique in children aged 9–12 years

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Abstract

Background and Study Aim School-based physical education includes structured efforts to maintain physical fitness in children. Various approaches such as non-linear pedagogy, constructivist methods, and physical literacy have been applied to support learning through movement. Despite their application, the relative effectiveness of integrated models that combine technical skill and aerobic development remains a matter of practical interest. This study aims to test the effects of Battle Shuttlecock on students' VO_2 max and lob performance while assessing its pedagogical relevance in physical education.

Material and Methods A pretest-posttest quasi-experimental study was conducted with a control group. Participants were elementary school students who took part in extracurricular badminton activities. The experimental group received 14 progressive Battle Shuttlecock sessions. The control group received standard badminton training. VO_2 max was measured using the Multistage Fitness Test. Lob shot skills were assessed using the French Clear Test. Additional instruments included Perceived Competence, Mini-PACES, a fidelity checklist, and observations of social, emotional, and cognitive behavior. Data were analyzed using MANCOVA at a significance level of $\alpha = 0.05$.

Results The experimental group showed a significant increase in VO_2 max from 38.5 ± 2.9 to 39.1 ± 2.6 ml/kg/min. Lob shot accuracy increased from 55.3 ± 6.7 to 64.2 ± 7.1 points ($p < 0.001$). The control group did not show a significant increase in either variable. The results indicate that Battle Shuttlecock supports learning and improves technical, emotional, and cognitive skills when used consistently. The game had a significant effect on both VO_2 max and lob performance.

Conclusions Battle Shuttlecock improved cardiorespiratory fitness and lob technique. It can be used in school programs to support physical, technical, emotional, and cognitive development.

Keywords: game-based learning, aerobic capacity, motor skill acquisition, primary school children, hybrid pedagogy

Introduction

Physical activity in childhood is closely linked to physical development, motor competence, and long-term health outcomes. Despite increasing awareness of its benefits, many children continue to demonstrate low levels of physical fitness, including limited aerobic capacity. These trends are influenced by a combination of lifestyle habits, reduced movement opportunities in school settings, and a lack of age-appropriate physical engagement. As a result, maintaining and improving cardiorespiratory fitness in school-age children remains a complex and relevant challenge within physical education.

One approach to supporting physical development in children involves structured extracurricular sports within elementary schools. These programs contribute to improving physical fitness, motor skills, and aspects of character formation. School-based initiatives have been shown to encourage participation in physical

activity, support fitness gains, and promote social-emotional development [1, 2]. The concept of proficiency barriers, proposed by Seefeldt, suggests that mastering fundamental motor skills provides a necessary foundation for the acquisition of more complex sport-specific abilities. This concept has been supported by recent longitudinal research [3]. Within this context, badminton is a widely practiced sport that combines recreational appeal with physical challenge. It engages coordination, agility, endurance, and focus, making it suitable for use in school programs [4].

The lob shot is a fundamental badminton skill that should be developed at an early stage. An effective lob is characterized by a high and long shuttlecock trajectory directed to the back of the opponent's court. This makes it difficult to return and gives the player time to reposition [5]. Mastery of this technique depends on a foundation of physical conditioning, particularly aerobic capacity (VO_2 max), as badminton involves prolonged rallies and high-intensity movement [5, 6]. At the same time, several studies have reported a decline in children's overall fitness, especially cardiorespiratory

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capacity, over recent decades. This trend highlights the importance of early intervention during the elementary school years [7].

Previous studies have shown that children's $VO_2\text{max}$ can improve through structured physical training and high-intensity activity. Meta-analyses have reported that badminton-specific programs, including interval and plyometric training, can enhance aerobic capacity and physical performance [5, 8]. In addition, backward walking has been identified as a useful movement variation. It supports the development of agility, balance, and other physical attributes relevant to badminton [9].

Game-based approaches such as Teaching Games for Understanding (TGfU) and Small-Sided Games (SSG) have served as foundational methods in physical education. However, both approaches have limitations, as they do not fully integrate technical skill development and biomotor capacity into a unified game format [12, 13, 14]. Research on hybrid pedagogical models highlights the importance of combining technical, tactical, and physical components to improve student learning and engagement [15, 16]. In constructivist frameworks, the use of representative learning tasks and adaptive movement challenges is associated with the development of motor competence and movement understanding [17]. Additionally, interventions that promote competence, confidence, motivation, and participation are linked to stronger physical literacy outcomes [18].

Meta-analytic evidence confirms that structured programs incorporating technical, tactical, and physical elements can lead to significant improvements in children's physical development and engagement [12]. Other studies have further emphasized that game-based models which integrate motor skills, aerobic capacity, and sport-specific techniques can support the development of physical literacy from both pedagogical and experiential perspectives [20, 21, 22, 23].

