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Kick-Pad versus Hanging-Ball Training for Overhead Service Performance in Adolescent Sepak Takraw Athletes: A Non-Randomized Pre-Post Study

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ABSTRACT

Purpose of the study: Overhead service is a decisive technical skill in sepak takraw, yet evidence comparing training aids for developing service performance in adolescent athletes remains limited. This study compared changes in overhead-service performance following kick-pad and hanging-ball training and examined whether improvement differed between the two approaches.

Materials and methods: A non-randomized two-group pre-test/post-test design involved eight male adolescent sepak takraw athletes (15–18 years), allocated by matching based on pre-test performance to a kick-pad group (n=4) or hanging-ball group (n=4). Participants completed 18 training sessions over six consecutive weeks. Performance was assessed through 20 overhead-service trials at pre-test and post-test using a composite T-score derived from service-zone accuracy and travel time. Within-group changes were analyzed using two-sided paired-samples t-tests, and between-group differences using an independent-samples t-test on change scores. Mean changes, 95% confidence intervals, and effect sizes were reported.

Results: The kick-pad group increased from 48.75 ± 11.21 to 50.67 ± 10.44 , with a mean change of 1.92 ± 1.31 points ($t(3)=2.94$, $p=0.061$, Cohen's $d_z=1.47$; 95% CI -0.16 to 4.01). The hanging-ball group increased from 49.58 ± 7.38 to 51.03 ± 7.65 , with a mean change of 1.46 ± 0.44 points ($t(3)=6.60$, $p=0.007$, Cohen's $d_z=3.30$; 95% CI 0.75 to 2.16). The between-group difference in change was 0.47 points and was not statistically significant ($t(6)=0.67$, $p=0.526$; 95% CI -1.23 to 2.16 ; Hedges' $g=0.41$).

Conclusions: Both conditions showed positive changes, but the evidence did not demonstrate a statistically significant difference in improvement between methods. The study adds context-specific evidence to international sport and motor-learning research by examining training-aid-based overhead-service practice in adolescent sepak takraw athletes. Generalization is limited by the small, non-randomized sample, absence of a non-training control group, and single training setting.

Keywords

sepak takraw; overhead service; motor learning; sports training; adolescent athletes; skill performance.

INTRODUCTION

Global and Theoretical Context

Sepak takraw is a technically demanding sport that requires athletes to coordinate high-speed lower-limb movements, flexibility, balance, timing, and precise ball control within a constrained playing environment (Nguyen et al., 2022, p. 1; Zulkifli et al., 2025). The technical complexity of the sport has attracted increasing biomechanical and performance-analysis research, particularly because successful execution depends on the interaction between body position, joint movement, ball-contact characteristics, and movement coordination (Travassos et al., 2013). A systematic review of sepak takraw biomechanics identified the importance of coordinated segmental movement and biomechanical control in the execution of sport-specific techniques (Fong et al., 2015). In the overhead service, these demands are particularly important because the service is simultaneously an initiating action and an offensive opportunity, requiring accurate placement and sufficient ball velocity to reduce the opponent's ability to organize an effective reception (Wiyaka et al., 2018).

The overhead service is therefore a multidimensional motor skill rather than a single accuracy task. Successful performance requires the athlete to control the trajectory and landing position of the ball while generating adequate speed through coordinated lower-limb and whole-body movement (Crespo et

al., 2024, p. 1406853; Maquirriain et al., 2016, p. 846). Biomechanical investigations of the *tekong* service have examined pre-service movement and ball-contact characteristics, while research on serve speed has shown that variables such as foot-to-foot distance and ball height at contact can contribute to differences in serve velocity (Hamdan et al., 2012; Kaharuddin et al., 2018). Consequently, training interventions intended to improve overhead-service performance should provide repeated opportunities to stabilize the movement pattern while simultaneously developing accurate target-directed execution.

Motor-learning theory provides a useful framework for understanding how different training aids may influence this process. The OPTIMAL theory of motor learning proposes that learning and performance can be enhanced through conditions that promote an external focus of attention, positive performance expectations, and autonomy (Wulf & Lewthwaite, 2016). An external focus directs the athlete's attention toward the intended movement effect rather than toward individual body movements. Practice variability may further facilitate motor learning by encouraging athletes to adapt their movement solutions to changing task demands rather than simply reproducing one fixed motor pattern (Chua et al., 2019).

