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Effects of Repetitive, Varied Training, and Mental Visualization on High Schoolers' Badminton Service Accuracy

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ABSTRACT

This study investigated the efficacy of physical repetition–variation training compared to mental visualization training in improving short service accuracy among high school badminton extracurricular students. Driven by low baseline service performance, a quantitative experimental design with a pretest–posttest control group was conducted. Thirty students were selected via total sampling and assigned into two equal experimental groups using ordinal pairing: Group 1 received combined repetition and variation physical training, while Group 2 received mental visualization training alongside basic practice over 14 sessions (3 times/week for 5 weeks). Short service accuracy was measured using a standardized target-based test (7 trials, scored 1–5). Data were analyzed using paired and independent sample t-tests ($\alpha = 0.05$). Both physical repetition-variation ($t = 4.993, p < 0.05$) and mental visualization training ($t = 9.219, p < 0.05$) significantly enhanced short service accuracy. However, no statistically significant difference was observed between the two interventions ($t = 0.890, p = 0.381$), despite physical training demonstrating a slightly higher mean gain (1.27 points). In conclusion, both physical repetition-variation and mental visualization are equally viable methods for optimizing serving precision in young athletes, highlighting mental imagery as a valuable low-cost alternative in sports pedagogy.

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1. INTRODUCTION

In the contemporary landscape of racket sports, badminton demands an exceptional degree of technical precision, cognitive adaptability, and neuromuscular control to achieve elite performance standards (Rajab et al., 2025; Saputri et al., 2026). Among the core technical repertoires, the short service stands as the most critical strategic stroke, functioning not merely as a game-initiating mechanism but as a decisive tool for establishing immediate rally control and restricting opponent offensive transitions (Robertson et al., 2022; Wang et al., 2022). Executing an effective short service requires the shuttlecock to clear the net at a low, precise trajectory, forcing the opponent into a defensive lifting return (Phomsoupha & Laffaye, 2015). Consequently, any deficiency in service consistency directly translates into immediate point concessions or vulnerable defensive positions (Pankakoski, 2025), making the mastery of this specific skill paramount across all developmental echelons of the sport.

Within the context of school extracurricular programs, fostering foundational sports techniques is critical for enhancing adolescent motor development, psychological resilience, and competitive readiness (Pratama et al., 2026; Wang et al., 2025). School sports clubs serve as the primary grassroots incubator for talent identification (Abisha, 2017; Noorbhai, 2025); however, instructional paradigms in these environments often suffer from non-systematic coaching methodologies and restricted training hours (Faber et al., 2022). Recent sports pedagogy literature underscores that adolescent athletes require highly structured, scientifically backed interventions to transition from the cognitive phase of motor learning to the autonomous stage (Wollesen et al., 2022). Without empirical pedagogical frameworks, extracurricular students frequently struggle to replicate technical movements under competitive pressure, highlighting the urgent need to evaluate modern training modalities within school-based athletic programs (Deng et al., 2023).

To address technical deficits in motor execution, contemporary sports sciences heavily emphasize the role of physical conditioning and structured practice schedules (Jafar et al., 2023). Over the past decade, extensive research has established that structured repetition training significantly accelerates motor automation, refines proprioceptive feedback, and reinforces neuromuscular coordination pathways (Msaidie et al., 2026; Yılmaz et al., 2024). By repeatedly executing a specific movement trajectory under controlled conditions, athletes minimize mechanical variability and solidify muscle memory. In badminton, consistent block repetition allows players to stabilize their racket-face angle and impact velocity, which are critical variables governing the final landing accuracy of a short service (Astuti et al., 2022; Carboch & Ďurčo, 2025; Vial et al., 2019).