Analysis of research findings has shown that combining technical skill development with aerobic training within a game-based format can enhance student engagement and learning outcomes. Scholars emphasize that hybrid pedagogical models grounded in constructivist principles provide promising strategies for supporting motor competence, motivation, and physical literacy in children. At the same time, the challenge of designing integrated, scalable, and age-appropriate interventions that address both physical and technical development remains. This gap continues to limit the practical application of combined skill-and-fitness programs in school settings and calls for further pedagogical innovation.

Therefore, this study aims to examine the effects of the Battle Shuttlecock game on $VO_2\text{max}$ and lob performance among elementary school students,

and to assess its pedagogical relevance within a school-based physical education context.

Materials and Methods

Participants

The study involved 32 elementary school students who participated in badminton extracurricular activities at SD Muhammadiyah Pakel, Yogyakarta. They were aged 9–12 years (11 girls and 21 boys). Participation was voluntary. Written informed consent was obtained from the students and from their parents or guardians.

Participants were assigned to the experimental group ($n = 16$) or the control group ($n = 16$) using block randomization with a block size of four. The allocation sequence was generated by an automated randomization program operated by an independent third party who was not involved in data collection or intervention delivery. To reduce selection bias, allocation concealment was maintained using sealed opaque envelopes. These envelopes were opened by the coach only after all pre-test assessments had been completed.

A priori power analysis was conducted using G*Power version 3.1 for a twogroup MANOVA with two dependent variables. With an assumed effect size of $f^2(V) = 0.30$ (medium), $\alpha = 0.05$, and power $(1-\beta) = 0.80$, the minimum required sample size was 28 participants. The final sample of 32 participants exceeded this threshold and ensured adequate statistical power. This study received ethical approval from the Research Ethics Committee of Universitas Negeri Yogyakarta (date: 03/10/2024; Decision Number: 16; Protocol: 04/2024).

Research Design

A quasi-experimental pre-test–post-test control group design was used. Participants with chronic illnesses, musculoskeletal injuries, or those undergoing long-term medication were excluded from the study. To maintain physiological consistency during the intervention, participants and their parents were instructed to follow regular sleep and dietary routines. They were also advised to avoid cold or carbonated drinks, foods known to cause gastric discomfort, late-night activities, and intense physical activity outside the scheduled training.

The study was conducted at Sorowajan Sports Hall (GOR Sorowajan) in Yogyakarta. The intervention included 16 sessions. Training was held three times per week (Tuesday, Thursday, and Sunday). Each session lasted approximately 90 minutes.

Participants were withdrawn from the study if they developed conditions that could affect physical performance or interfere with physiological responses to training.

The Battle Shuttlecock model integrates specific skill training (lob technique) and aerobic development (VO₂max) into a single cooperative-competitive game structure. Table 1 presents a conceptual comparison between Battle Shuttlecock and established game-based pedagogical models.

The intervention in this study is structured as an educational game based on shuttlecocks and played on a badminton court. The default format is 4 vs 4. However, in practice, the number of players per team may vary (e.g., 3 vs 3 or 5 vs 5), depending on student availability, time constraints, and the need to ensure equal playing opportunities. These adjustments do not change the core structure of the game, as the rules, objectives, and activity flow remain consistent.

This game is not only a competitive physical activity. It also serves as a structured medium for motor, socio-affective, and cognitive learning. The

objectives of the Battle Shuttlecock intervention include the integration of the following components:

- Physical – endurance, agility, aerobic capacity (VO₂max), hand-eye coordination.
- Technical – shuttlecock control, throwing accuracy, spatial awareness.
- Social-affective – cooperation, communication, sportsmanship, emotional regulation.
- Cognitive – quick decision-making, strategic planning, angle selection when throwing.

Game Phase. Court

The Battle Shuttlecock game is played on a modified badminton court, using standard dimensions with instructional adaptations. The court layout and setup are illustrated in Figure 1.

Using a standard badminton court (Figure 1):

- Length: 13.40–13.60 m
- Width: 6.10 m

The outer boundary lines are used as the playing

Table 1. Conceptual comparison of Battle Shuttlecock with existing approaches

Comparison Aspect	Teaching Games for Understanding (TGfU)	Small-Sided Games (SSG)	Conventional Technical Training	Battle Shuttlecock
Main Objective	Tactical understanding	Increased playing intensity	Technical mastery	Integration of lob technique and VO ₂ max through gameplay
Pedagogical Focus	Tactical-cognitive	Physical activity	Technical-motor	Hybrid: technical, physical, tactical, social
Joyful Learning Aspect	High	High	Low	Very high (cooperative competition)
Specific Technical Integration	Not specific	Not focused	Highly focused	Integrated within gameplay
Activity Structure	Tactical modifications	Small-sided games	Drills	Mission-based team shuttlecock game
Biomotor Component	Minimal	Aerobic emphasis	Limited	Designed to improve VO ₂ max
Degree of Innovation	Established	Established	Traditional	New hybrid pedagogical model