These principles provide a theoretical rationale for

comparing kick-pad and hanging-ball training. Hanging-ball training provides a relatively stable and reproducible external target. The ball can be positioned at a predetermined height, allowing athletes to repeat the overhead-service movement under relatively consistent spatial conditions (Chua et al., 2019, p. 309). In contrast, kick-pad training provides a target that can be held and adjusted by a coach or training partner, allowing variation in target height, orientation, and position (Taha et al., 2024). Such differences may alter the information available to the learner and the degree of movement variability experienced during practice (Ranganathan & Newell, 2010, 2012). Thus, although both interventions involve repetitive service-specific practice, they may provide different task constraints for developing accuracy, movement consistency, and ball-contact control.

Critical Review of Existing Evidence

Previous quantitative research generally supports the use of targeted practice to improve sepak takraw service performance, but the available evidence is heterogeneous with respect to participants, design, training dose, outcome measures, and methodological quality. For example, Wiyaka et al. (2018) investigated the interaction between eye-foot coordination and service-learning methods using a 2 × 2 factorial experimental design involving 72 university students. The study found differences associated with coordination level and service-learning method and reported an interaction between the two factors. This finding indicates that the effectiveness of a training method may depend partly on athlete characteristics rather than being universally consistent across performers.

Evidence specifically concerning hanging-ball training has also reported positive changes. (Irawady et al., 2024) examined eight PPLP Riau athletes using a one-group pre-test/post-test design and reported a statistically significant improvement following hanging-ball training. However, the absence of a comparison group means that the observed change cannot be separated confidently from maturation, concurrent training, repeated testing, or other temporal effects. The small sample size also limits the precision and generalizability of the estimated intervention effect.

More directly relevant is the study by Male et al. (2024), which compared kick-pad and modified hanging-ball training among 10 high-school sepak takraw students using a two-group pre-test/post-test experimental design. Both interventions improved upper-service accuracy, while the authors reported a larger percentage improvement for the kick-pad group. Importantly, the outcome was primarily service accuracy, meaning that the findings do not establish whether the same pattern would occur when performance is evaluated using a multidimensional measure incorporating both accuracy and ball travel time (Crespo et al., 2024, p. 1406853; Lee et al., 2014, p. 8).

Measurement selection is an additional methodological consideration. Irawan et al., (2021) developed a top-service accuracy test for sepak takraw and reported expert-content evaluation together with validity coefficients of 0.781 and 0.812 and reliability coefficients of 0.896 and 0.917 across small- and large-group trials. These findings provide empirical support for structured assessment of service accuracy. Nevertheless, an accuracy test and a composite accuracy–speed outcome are not equivalent constructs (Schumann et al., 2022, p. 946631; Weiner et al., 2017, p. 116). Therefore, extending service

assessment to include both spatial accuracy and temporal performance requires explicit calculation procedures and should not be presented as automatically validated by the accuracy test alone.

Taken together, the existing literature provides evidence that service-specific practice can improve performance, but several uncertainties remain. Studies have used small samples, different athlete populations, different comparison conditions, and different outcome measures. Intervention durations and training volumes have also varied. Furthermore, many studies have emphasized statistical significance without consistently reporting effect sizes and confidence intervals, limiting interpretation of the magnitude and precision of observed effects (Nedergård et al., 2021, p. 12). These methodological differences provide plausible explanations for inconsistent findings concerning whether a stable target or a more adaptable target-training approach produces greater improvement.

Research Gap, Novelty, and International Contribution

Although previous studies show that hanging-ball and kick-pad training can improve aspects of sepak takraw service performance, it remains unclear whether these two training modalities produce different magnitudes of improvement in multidimensional overhead-service performance among adolescent male athletes when training duration and volume are standardized.

The present study addresses this gap through a direct comparison of kick-pad and hanging-ball interventions in adolescent male sepak takraw athletes. Its principal novelty is the use of a composite overhead-service performance measure incorporating both target-zone performance and ball travel time, rather than evaluating service accuracy alone. The measurement procedure involved 20 service trials at each assessment point, with zone performance and travel time transformed into T-scores and combined into a trial-level composite score. The participant-level outcome was then calculated as the mean of the 20 trial-level composite scores.

This approach extends previous sepak takraw research in several respects. First, it provides a direct head-to-head comparison of two commonly used service-training aids. Second, it integrates two dimensions of performance—accuracy and temporal execution—into one predefined outcome. Third, the study uses a matched-pair allocation procedure based on baseline performance and an equivalent six-week, 18-session intervention structure. Finally, the statistical analysis emphasizes mean change, exact two-sided p-values, effect sizes, and 95% confidence intervals rather than relying solely on critical t-values.