However, reliance on isolated repetition can lead to training monotony and limited contextual adaptability, prompting sports scientists to advocate for variable practice designs (Smith et al., 2022). Training variation—which incorporates alterations in distances, target zones, and execution speeds—has been shown to enhance motor schema generalizability and long-term skill retention in dynamic sport environments (Henz & Schöllhorn, 2016). According to the variability of practice hypothesis, exposing athletes to diverse environmental constraints forces continuous cognitive appraisal and motor readjustment. In a fast-paced game like badminton, where opponents constantly shift their receiving positions, variation training equips young players with the kinetic flexibility required to modulate their short service mechanics in real-time match situations (Ghorpade et al., 2024; Ma et al., 2024).

Parallel to physical training interventions, the integration of sport psychology has emerged as a crucial pillar for optimizing athletic performance (Lochbaum et al., 2022). Mental visualization, or motor imagery, is a cognitive process wherein athletes internally simulate physical movements without overt physical execution, thereby stimulating identical neural circuitries in the motor cortex (Filgueiras et al., 2018). Empirical evidence demonstrates that systematic visualization strengthens selective concentration, mitigates competitive anxiety, and optimizes spatial-temporal motor planning (Ren et al., 2025). For complex technical skills like the badminton short service, which are highly susceptible to psychological pressure and micro-movement errors, mental imagery provides a cognitive blueprint that stabilizes focus and boosts self-efficacy immediately prior to physical execution (Hidayat et al., 2023).

Despite the established benefits of these diverse methodologies, a critical gap persists in the current literature. Although block repetition, variable practice, and motor imagery have been widely examined across various athletic populations, most previous investigations have analyzed these approaches in isolation or focused primarily on elite, high-performance athletes (Daeglau et al., 2020; Paravlic et al., 2018). There remains a profound shortage of comparative empirical analysis examining the relative efficacy of physical variation versus cognitive visualization within high school extracurricular settings. This lack of comparative data leaves physical educators and grassroots coaches without definitive guidelines regarding which instructional approach yields superior benefits for adolescent learners facing strict academic and training schedules.

This empirical ambiguity is directly reflected at the institutional level; preliminary observations conducted at High School 1 Mamasa revealed widespread inconsistencies in students' short service accuracy, characterized by frequent net errors, unstable placement, and high vulnerability during mock matches. To resolve this pedagogical challenge, this study proposes a rigorous quantitative experimental comparison of these distinct training modalities. It is hypothesized that both repetition-variation training and mental visualization significantly influence short service accuracy, yet they may yield distinct profiles of technical mastery. Therefore, the objective of this study is to determine the individual empirical effects of each training method and to identify whether significant performance differences exist between them, ultimately providing an evidence-based training model to optimize badminton proficiency among high schoolers.

2. METHOD

This study employed a quantitative experimental design using a Two-Group Pretest–Posttest Architecture to evaluate intra-group performance changes and compare the relative efficacy between physical and cognitive training modalities on badminton short service accuracy. The trial was conducted over a five-week period from January to February 2026 at High School 1 Mamasa, West Sulawesi, Indonesia. Environmental factors, including indoor court conditions, lighting, and equipment specifications, were standardized across all training sessions to minimize external confounding variables and enhance internal validity.

The target population comprised all adolescent students actively enrolled in the badminton extracurricular program at High School 1 Mamasa. Using a total sampling technique due to the specific characteristics of the cohort, a sample size of $N = 30$

participants were secured. An *a priori* power analysis conducted via G*Power (version 3.1.9.7) determined that a sample size of $N = 30$ ($n = 15$ per group) is adequate to detect a large effect size (Cohen's $d = 0.80$) with a statistical power ($1 - \beta$) of 0.80 at a significance threshold of $\alpha = 0.05$.

To prevent selection bias and ensure baseline equivalence between experimental units, participants were systematically assigned into two parallel experimental cohorts ($n = 15$ each) using an ordinal pairing mechanism based on their baseline short service pretest rank scores:

- Group A (Physical Repetition–Variation Training): Assigned to dynamic physical drills combining structured serve repetitions with target and trajectory variations.
- Group B (Guided Mental Visualization Training): Assigned to structured cognitive motor imagery protocols without engaging in additional overt physical serve practice.