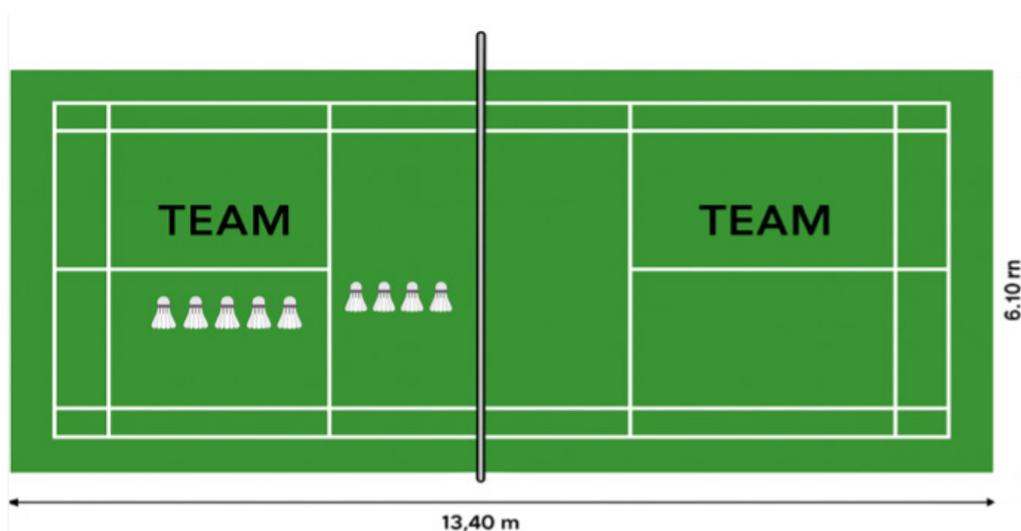


Figure 1. Battle Shuttlecock court

area limits.

The net is installed at the center of the court, with a height of 155 cm at the posts and 152.4 cm at the center, following standard badminton specifications.

Start Setup (Performed before each round).

Two teams face each other on opposite sides of the court, separated by a net.

The number of players is flexible (2–5 players per team) and may be adjusted depending on the number of students and the duration of the lesson.

Seven shuttlecocks are placed in one team's area to start the round.

Each shuttlecock must be thrown over the net into the opponent's area.

The round begins with a whistle or instruction and ends with another signal at a specified time limit.

Round Objective

Teams aim to keep their side of the court as clear as possible by the end of the round. The team with fewer shuttlecocks remaining in their area wins the round.

Rules of the Game

The Battle Shuttlecock game follows a set of structured rules to ensure consistency, safety, and educational value. These rules are summarized in Table 2.

Progressive Training Structure

The intervention consisted of 14 training sessions. This number was selected based on findings by Teixeira et al., which indicated that interventions with 14 to 16 sessions are effective in improving fitness and motor skills in children [24]. The structure and progression of the training sessions are outlined in Table 3.

Complete Procedure for Each Intervention Session

Each intervention session followed a structured sequence, consisting of four main phases: opening, warm-up, game play, and cool-down.

Opening Session:

- Attendance and readiness check.
- Prayer according to each participant's belief.
- Brief explanation of the session's objectives.

Warm-up:

Light jogging around the field (7 laps or approximately 5 minutes).

Dynamic stretching (10 minutes), including:

- Leg swings
- Arm circles
- Hip rotations.

Game Play (Main Session). The session began with a standard instructional script:

“Children, remember that the goal of the game is to keep our area clean of shuttlecocks. All shuttlecocks must be thrown over the net into the opponent's area. Use your dominant hand and throw

Table 2. Rules of the Battle Shuttlecock Game

Category	Specifications
Throw	The shuttlecock must pass over the net and land within the opponent's court. The target area is the deep zone of the opponent's court but must not cross the boundary lines. The throwing motion should resemble the lob technique in badminton, using correct stance and footwork.
Violations	Throwing the shuttlecock with the non-dominant (weak) hand. Throwing more than one shuttlecock at a time. Holding the shuttlecock for more than two seconds. Making intimidating gestures. Intentionally throwing the shuttlecock at an opponent's body.
Player Interaction	Players must throw the shuttlecock actively. Slow tossing or simply dropping the shuttlecock near the net is not allowed. Players must be ready to catch or retrieve shuttlecocks in their area. The game must remain dynamic and competitive.
Winner of the Round	The team with fewer shuttlecocks remaining in their area when time runs out.

Table 3. Progressive Training Structure

Session Phase	Games per Session	Game Duration	Rest Interval
Sessions 1–4	6 games	45 seconds	120 seconds
Sessions 5–9	7 games	45 seconds	100 seconds
Sessions 10–15	8 games	45 seconds	90 seconds
Session 16	Post-test	–	–

strongly, high, and far. Do not hold the shuttlecock for more than two seconds, and do not throw more than one at a time. Ready? We start when the whistle blows.”