The study therefore contributes evidence for determining whether the theoretical distinction between relatively stable-target practice and more adjustable target practice translates into measurable differences in overhead-service improvement. Rather than assuming that one practice condition is universally superior, the study tests whether the magnitude of change differs when both interventions are delivered under comparable training conditions.

Objectives and Hypotheses

The primary objective of this study was to compare the change in composite overhead-service performance from pre-test to post-test between adolescent male sepak takraw athletes receiving kick-pad training and those receiving hanging-ball training over a six-week intervention. The

secondary objectives were to determine whether: 1) kick-pad training was associated with a positive pre-to-post change in composite overhead-service performance; and 2) hanging-ball training was associated with a positive pre-to-post change in composite overhead-service performance. Based on motor-learning theory and previous empirical evidence, the following directional hypotheses were formulated:

H₁: Kick-pad training will produce a positive change in composite overhead-service performance from pre-test to post-test.

H₂: Hanging-ball training will produce a positive change in composite overhead-service performance from pre-test to post-test.

H₃: The magnitude of improvement in composite overhead-service performance will differ between the kick-pad and hanging-ball groups.

All hypotheses were evaluated using two-sided inferential tests with $\alpha = .05$, consistent with the statistical analysis specified in the present study.

METHODOLOGY

Study Design and Setting

A non-randomized, two-group pre-test/post-test comparative design was used to examine changes in overhead-service performance following kick-pad and hanging-ball training. The study was conducted at the PSTI Serdang Bedagai training centre, Tualang Village, Perbaungan Sub-district, Serdang Bedagai Regency, North Sumatra, Indonesia. The training centre conducted regular sepak takraw training three times per week under the supervision of a qualified coach. The study compared two training conditions: kick-pad training and hanging-ball training. The primary comparison was the difference in individual pre-to-post change scores between the two groups. Because participants were not randomly assigned and no non-training control group was included, the study was designed to evaluate comparative changes rather than establish definitive causal effectiveness. The intervention comprised 18 training sessions over six consecutive weeks, with three sessions per week on Tuesdays, Thursdays, and Saturdays. Each session lasted approximately 90 minutes. Both groups trained at the same facility and under comparable coaching and environmental conditions. The exact calendar dates of the intervention should correspond to the verified attendance and training records.

Participants

The accessible population consisted of 16 male athletes registered at the PSTI Serdang Bedagai training centre. Eight athletes were selected using purposive sampling according to predefined eligibility criteria. Participants were eligible if they were male athletes who were actively registered with the training centre, regularly participated in training, were within the target adolescent age range, provided informed consent, and were willing to complete the intervention. Athletes with a current musculoskeletal injury, contraindications to vigorous physical activity, or attendance below 80% of the prescribed training sessions were excluded. The final sample consisted of eight male adolescent athletes, with a mean age of 15.5 ± 0.5 years. Four athletes participated in the kick-pad group and four in the hanging-ball group. Because of the small sample size, participant characteristics and individual performance data should be interpreted descriptively rather than as representative of the wider adolescent sepak takraw population.

Group Allocation and Matching Procedure

Participants were not randomly assigned to the intervention groups. Following the baseline performance assessment, the eight athletes were ranked according to their pre-test overhead-service performance scores. A matching-pair allocation procedure was then used to distribute athletes between the two training groups according to their baseline performance. The allocation procedure was intended to reduce

obvious baseline imbalance between groups rather than constitute randomization. Group A ($n = 4$) received kick-pad training, whereas Group B ($n = 4$) received hanging-ball training. Both groups received comparable training exposure, including the same intervention duration, training frequency, approximate session duration, training environment, and overall training volume. However, because allocation was non-randomized, residual selection and baseline confounding cannot be excluded.

Overhead-Service Performance Test

Overhead-service performance was assessed using a target-zone sepak takraw service-testing procedure based on the testing procedure described by (Hanif et al., 2020). The test was conducted on a regulation sepak takraw court measuring 13.40×6.10 m. The opponent's court was divided into predefined scoring zones, and an additional horizontal rope was positioned 70 cm above the upper edge of the net to provide a reference for service trajectory. The testing equipment consisted of a standard sepak takraw ball, regulation net and posts, a 70-cm reference rope, a timing device, and a standardized scoring sheet. Each athlete performed 20 overhead-service trials from the designated tekong service area. For each trial, a feeder delivered the ball to the athlete, who executed the overhead service toward the designated target zones. The landing position of the ball was recorded as the zone score. When the ball cleared the additional reference rope at or above the specified height, the corresponding zone score was multiplied according to the scoring protocol used in the present study.