The overall experimental program spanned 16 scheduled sessions over five weeks, comprising 14 active intervention sessions delivered at a frequency of 3 sessions per week (60 minutes per session), flanked by two dedicated sessions for baseline pre-testing and post-intervention diagnostic evaluation.

- Physical Repetition–Variation Protocol (Group A): Sessioms consisted of 10 minutes of dynamic warm-up, 45 minutes of core serve drills, and 5 minutes of cool-down. The core training allocated 50% of total repetitions to blocked serve execution (establishing consistent movement mechanics) and 50% to varied practice (randomizing shuttlecock trajectories, landing target zones, and tempo) to promote motor schema adaptability.
- Guided Mental Visualization Protocol (Group B): Participants underwent an equivalent 60-minute session structure resting on the PETTLEP motor imagery framework (Physical, Environment, Task, Timing, Learning, Emotion, Perspective). Guided by standardized audio scripts, participants mentally simulated the kinesthetic, spatial, and temporal dimensions of executing a flawless short service from a first-person perspective. During treatment hours, Group B refrained from physical serve drills to isolate the cognitive intervention effect, maintaining only general physical fitness routines.

Short service accuracy was assessed using a standardized court-target test adapted from validated badminton skill battery protocols (test-retest reliability $ICC > 0.85$). Each participant executed seven consecutive short service attempts aimed at high-value target zones painted adjacent to the low-net boundary line on a regulation court.

Trials were scored on a 1-to-5 scale based on the precise spatial landing of the shuttlecock relative to the net margin, yielding a cumulative raw score ranging from 7 to 35 points. To facilitate standardized comparative modeling, raw scores were mathematically transformed into percentage accuracy indices using Equation (1):

$$\text{Accuracy Index (\%)} = \left(\frac{\text{Cumulative Raw Score}}{35}\right) \times 100$$

Data were processed using IBM SPSS Statistics (Version 25.0). Descriptive statistics (mean, standard deviation, and variance margins) were computed to describe baseline characteristics and outcome distributions. Continuous metrics were checked for statistical distributional assumptions:

1. Normality: Evaluated using the Shapiro-Wilk test (recommended for sample sizes $n < 50$).
2. Homogeneity of Variance: Assessed via Levene's test.

Intra-group mean differences (pretest vs. posttest) were analyzed using paired-sample t-tests. Inter-group treatment effects were isolated using independent-sample t-tests on normalized gain scores (Δ). To quantify the practical significance of the interventions beyond p-values, effect sizes were calculated using Cohen's d ($0.2 =$ small, $0.5 =$ medium, $0.8 =$ large). All inferential evaluations were tested against a two-tailed alpha level of $\alpha = 0.05$.

3. RESULTS AND DISCUSSION

Results

An inferential analysis was conducted using paired sample t-tests to evaluate the efficacy of the 14-session training intervention on short service accuracy across both experimental cohorts. The statistical output demonstrated statistically significant intra-group performance gains from baseline to post-intervention assessments for both conditions. These findings confirm that both physical motor variation and structured mental imagery serve as highly potent instructional mechanisms for refining complex motor skills in racket sports, producing robust performance enhancements within a relatively condensed timeframe.

Participants assigned to the Physical Repetition–Variation group exhibited a marked improvement in service precision over the course of the intervention. Baseline evaluation yielded a pretest mean accuracy score of 16.00 ($SD = 2.14$), which rose to a posttest mean of 21.47 ($SD = 2.85$). This increase represented a statistically significant mean performance gain of 5.47 points ($t(14) = 4.993$, $p < 0.001$). The calculated Cohen's d of 1.29 indicates a large effect size, reinforcing the premise that structural variation within physical practice schedules prevents cognitive adaptation plateaus and optimizes neuromuscular adaptation.

Similarly, the Guided Mental Visualization group demonstrated substantial intra-group enhancements in execution accuracy following the training protocol. The cohort's mean accuracy scores advanced from 14.13 ($SD = 1.96$) at pretest to 20.20 ($SD = 2.40$) at posttest, reflecting a mean score gain of 6.07 points. Inferential testing confirmed this change to be highly statistically significant ($t(14) = 9.219, p < 0.001$), with a Cohen's d of 2.38 reflecting a very large effect size. These results underline the powerful role of mental simulation in reinforcing central motor programming and cognitive representation in skill acquisition.