Round 1 procedure:

- The teacher or coach blows the whistle → the round begins.
- Players immediately throw shuttlecocks into the opponent’s area as quickly and accurately as possible.
- The observer monitors and records any rule violations.
- After 45 seconds, the whistle is blown again → the round ends.
- Remaining shuttlecocks in each court area are counted → the winner is announced.

Number of rounds per session:

The number of rounds follows the progressive training structure (6–8 rounds per session).

Cool-down:

- Static stretching
- Deep breathing
- Muscle relaxation
- Closing prayer.

Intervention Fidelity Monitoring Elements

To ensure consistent implementation of the Battle Shuttlecock intervention, a structured checklist was used for session monitoring. The checklist covered key procedural and instructional elements. Table 4 presents the items used to monitor intervention fidelity.

Program Adaptation for Various Conditions

The Battle Shuttlecock program can be adapted to suit different class settings, facility limitations,

and variations in student ability. The following adaptations are recommended:

Classes with Large Numbers of Students

To ensure fair and safe participation in large classes, the following adjustments can be made:

- Increase the number of players per team to a maximum of five.
- Use a rotation system between groups every 5–7 minutes to ensure all students participate.
- Create 1–2 additional courts using chalk lines or cones, allowing several groups to play in parallel.

Mixed-Gender Classes

To promote inclusive and balanced interaction between male and female students:

- Form teams with proportional representation of both genders.
- Provide a short briefing on sportsmanship, cooperation, and respectful communication before starting the game.

Limited Facilities and Infrastructure

If school facilities are incomplete, the following modifications can be implemented:

- If a net is unavailable, use a rope (e.g., raffia) and attach it to poles approximately 155 cm in height.
- If shuttlecocks are limited, use five shuttlecocks or replace them with foam balls.
- If there is no badminton court, draw a simple court using chalk.

Differences in Student Skill Levels

The program can be adapted to accommodate both beginners and more advanced students:

a. Beginners:

- Increase the number of players per team.
- Use more shuttlecocks.
- Reduce emphasis on lob shot technique; allow

Table 4. Intervention Implementation Monitoring Checklist

No.	Item Checklist	Yes	No	Notes
1	The court uses standard badminton dimensions and boundary lines.	<input type="checkbox"/>	<input type="checkbox"/>	
2	The number of shuttlecocks is as specified (7).	<input type="checkbox"/>	<input type="checkbox"/>	
3	Foul rules are enforced consistently.	<input type="checkbox"/>	<input type="checkbox"/>	
4	Each round lasts exactly 45 seconds (a timer is used).	<input type="checkbox"/>	<input type="checkbox"/>	
5	The number of rounds follows the session progression (6–8 rounds depending on phase).	<input type="checkbox"/>	<input type="checkbox"/>	
6	A complete warm-up is conducted (approximately 15 minutes).	<input type="checkbox"/>	<input type="checkbox"/>	
7	A complete cool-down is conducted (approximately 15 minutes).	<input type="checkbox"/>	<input type="checkbox"/>	
8	Initial instructions are delivered clearly before gameplay begins.	<input type="checkbox"/>	<input type="checkbox"/>	
9	Two coaches or teachers supervise each session.	<input type="checkbox"/>	<input type="checkbox"/>	
10	The winning team is determined objectively (based on remaining shuttlecocks).	<input type="checkbox"/>	<input type="checkbox"/>	
11	No rule modifications are made without the researcher’s approval.	<input type="checkbox"/>	<input type="checkbox"/>	
12	All equipment (net, shuttlecocks, court lines, floor) is in safe condition.	<input type="checkbox"/>	<input type="checkbox"/>	
13	No player uses their non-dominant (weak) hand to throw.	<input type="checkbox"/>	<input type="checkbox"/>	
14	No player throws more than one shuttlecock at a time.	<input type="checkbox"/>	<input type="checkbox"/>	

- basic throwing without requiring correct footwork.
- Allow free throwing based on ability, without focusing on accuracy or control.
- b. Skilled Students:
 - Reduce the number of players per team.
 - Introduce narrow target zones using cones or markings to encourage precision.
 - Emphasize lob technique with proper footwork, adapted from badminton throwing mechanics.

Instruments

1. Bleep Test (Multistage Fitness Test)

The Bleep Test is a practical and validated field method for measuring aerobic capacity (VO₂max). It is conducted as a 20-meter shuttle run with a progressively increasing pace. VO₂max is estimated based on the final level and number of shuttles completed [25]. Recent studies confirm the test’s reliability in school-based physical education settings. Technological advancements—such as infrared sensors and automated VO₂max recording software—have improved the accuracy and ease of implementation [26, 27]. Comparative studies with rowing ergometers further support the Bleep Test as an efficient tool for assessing cardiorespiratory fitness in youth field environments [28].

2. French Clear Test (Test Pukulan Lob)

The French Clear Test is a standardized tool for assessing badminton lob skills. The test consists of 20 attempts, each scored for directional accuracy, height, and power using a zone-based system (3–5–4–2–1). Additional scoring criteria include zero points for missed shots, counting the boundary lines as part of the higher-value zone, and disqualifying attempts that fail to clear an 8-foot tape positioned 14 feet from the net.