In addition to the target-zone score, ball travel time was recorded from foot-ball contact until the ball landed in the target court. The same testing procedure and measurement sequence were applied during both the pre-test and post-test assessments. The target-zone component of the test was based on the sepak takraw service-testing procedure attributed to (Hanif et al., 2020). The travel-time measure and the subsequent composite accuracy-speed index were operational components added to the present study and should therefore not be interpreted as independently validated components of the Hanif (2020) test unless their original validation source is established.

Calculation of the Composite Performance Score

The complete trial-level dataset comprised 320 observations, corresponding to eight athletes, two assessment occasions, and 20 service trials per assessment occasion ($8 \times 2 \times 20$). For each trial, two performance components were recorded: (1) target-zone performance, representing service accuracy, and (2) ball travel time, representing temporal execution of the service. The target-zone and travel-time variables were transformed into T-scores using the

conventional linear T-score transformation:

$$T = 50 + 10 \left(\frac{X - \bar{X}}{SD} \right)$$

For the target-zone component, the present study used a predefined reference mean of 10 and a reference standard deviation of 2: $T_{zone} = 50 + 10 \left(\frac{[X_{zone} - 10]}{2} \right)$

For the travel-time component, because lower travel time represents faster execution, the direction of the transformation was reversed:

$$T_{speed} = 50 + 10 \left(\frac{0.8 - X_{time}}{0.1} \right)$$

where 0.8 s and 0.1 s represent the reference mean and standard deviation, respectively, used in the present study's data-processing protocol.

The four numerical reference parameters (zone mean = 10, zone SD = 2, travel-time mean = 0.8 s, and travel-time SD = 0.1 s) were predefined for the data-processing protocol of the present study and were not treated as normative parameters established by (Hanif et al., 2020).

The composite T-score for each trial was calculated as the arithmetic mean of the accuracy and speed components:

$$T_{composite} = \frac{T_{zone} + T_{speed}}{2}$$

The participant-level performance score at each assessment occasion was calculated as the arithmetic mean of the 20 trial-level composite T-scores:

$$Performance\ Score = \frac{\sum_{i=1}^{20} T_{composite,i}}{20}$$

Thus, the primary participant-level score represented the mean composite performance across 20 service trials rather than the cumulative sum of the trial scores. All subsequent statistical analyses were performed using participant-level scores to avoid treating individual trials as independent participants.

Outcome Variable

The primary outcome was the change in participant-level mean composite T-score from pre-test to post-test. For each athlete, the change score was calculated as:

$$\Delta_i = Post - test\ Mean_i - Pre - test\ Mean_i$$

A positive value indicated an increase in composite overhead-service performance. The resulting participant-level change scores were used for the primary between-group comparison, which examined the difference in mean change between the kick-pad and hanging-ball training groups. Because the composite index combines target-zone accuracy and ball travel

time using study-specific reference parameters, the resulting score should be interpreted as a predefined operational performance measure for the present investigation rather than as a fully validated standardized norm-referenced instrument.

Statistical Analysis

Descriptive statistics were calculated from the participant-level mean composite T-scores. For each training group, pre-test scores, post-test scores, and change scores were summarized using the mean and standard deviation (SD). Within-group pre-to-post changes were evaluated using two-sided paired-samples *t*-tests. The standardized magnitude of within-participant change was expressed using *Cohen's d_z*.

The primary comparative analysis examined whether the magnitude of improvement differed between the two training conditions. Individual participant change scores were compared using a two-sided independent-samples *t*-test with pooled variance. Hedges' *g* was reported as the standardized between-group effect size. All inferential analyses were conducted using the participant-level means, not the individual trial-level observations. The 20 trials per assessment occasion were therefore used to obtain a more stable participant-level estimate of service performance, while the participant remained the statistical unit of analysis. Statistical significance was evaluated using a two-sided $\alpha = .05$ $\alpha = .05$. Results were reported with exact *p*-values, 95% confidence intervals, and standardized effect sizes.

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was granted by the Faculty of Sport Science, Universitas Negeri Medan, under Approval Number FIKK-Re-3121, dated 20 January 2026. The chronological relationship between this approval date and the actual participant recruitment, intervention, and data-collection dates should be verified against the institutional research records before submission. Written informed consent was obtained from the participants and, because the participants were adolescents, from their parents or legal guardians. Participants and guardians were informed about the study procedures, voluntary participation, potential risks and benefits, confidentiality, and the right to withdraw without penalty. All participant performance data were anonymized and used for research purposes. Training and testing procedures were conducted under appropriate supervision to minimize potential risks to participants.