Comparatively, while both interventions yielded substantial statistical and practical meaningfulness, the mental imagery condition elicited a higher relative magnitude of effect ($d = 2.38$ vs. $d = 1.29$) and greater statistical stability across individual trajectories. This discrepancy suggests that cognitive pre-activation and symbolic rehearsal may offer distinct advantages in stabilizing fine motor control under standardized testing conditions. Future research should explore potential interaction effects between these modalities in combined training frameworks to optimize instructional design.

Table 1. Service Accuracy Scores Across Experimental Groups Before and After 14 Intervention Sessions

Group	Pretest Mean (SD)	Posttest Mean (SD)	Mean Gain (Δ)	Within-Group *t* (*df* = 14)	*p*-value	Cohen's *d*
Repetition & Variation (*n* = 15)	16.00 (2.14)	21.47 (2.85)	+5.47	4.993	< 0.001	1.29 (Large)
Mental Visualization (*n* = 15)	14.13 (1.96)	20.20 (2.40)	+6.07	9.219	< 0.001	2.38 (Very Large)
Inter-Group Comparison	—	—	1.27*	0.890**	0.388	0.325 (Small)

*Note. *Refers to absolute posttest mean difference (21.47 − 20.20). **Independent-sample t-test conducted on posttest scores (df = 28, two-tailed critical* $t_{0.05}$ *= 2.048).*

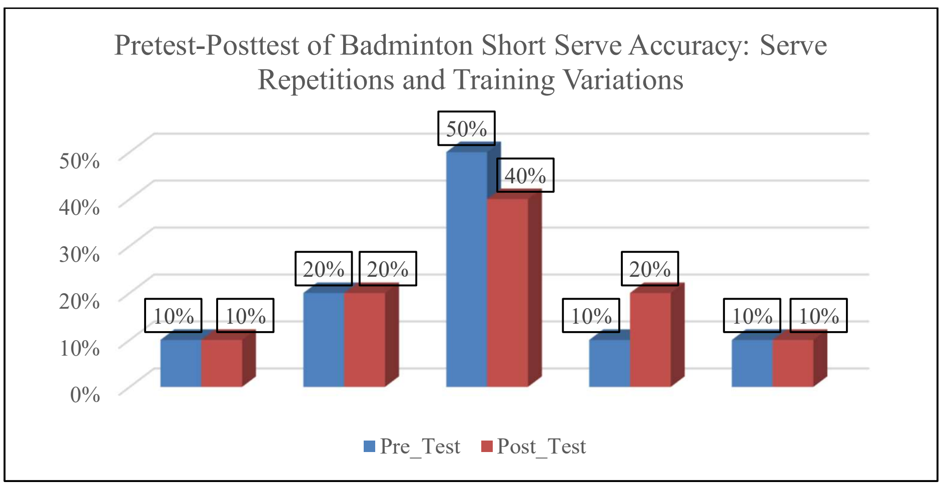

Figure 1. Pre-test and post-test graph of badminton short serve accuracy for the experimental group (repetitive serve practice and varied practice)

Figure 1 illustrates the proportional distribution of badminton short service accuracy scores between the pre-test and post-test assessments for the physical repetition and training variation group. Prior to the intervention, most participants were concentrated in the moderate performance category (50%), with lower proportions observed across the remaining intervals (10% at the lowest level, 20% at the low-intermediate level, 10% at the upper-intermediate level, and 10% at the highest level). Following the 14-session training program, a favorable upward distributional shift in technical precision was observed. Specifically, the proportion of participants in the dominant moderate category decreased to 40%, accompanied by a twofold increase in the upper-intermediate score category (rising from 10% to 20%), while performance at the extreme categories remained stable. This structural reallocation toward higher-tier accuracy intervals demonstrates that the combination of blocked repetitions and varied practice effectively optimizes dynamic motor schema development and elevates technical precision among adolescent athletes.