The test demonstrates strong reliability (0.96) and moderate validity (0.60) [29]. It functions not only as an objective assessment tool but also as a pedagogical resource in elementary physical education. It supports structured and measurable learning of fundamental badminton techniques in alignment with sport pedagogy principles. The test layout and scoring zones are illustrated in Figure 2.

3. Battle Shuttlecock Game Intervention Evaluation Instrument

a. *Perceived Competence (Illustrated)*. This instrument assesses students’ perceived competence in motor activities. It includes indicators such as confidence in performing motor skills, ability to follow instructions, and perceived success in completing tasks. A pictorial format was selected to enhance comprehension among elementary school students. This approach is supported by findings from Morano et al., who demonstrated the effectiveness of visual response formats for measuring self-efficacy in children [31].

Measurement category: Psychological aspects – self-perception / self-efficacy. Scoring Interpretation:

- 3–5: Low – limited confidence and perceived ability in motor tasks
- 6–7: Moderate – adequate ability with partial confidence
- 8–9: High – strong self-confidence, ability, and task competence.

b. Mini-PACES (Physical Activity Enjoyment Scale – Short Version)

Mini-PACES is used to assess students’ enjoyment while playing Battle Shuttlecock. It includes four indicators: pleasure, interest, perceived excitement, and willingness to participate again. The scale has demonstrated validity and reliability for use with children [32, 33].

Measurement category: Affective domain – enjoyment.

Assessment rules: Responses are rated on a 1–5 Likert scale (total score range: 4–20).

Scoring Interpretation:

- 16–20: High – strong enjoyment and engagement
- 12–15: Moderate – moderate enjoyment
- <12: Low – limited enjoyment or engagement.

C. Fidelity Checklist

The fidelity checklist is used to ensure that the Battle Shuttlecock intervention is implemented in accordance with the established protocol. It evaluates key aspects such as rule consistency, number of rounds, session duration, warm-up and

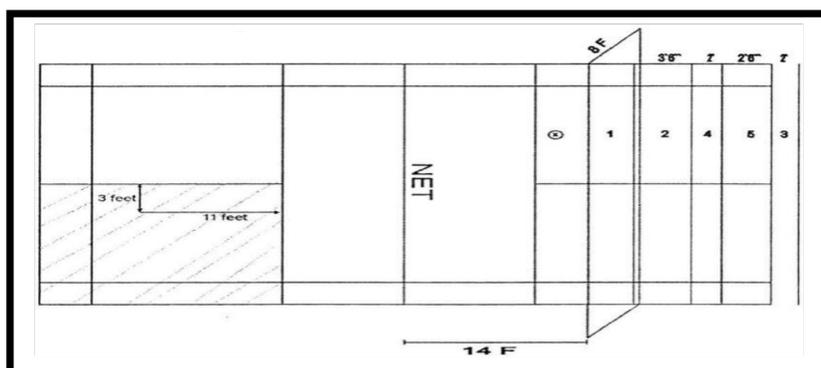


Figure 2. French Clear Test (Badminton Lob Skill Test) [30]

cool-down implementation, facility safety, clarity of instructions, availability of equipment, and teacher supervision.

A high level of implementation fidelity is essential for the accurate interpretation of outcomes and for consistent program replication. It also strengthens the validity of findings by ensuring that the intervention is delivered as intended [34, 35].

Measurement category: Treatment fidelity / implementation integrity.

Assessment method: Dichotomous scale (0 = not implemented, 1 = implemented). Scoring Interpretation:

- High: 85% or more of items fulfilled
- Moderate: 70–84%
- Low: less than 70%.

d. Observation Sheet (Social–Affective & Cognitive)

This observation sheet is used to assess student behavior during gameplay across two domains: social–affective and cognitive. Three observers independently rate each student, and the average score is calculated to enhance inter-rater reliability in accordance with physical education research standards.

Measurement category: Behavioral observation – social, affective, and cognitive domains. Scoring Interpretation:

Social–Affective Domain:

- 4–7: Low – limited cooperation, weak emotional regulation, inconsistent sportsmanship
- 8–10: Moderate – adequate cooperation and sportsmanship, but unstable
- 11–12: High – strong cooperation, communication, emotional control, and sportsmanship

Cognitive Domain:

- 4–6: Low – limited rule understanding and decision-making
- 7–8: Moderate – basic rule comprehension and emerging decision-making, but inconsistent

- 9–12: High – good understanding of rules, strategic thinking, and adaptability

Statistical Analysis

All data were analyzed using SPSS version 26. To assess the effect of the Battle Shuttlecock intervention on VO₂max and lob performance, a Multivariate Analysis of Variance (MANOVA) was conducted. This procedure was used to compare differences between the experimental and control groups across both dependent variables simultaneously. Prior to analysis, the assumption of normality was tested using the Shapiro–Wilk test, and homogeneity of variance was assessed using Levene’s test. The significance level was set at $\alpha = 0.05$. When MANOVA results indicated a significant effect ($p < 0.05$), follow-up independent t-tests were performed for each dependent variable to identify specific group differences.