RESULTS

Descriptive Statistics

A total of eight male adolescent sepak takraw athletes completed the study, with four athletes assigned to the kick-pad training group and four athletes assigned to the hanging-ball training group. Each athlete completed 20 overhead service trials at both pre-test and post-test. For statistical analysis, the mean composite T-score across the 20 trials was used as the

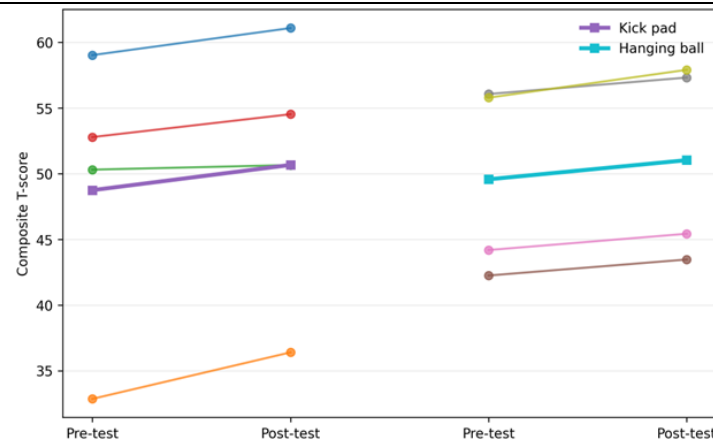
participant-level performance score.

As shown in Table 1, the kick-pad group increased from a pre-test mean of 48.75 ± 11.21 to a post-test mean of 50.67 ± 10.44 , representing a mean improvement of 1.92 ± 1.31 points. The hanging-ball group increased from 49.58 ± 7.38 at pre-test to 51.03 ± 7.65 at post-test, representing a mean improvement of 1.46 ± 0.44 points. All eight participants demonstrated positive changes between pre-test and post-test.

Table 1. Descriptive Statistics of Overhead Service Performance at Pre-Test and Post-Test

Training group	n	Pre-test, Mean $\pm$ SD	Post-test, Mean $\pm$ SD	Mean change $\pm$ SD	Minimum change	Maximum change
Kick pad	4	48.75 $\pm$ 11.21	50.67 $\pm$ 10.44	1.92 $\pm$ 1.31	0.35	3.54
Hanging ball	4	49.58 $\pm$ 7.38	51.03 $\pm$ 7.65	1.46 $\pm$ 0.44	1.22	2.12

Note. SD = standard deviation. Mean change was calculated as post-test minus pre-test. Positive values indicate improvement in overhead service performance.



DRAFT — based on unverified research-ready working data; verify against original field records before submission.

Figure 1. Individual pre-test to post-test changes in the composite overhead-service performance score by training group. Draft figure based on the current research-ready working dataset; verify against original field records before submission.

Within-Group Changes

Within-group changes were examined using two-sided paired-samples *t*-tests with a significance level of $\alpha = .05$. The results are presented in Table 2. For the kick-pad group, the mean performance score increased by 1.92 points, from 48.75 at pre-test to 50.67 at post-test. The paired-samples *t*-test yielded $t(3) = 2.94, p = .061$, with a 95% confidence interval (CI) for the mean change ranging from -0.16 to 4.01 . Therefore, the

observed increase did not reach statistical significance under the prespecified two-sided $\alpha = .05$ criterion. The standardized within-group change was Cohen's $d_z = 1.47$.

For the hanging-ball group, the mean performance score increased by 1.46 points, from 49.58 at pre-test to 51.03 at post-test. The paired-samples *t*-test yielded $t(3) = 6.60, p = .007$, with a 95% CI ranging from 0.75 to 2.16 . Thus, the increase was statistically significant at $\alpha = .05$. The standardized within-group change was Cohen's $d_z = 3.30$.

Table 2. Within-Group Changes in Overhead Service Performance

Training group	Mean change	SD change	<i>t</i>	df	<i>p</i>	95% CI for mean change	Cohen's d_z
Kick pad	1.92	1.31	2.94	3	.061	-0.16 to 4.01	1.47
Hanging ball	1.46	0.44	6.60	3	.007	0.75 to 2.16	3.30

Note. Two-sided paired-samples *t*-tests; $\alpha = .05$. Mean change = post-test – pre-test. CI = confidence interval; SD = standard deviation; Cohen's d_z = standardized within-group change.