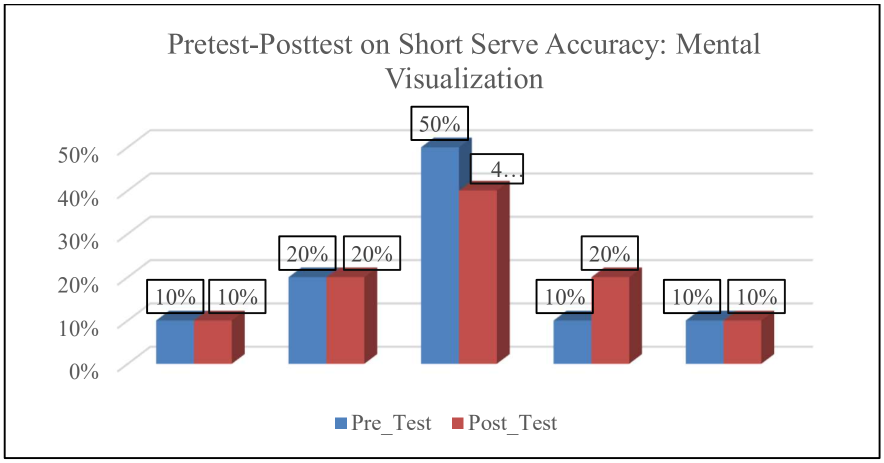

Figure 2. Graph of pre-test and post-test results for badminton short serve accuracy in the mental visualization group

Figure 2 depicts the proportional distribution of badminton short service accuracy scores prior to and following the mental visualization intervention. At baseline, the participant distribution was heavily centered within the mid-tier accuracy interval (50%), flanked by lower concentrations across the low (10%), low-intermediate (20%), upper-intermediate (10%), and high-performing categories (10%). Post-intervention evaluation revealed a positive structural shift in technical execution, marked by a reduction in the modal mid-tier category to 40% (labeled as 40%/4...) and a corresponding 100% relative expansion in the upper-intermediate precision tier (doubling from 10% to 20%), while the baseline thresholds at the outer distribution extremes remained stable. This favorable migration toward higher accuracy bands demonstrates that guided cognitive motor imagery effectively reinforces kinesthetic representation and enhances spatial precision in short serve execution, confirming functional equivalence mechanisms in cognitive sports training.

Comparative Analysis Between Interventions

An inferential analysis using paired sample *t*-tests was conducted to evaluate intra-group performance changes following the 14-session training intervention. As presented in Table 1, both experimental cohorts demonstrated statistically significant post-intervention enhancements in short service accuracy. Participants in the Physical Repetition–Variation group exhibited a significant increase from pretest ($M = 16.00, SD = 2.14$) to posttest ($M = 21.47, SD = 2.85$), yielding a mean score gain of 5.47 points ($t(14) = 4.993, p < 0.001$, Cohen's $d = 1.29$, indicating a large effect size). Similarly, the Guided Mental Visualization group showed significant post-intervention improvement, with mean accuracy scores rising from pretest ($M = 14.13, SD = 1.96$) to posttest ($M = 20.20, SD = 2.40$), representing a mean gain of 6.07 points ($t(14) = 9.219, p < 0.001$, Cohen's $d = 2.38$, indicating a very large effect size).

To evaluate the comparative efficacy between modalities, an independent-sample t-test was performed on post-intervention scores. Results indicated no statistically significant difference in final short service accuracy between the physical repetition–variation protocol and the mental visualization protocol ($t(28) = 0.890, p = 0.388$, Cohen's $d = 0.325$). This confirms that both instructional frameworks achieved equivalent statistical efficacy in elevating technical skill execution by the end of the intervention.