Results

Descriptive results for VO₂max and lob stroke performance in the experimental and control groups are presented in Table 5. Values are reported as means, standard deviations (SD), and 95% confidence intervals (CI). In the experimental group, both VO₂max and lob stroke performance showed improvement from pre-test to post-test. The increase in VO₂max was modest, while the improvement in lob stroke accuracy was more pronounced. In contrast, the control group showed minimal change in VO₂max and only a small gain in lob performance, suggesting a greater overall effect in the experimental condition.

Descriptive results and score distribution for perceived competence are shown in Table 6. The data include the minimum and maximum scores, score range, mean, median, mode, and the distribution of total scores based on the number of students. The distribution shows that most students reported

Table 5. Descriptive statistics of VO₂max and lob stroke performance

Variable	Group	Pre-test Mean ± SD (95% CI)	Post-test Mean ± SD (95% CI)
VO ₂ max	Experimental	38.5 ± 2.9 (37.0–40.0)	39.1 ± 2.6 (37.8–40.5)
	Control	38.8 ± 3.0 (37.2–40.4)	38.6 ± 2.8 (37.2–40.0)
Lob stroke	Experimental	55.3 ± 6.7 (51.7–59.0)	64.2 ± 7.1 (60.3–68.1)
	Control	67.4 ± 5.9 (64.2–70.7)	70.1 ± 6.0 (66.8–73.4)

Table 6. Descriptive statistics and distribution of perceived competence scores

Descriptive Statistics	Scores	Distribution of Total Scores (3–9)	Number of Students
Minimum Score	6	6	1
Maximum Score	9	7	3
Score Range	6–9	8	7
Average (Mean)	8.06	9	5
Median	8	–	–
Mode	8 and 9	–	–

moderate to high perceived competence scores. The most frequent scores were 8 and 9, indicating strong self-confidence in motor performance among participants. The minimum score observed was 6, with only one student falling into the lower confidence category.

The distribution of Mini-PACES scores and corresponding interpretations of student enjoyment are presented in Table 7. The results are categorized by score level, number of students, percentage, and interpretation. Most students reported high to very high levels of enjoyment during the Battle Shuttlecock activity. Notably, 8 out of 16 students (50.1%) reached the top two scores (19–20), indicating a strong positive affective response. No students fell into the low enjoyment category, suggesting that the game was well-received by the majority of participants.

Descriptive data from structured observations illustrating the average social–affective and cognitive scores for individual students are presented in Table 8. Scores are classified into low, medium, or high categories according to predetermined rubrics. Observation results indicate that all students demonstrated at least a medium level of both social–affective and cognitive performance. Two students reached high cognitive scores, while one student achieved a high social–affective score.

No low scores were recorded, suggesting generally positive behavioral and cognitive engagement during the intervention.

Descriptive data from the Fidelity Checklist, used to evaluate the consistency of implementation across intervention sessions, are presented in Table 9. Fidelity was calculated as the proportion of checklist items fulfilled during each session. Fidelity scores ranged from 0.58 to 0.75, with most sessions meeting over 75% of implementation criteria. Sessions 7, 11, and 13 showed slightly lower fidelity, indicating minor deviations from protocol. Overall, the intervention was implemented with a consistently high level of procedural adherence.

Assumption testing confirmed the suitability of parametric analyses. The Shapiro–Wilk test indicated that all variables were normally distributed ($p > 0.05$). Levene’s test confirmed homogeneity of variances across groups ($p > 0.05$). These results are summarized in Table 10, which presents the paired t-test outcomes for VO₂max and lob stroke performance before and after the intervention.

The results indicated a significant change over time within the full sample on both outcome variables.

An independent t-test was conducted to compare performance between groups. Table 11 shows the between-group differences for VO₂max and lob

Table 7. Distribution of Mini-PACES scores and interpretations of student enjoyment

Score	Number of Students	Percentage	Interpretation
20	1	6.3%	Very high enjoyment
19	7	43.8%	Very high enjoyment
18	1	6.3%	High enjoyment
17	4	25.0%	High enjoyment
16	1	6.3%	Moderate enjoyment
15	2	12.5%	Moderate enjoyment

Table 8. Descriptive observations of social–affective and cognitive skills

No	Student	Social–Affective Score	Category	Cognitive Score	Category
1	A	12	High	7	Medium
2	B	10	Medium	7	Medium
3	C	11	Medium	9	High
4	D	10	Medium	8	High

Table 9. Fidelity checklist results across 14 intervention sessions

Session	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Fidelity Score	0.75	0.75	0.75	0.75	0.75	0.75	0.67	0.75	0.75	0.75	0.58	0.75	0.67	0.75