Between-Group Comparison of Change Scores

To determine whether the magnitude of improvement differed between the two training methods, individual change scores were calculated as the difference between post-test and pre-test performance for each athlete. The mean change was 1.92 ± 1.31 points in the kick-pad group and 1.46 ± 0.44 points in the hanging-ball group. The observed difference in mean change between groups was 0.47 points, with the kick-pad group showing the numerically larger mean change. However,

the independent-samples *t*-test comparing change scores did not demonstrate a statistically significant difference between the two training groups, $t(6) = 0.67, p = .526$, 95% CI $[-1.23, 2.16]$. The standardized between-group difference was Hedges' $g = 0.41$. Thus, although the numerical mean change was slightly greater in the kick-pad group, the data did not provide statistical evidence that the magnitude of improvement differed between the kick-pad and hanging-ball training methods.

Table 3. Between-Group Comparison of Change Scores

Outcome	Kick pad, Mean $\pm$ SD	Hanging ball, Mean $\pm$ SD	Mean difference	<i>t</i>	df	<i>p</i>	95% CI	Hedges' g
Change score	1.92 ± 1.31	1.46 ± 0.44	0.47	0.67	6	$.526$	-1.23 to 2.16	0.41

Note. Mean difference = kick-pad change – hanging-ball change. The analysis used a two-sided independent-samples *t*-test with pooled variance. CI = confidence interval; SD = standard deviation.

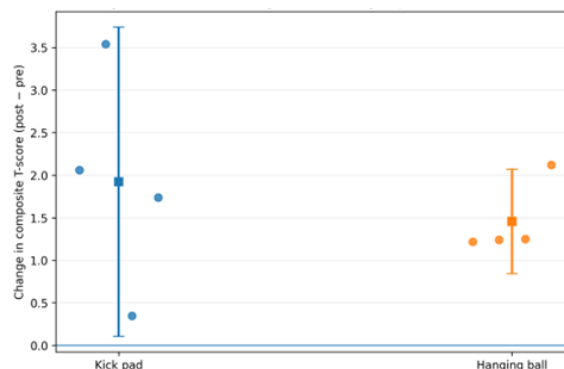


Figure 2. Individual change scores (post-test minus pre-test) with group means and 95% confidence intervals. Draft figure based on the current research-ready working dataset; verify against original field records before submission.

Trial-Level Performance and Composite Score Calculation

The trial-level dataset consisted of 320 observations, corresponding to eight athletes, two assessment occasions, and 20 service trials per assessment occasion. For each trial, service accuracy was represented by the zone score, while service speed was represented by ball travel time. The composite performance score was calculated from the standardized accuracy and speed components. The zone T-score was calculated as: $T_{zone} = 50 + 10 \left(\frac{x-10}{2} \right)$ where 10 represented the predefined zone-score reference mean and 2 represented the predefined zone-score reference standard deviation. The speed T-score was calculated as: $T_{speed} = 50 + 10 \left(\frac{0.8-x}{0.1} \right)$ where 0.8 s represented the predefined reference mean travel time and 0.1 s represented the predefined reference standard deviation. The composite T-score for each trial was calculated as the arithmetic mean of the zone and speed T-scores. The participant-level outcome used in the inferential analyses was the mean composite T-score across the 20 trials at each assessment occasion. Recalculation of the composite scores from the trial-level data reproduced the participant-level pre-test and post-test scores reported in Table 1 to two decimal places. The predefined reference parameters and scoring formulas are reported explicitly because the composite accuracy-speed index is central to the primary outcome.

Table 4. Trial-Level Structure and Composite Performance Scoring

Component	Calculation	Interpretation
Zone T-score	$50 + 10[(\text{Zone} - 10)/2]$	Higher score = better accuracy
Speed T-score	$50 + 10[(0.8 - \text{Travel time})/0.1]$	Higher score = faster service
Composite	(Zone T-score + Speed T-score)/2	Higher score = better