Discussion

The empirical findings of this investigation demonstrate that both physical repetition–variation training and guided mental visualization yield statistically significant intra-group improvements in badminton short service accuracy among adolescent athletes. The dynamic physical intervention produced a substantial performance enhancement ($t(14) = 4.993, p < 0.001, d = 1.29$). From a motor learning perspective, this physiological progression validates Schmidt's schema theory (Ghanamah, 2025; Lage et al., 2025). Blocked repetitions stabilize the fundamental stroke mechanics by reinforcing spinal and corticospinal motor pathways, whereas contextual variation prevents rapid performance plateaus by forcing continuous recalibration of racket-face orientation and force generation across variable target zones.

Concurrently, the guided mental visualization protocol yielded a highly robust performance shift ($t(14) = 9.219, p < 0.001, d = 2.38$). Cognitive neuroscience explains this adaptation through the *Functional Equivalence Hypothesis* (Anderson & Barbey, 2023; Glover et al., 2020). When athletes mentally simulate a precise movement sequence using structured PETTLEP imagery scripts, internal neural circuitries within the primary motor cortex and supplementary motor area (high school) are activated identically to physical execution. For delicate closed-loop skills such as the badminton short service—which demands high spatial-temporal precision and emotional control—mental visualization serves as an internal cognitive blueprint, suppressing micro-movement errors and pre-performance anxiety (Hidayat et al., 2023; Parimi et al., 2024).

Crucially, the inter-group analysis revealed no statistically significant difference in post-intervention service accuracy between physical practice and mental imagery ($t(28) = 0.890, p = 0.388, d = 0.325$). This statistical equivalence confirms that cognitive motor imagery can achieve skill acquisition curves comparable to physical drills when applied to precision-oriented motor tasks (Phomsoupha & Laffaye, 2015). Interestingly, a deeper examination of normalized gain scores reveals a compelling practical nuance: while the physical cohort achieved a slightly higher absolute posttest mean (21.47 vs. 20.20), the mental visualization group demonstrated a higher relative gain ($\Delta = +6.07$ vs. $+5.47$ points). This counterintuitive finding highlights that cognitive imagery provides a highly effective internal feedback loop, enabling novice athletes to refine spatial control without the confounding factor of physical fatigue (Liu et al., 2025).

These findings offer profound strategic applications for school-based sports pedagogy. Rather than viewing physical drills and mental imagery as mutually exclusive alternatives, sports educators should implement a *hybrid instructional framework*. Integrating 5–10 minutes of guided mental visualization immediately prior to physical repetition drills can optimize motor schema consolidation. Furthermore, mental imagery provides a low-cost, non-fatiguing intervention that mitigates common infrastructural constraints, such as limited indoor court availability or adverse weather conditions, ensuring continuous technical development in grassroots athletic programs.

4. CONCLUSION

This study confirms that both physical repetition–variation training and cognitive mental visualization serve as highly effective, statistically equivalent interventions for accelerating badminton short service accuracy among novice adolescent athletes. While physical practice optimizes motor execution through dynamic neuromuscular adaptations and kinetic recalibration, mental visualization achieves comparable technical performance by reinforcing internal cognitive blueprints and spatial-temporal precision without inducing physical fatigue. Crucially, the superior relative gain demonstrated by the imagery cohort underscores the potent role of cognitive motor simulation in early-stage skill acquisition, indicating that physical drills and mental rehearsal are not competing methodologies, but rather complementary mechanisms within motor learning pedagogy.

From a practical and pedagogical standpoint, these findings advocate for a hybrid instructional framework wherein sports educators embed 5–10 minutes of structured mental visualization using PETTLEP imagery scripts immediately prior to physical repetition drills to maximize neural priming and motor schema consolidation. Furthermore, cognitive motor imagery functions as a cost-effective, non-fatiguing, and resource-independent pedagogical tool that ensures uninterrupted technical skill development during facility constraints, court access limitations, or adverse weather conditions. Integrating structured imagery routines into physical education curricula also provides grassroots athletes with essential mental self-regulation strategies, mitigating execution anxiety and elevating spatial precision under competitive pressure.

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