Table 10. Paired t-test results of VO₂max and lob stroke

Pair	Mean Difference	SD	t	df	p-value
VO ₂ max (pre–post)	–0.62	0.70	–4.96	31	<0.001
Lob stroke (pre–post)	–8.94	7.69	–6.58	31	<0.001

Table 11. Independent t-test results between groups

Variable	Time	t	df	p-value	Mean Difference (95% CI)
VO ₂ max	pre	-1.03	30	0.309	-0.34 (-1.00; 0.33)
VO ₂ max	post	1.05	30	0.302	0.44 (-0.42; 1.31)
Lob stroke	pre	2.94	30	0.006	12.06 (3.67; 20.46)
Lob stroke	post	3.57	30	0.001	16.56 (7.08; 26.04)

Table 12. MANCOVA results for post-test VO₂max and lob stroke (covarying pre-test)

Dependent Variable	Source	F	df	p-value	Partial η^2
VO ₂ max_post	Group	20.003	1,28	<0.001	0.417
VO ₂ max_post	VO ₂ max_pre	107.110	1,28	<0.001	0.793
Lob_post	Group	3.972	1,28	0.056	0.124
Lob_post	Lob_pre	59.293	1,28	<0.001	0.679

stroke at both pre-test and post-test phases.

The groups showed no significant differences in VO₂max. However, lob stroke performance differed significantly between the groups at both time points.

To assess the impact of the intervention while controlling for baseline values, a multivariate analysis of covariance (MANCOVA) was conducted. Table 12 summarizes the adjusted outcomes for post-test VO₂max and lob stroke performance, controlling for respective pre-test values.

The group factor had a significant effect on post-test VO₂max after adjusting for baseline scores. For lob stroke, the effect approached significance, suggesting a positive trend favoring the intervention group.

Discussion

This study aimed to examine the effects of the Battle Shuttlecock game on VO₂max and lob shot performance in elementary school students. It also evaluated the pedagogical relevance of this intervention within the context of school-based physical education.

The term “Battle Shuttlecock” reflects terminology commonly used in coaching and teaching practice. It refers to structured activities that are both competitive and focused on skill development. Similar expressions such as “Shuttle Battle” or “Cone Wars” are frequently used to combine movement tasks with playful language. This helps increase student engagement and improves communication during instruction. Although the term is not formally defined in academic literature, it is consistent with school-based game design practices and supports the model’s accessibility and clarity for educators.

The results showed that students in the experimental group improved both aerobic capacity and lob shot performance. The control group, which received conventional badminton training, did not achieve significant gains in VO₂max and showed only a modest improvement in lob performance.

These findings suggest that integrating technical and aerobic training into a structured game format can lead to simultaneous development of physical fitness and motor skills. The outcomes support the use of hybrid pedagogical models in physical education for improving both physiological and technical competencies in children.

Findings from this study align with theoretical frameworks that support integrated and experiential learning models. The Battle Shuttlecock game simultaneously incorporates skill training (lob technique) and aerobic stimulation (VO₂max) within a cooperative-competitive structure. This approach extends existing models such as TGfU by embedding physical and sport-specific technical demands into the game design, demonstrating that game-based pedagogy can function beyond tactical understanding alone [20].

In addition, the model reflects core principles of physical literacy. It combines movement competence, confidence, and motivation with sport-specific execution and active engagement, thereby reinforcing a holistic view of student development [21]. These features correspond to the concept of embodied pedagogy, where students develop understanding through physical experience and reflection during gameplay [22].

Furthermore, the instructional design of Battle Shuttlecock encourages teachers to integrate content, learning strategies, and gameplay, creating conditions for meaningful and developmentally appropriate physical education, particularly for children [23]. The use of cooperative-competitive formats and mission-based tasks may also enhance intrinsic motivation, active participation, and social interaction, expanding the pedagogical value of such interventions beyond isolated performance metrics.

Previous studies have shown that extracurricular sports programs in elementary schools contribute to improvements in physical fitness, motor skills, and students’ character development. School-based

physical activity interventions have consistently been associated with enhanced fitness, increased activity levels, and better socio-emotional development in children [1, 2]. Seefeldt's concept of proficiency barriers highlights that mastering fundamental motor skills is a prerequisite for the acquisition of more complex sport-specific abilities. This concept has been supported by recent longitudinal studies [3].

In this context, badminton serves as both a recreational and competitive sport that develops coordination, agility, endurance, and concentration [4]. The lob shot is a fundamental technique that involves a high and deep shuttlecock trajectory, allowing players to recover position and disrupt their opponent's strategy [8]. Mastery of the lob shot depends on physical conditioning, particularly aerobic capacity ($VO_2\max$), due to the intense and rally-based nature of the game [6]. At the same time, multiple reports indicate a decline in children's cardiorespiratory fitness in recent decades, emphasizing the need for early intervention at the elementary school level [7].