DISCUSSION

Principal Findings

This study investigated whether kick-pad and hanging-ball training produced different changes in composite overhead-service performance among adolescent male sepak takraw athletes. The principal finding was that both interventions produced positive individual changes, but the statistical evidence did not support a differential training effect between the two methods. The kick-pad group increased by 1.92 ± 1.31 T-score points, whereas the hanging-ball group increased by 1.46 ± 0.44 points. The within-group analysis showed that the change in the kick-pad group did not reach the prespecified two-sided significance threshold, $t(3) = 2.94, p = .061$, 95% CI $[-0.16, 4.01]$, although the standardized paired effect was large ($d_z = 1.47$). In contrast, the hanging-ball group demonstrated a statistically significant pre-to-post improvement, $t(3) = 6.60, p = .007$, 95% CI $[0.75, 2.16]$, $d_z = 3.30$. Despite these observed within-group improvements, the lack of significant differences between the intervention groups suggests that both modalities may facilitate comparable longitudinal adaptations in service mechanics (Buszard et al., 2017, p. 1939; Liu et al., 2026, p. 8). These results align with previous experimental evidence highlighting the efficacy of hanging-ball interventions in enhancing volleyball service mechanics, where significant improvements in skill acquisition have been documented among adolescent athletes (Perdana, 2026; Ünver et al., 2025, p. 450).

The most important comparative finding, however, was that the difference in change scores between groups was not

T-score Participant score	Speed T-score)/2 Mean of 20 trial composite scores	overall performance Primary outcome at each time point
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Note. The predefined reference parameters used in the present study were zone-score mean = 10, zone-score SD = 2, travel-time mean = 0.8 s, and travel-time SD = 0.1 s.

Summary of Statistical Findings

The statistical findings are summarized in Table 5. The kick-pad group demonstrated a positive change in overhead service performance, but the change did not reach statistical significance under the two-sided $\alpha = .05$ criterion. In contrast, the hanging-ball group demonstrated a statistically significant within-group increase. Nevertheless, the direct comparison of change scores showed no statistically significant difference between the two training methods.

Table 5. Summary of Inferential Statistical Results

Analysis	Result	Interpretation
Kick pad: pre-test vs. post-test	$t(3) = 2.94, p = .061$	No statistically significant change
Hanging ball: pre-test vs. post-test	$t(3) = 6.60, p = .007$	Statistically significant increase
Change score: kick pad vs. hanging ball	$t(6) = 0.67, p = .526$	No statistically significant between-group difference

Note. All inferential tests were two-sided with $\alpha = .05$.

Overall, the findings indicate that performance scores increased following both training interventions; however, the statistical evidence for within-group improvement was stronger for the hanging-ball group. The absence of a statistically significant between-group difference indicates that the present dataset does not provide evidence of a differential change between the two training methods. Given the very small sample size of four athletes per group, these estimates should be interpreted cautiously.

statistically significant, $t(6) = 0.67, p = .526$, 95% CI $[-1.23, 2.16]$, with Hedges' $g \approx 0.41$. Thus, H1 was not statistically supported, H2 was supported by the within-group analysis, and H3 was not supported. The distinction between within-group and between-group inference is critical. A statistically significant improvement in one group and a non-significant improvement in another do not, by themselves, establish that the interventions differ. The appropriate evidence for the comparative question is the direct analysis of change scores, which did not identify a statistically significant difference. Furthermore, while these results are constrained by a limited cohort, they underscore the necessity for future research to employ larger sample sizes to clarify the nuances of motor skill acquisition in sepak takraw (Ulfa et al., 2024). This outcome suggests that while specialized media such as hanging balls effectively refine fundamental techniques, alternative paired practice models may offer additional benefits for developing competitive-ready motor patterns in similar sports contexts (Yudanto et al., 2022, p. 490). Indeed, integrating diverse pedagogical tools—such as professional athlete-led online instruction—may further optimize technical skill development in digital sports environments, where comparative efficacy across methods remains a significant area of investigation (Zulkifli et al., 2026).

The findings should also be distinguished from practical importance. The positive mean changes and relatively large standardized within-group effects indicate that the observed improvements may have practical relevance for skill

development, but the small sample produces considerable uncertainty around those estimates. In particular, the 95% confidence interval for the kick-pad mean change crosses zero, whereas the interval for the hanging-ball group remains above zero. Therefore, the present data provide stronger statistical evidence for improvement under the hanging-ball condition, but they do not establish that hanging-ball training is more effective than kick-pad training. The observed Hedges' g of approximately 0.41 suggests a potentially meaningful standardized difference, but the sample is too small to provide a precise estimate of comparative effectiveness. Future investigations should therefore prioritize larger randomized samples and extended intervention durations to enhance the precision of these effect size estimates (Azani et al., 2025; Espoz-Lazo et al., 2025, p. 1673430). Furthermore, future studies should consider longitudinal designs to evaluate the long-term sustainability of these motor adaptations, as sustained interventions are essential for determining the cumulative benefits of specific exercise programs (Cahyono et al., 2024, p. 118).