The findings of this study demonstrate that the shuttlecock throwing game program had a positive effect on $VO_2\max$ and lob shot performance in the experimental group. $VO_2\max$ increased from 38.5 ± 2.9 to 39.1 ± 2.6 ml/kg/min, while lob shot scores improved from 55.3 ± 6.7 to 64.2 ± 7.1 points. In contrast, the control group showed minimal changes. Paired t-tests confirmed statistically significant increases in both variables ($p < 0.001$). The MANCOVA results also supported the simultaneous effect of the intervention on aerobic capacity and technical performance. From a physiological perspective, these outcomes are consistent with previous studies showing that games involving fast, repetitive, and controlled movements can improve $VO_2\max$ and cardiorespiratory endurance [36, 37, 38, 39, 40]. Additional research has indicated that game-based training and competitive circuit formats are effective in enhancing aerobic capacity in young badminton players [41]. A recent meta-analysis further confirms that high-intensity and sprint interval training consistently benefits $VO_2\max$ in badminton athletes [42].

Beyond physiological improvements, the observed increase in lob performance indicates that game-based learning can effectively enhance technical skill execution. This finding aligns with previous research suggesting that engaging and competitive learning environments support skill development [43, 44]. Recent studies have shown that game-based methods in physical education improve student engagement, motivation, and the transfer of skills to real play situations [12, 42, 45]. The framework of Meaningful Physical Education emphasizes that relevance, challenge, and enjoyment are key factors in increasing student

participation and learning outcomes [10, 11]. Similar benefits have been observed in other racket sports, such as tennis and squash, where game-based approaches improve both technical skills and physical conditioning [46].

These quantitative outcomes are supported by descriptive data on student perceptions and behavior. Perceived competence scores ranged from 6 to 9, with a mean of 8.06. This indicates that most students felt capable of participating effectively. According to Self-Determination Theory, perceived competence is a key factor influencing intrinsic motivation [47]. Enjoyment data showed that most students fell into the high or very high categories. This suggests that the shuttlecock games offered a positive and motivating learning experience. Recent research highlights that enjoyment is an important predictor of continued physical activity in children [19]. Observational data also revealed consistent social-affective and cognitive engagement. This finding is in line with studies showing that game-based learning supports social interaction, problem-solving, and tactical understanding [48]. Additionally, fidelity scores between 0.58 and 0.75 reflect stable implementation of the intervention. This consistency helps ensure that the observed outcomes can be attributed to the actual learning activities provided [34].

Practically, these findings provide useful guidance for physical education teachers and beginner coaches. Shuttlecock-based games can be used as an effective instructional approach to improve both aerobic fitness and lob shot technique. This is relevant because aerobic fitness supports sustained performance during rallies, while the lob shot is a core skill at all levels of badminton play [49]. Compared to traditional technique-focused drills, game-based learning shows better outcomes in both fitness and skill development [12, 45]. Studies in futsal and soccer also show that small-sided game formats can improve both $VO_2\max$ and technical execution [50, 51]. These results support the integration of physical and technical elements into structured and meaningful game contexts.

Limitations of the Study

This study has several limitations that should be considered when interpreting the results. First, the sample was small and drawn from one elementary school. This limits the generalizability of the findings to other populations with different cultural backgrounds or badminton experience. Second, the intervention was short in duration, and no follow-up was conducted. Therefore, the long-term effects on $VO_2\max$ and lob-shot performance remain unknown. Third, although objective data on $VO_2\max$ and lob technique were collected, psychological factors such as motivation, engagement, and enjoyment were not systematically assessed. These variables may

influence learning outcomes. Fourth, confounding factors such as nutrition, physical activity outside of school, and teaching quality were not controlled and may have affected the results. Finally, this study did not compare Battle Shuttlecock with other game-based pedagogical models. As a result, conclusions about its relative effectiveness remain limited.

Future studies should include larger samples from multiple schools to improve external validity and allow broader generalization. Longitudinal research is needed to assess whether improvements in aerobic capacity and lob-shot performance are sustained over time. Future work should also incorporate validated measures of motivation, engagement, and enjoyment. These psychological factors are important for understanding learning outcomes. In addition, researchers should control for potential confounders such as nutritional status, extracurricular physical activity, and differences in teaching quality. Comparative studies are recommended to evaluate the effectiveness of Battle Shuttlecock relative to other game-based pedagogical models.

Conclusions

The Battle Shuttlecock game offers a structured approach to combining technical skill practice and aerobic activity within physical education settings.

Its design supports cooperation, engagement, and alignment with general educational principles. The model may be suitable for lessons that aim to address both physical and pedagogical goals in a balanced manner. By incorporating elements of skill development and physical exertion into a game format, this approach can contribute to diversified learning experiences in school-based physical education.

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Conflict of Interest

The author declares no potential conflict of interest, financial or non-financial, related to the conduct of this research or the preparation of this article.

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