Comparison with International Evidence

The present findings are broadly consistent with previous sepak takraw research showing that structured, task-specific training can improve service-related performance, although the magnitude and statistical certainty of effects vary according to population, intervention, and measurement. Male et al. (2024), for example, directly compared kick-pad and modified hanging-ball training among 10 high-school sepak takraw students in Indonesia. Both groups improved upper-service accuracy, while the reported percentage improvement favored the kick-pad condition. Their findings are therefore compatible with the positive direction observed in the present kick-pad group, but they differ in the comparative interpretation because the current study did not detect a statistically significant between-group difference. The discrepancy may partly reflect the outcome measure: Male et al. focused primarily on service accuracy, whereas the present study combined target-zone performance and ball travel time into a composite T-score. Additionally, the lack of assessment regarding biological maturity and total ground contacts across sessions remains a notable constraint that may have influenced individual responsiveness to the training stimuli (Naji & Hussein, 2026, p. 1089).

Research from other Indonesian athlete populations also supports the general responsiveness of sepak takraw service performance to targeted practice. Irawady et al. (2024) reported improvement following hanging-ball training among PPLP Riau athletes. Similarly, research examining eye-foot coordination and learning methods has shown that service outcomes can vary according to both the training method and individual coordination characteristics (Wiyaka et al., 2018). These findings suggest that the effectiveness of a service intervention may not depend solely on the training aid itself but also on athlete characteristics and the way the practice environment is organized. Beyond the immediate influence of training aids, methodological rigor in future studies must account for external variables such as nutritional status, sleep quality, and biological maturation to ensure a comprehensive understanding of performance outcomes (Hu et al., 2025, p. 1678876).

Evidence from biomechanical research further supports the importance of task-specific coordination. Studies of sepak takraw service mechanics have emphasized the contribution of coordinated lower-limb movement, body positioning, and ball-

contact characteristics to successful service execution. Recent kinematic work reports that coordination among the preparatory movement, leg swing, and ball-contact phase is closely associated with service speed and accuracy (Maquirriain et al., 2016, p. 846; Wood et al., 2023). This provides a plausible explanation for why both training tools could generate improvement: both require repeated execution of the fundamental overhead-service movement rather than isolated conditioning of a single physical component.

The present findings also need to be interpreted against the broader international motor-learning literature. Research from North America and Europe has traditionally suggested that directing attention toward the external effect of a movement can facilitate motor performance and learning. Wulf and Lewthwaite's OPTIMAL theory provides a theoretical framework for this proposition, emphasizing external focus, autonomy, and enhanced expectancies as potentially important learning conditions. However, more recent evidence has challenged the assumption that external-focus strategies produce uniformly large benefits. McKay et al. (2024), using a robust Bayesian meta-analysis, reported evidence of publication bias and found that corrected average effects of external focus were small to negligible, with substantial heterogeneity between studies.

This more cautious international evidence is relevant to the present study. The hanging-ball intervention provided a stable external target, while the kick-pad intervention permitted the coach to manipulate target position and orientation (Peek et al., 2023, p. 1347; Wulf et al., 2010, p. 192). If the external target itself were sufficient to generate a consistently superior learning effect, a clearer between-group difference might have been expected. Instead, the two interventions produced relatively similar mean changes. The result therefore suggests that the mere presence of an external target may not be sufficient to determine intervention effectiveness; task difficulty, athlete experience, feedback, practice organization, and implementation fidelity may also contribute.

Similarly, research on contextual interference indicates that more variable practice can improve retention under some conditions, but its effects are strongly dependent on age and practice context. A 2024 systematic review and meta-analysis involving 54 studies and 2,068 participants found a medium pooled benefit of high contextual interference overall, but the benefit was much less convincing in applied settings and negligible among young participants (Czyż et al., 2024, p. 16014; Mazzardo, 2004). This provides an important explanation for why theoretical expectations concerning variable or stable practice should not be directly translated into claims about superiority in adolescent sport training.

Differences between the current study and previous investigations may therefore arise from several methodological factors. The present study involved only eight adolescent athletes, whereas other studies have included school students, university students, regional athletes, or larger experimental samples. Training dose has also varied: the current intervention comprised 18 sessions over six weeks, while previous studies have used different numbers of sessions and durations. Outcome measurement is another important source of heterogeneity. Accuracy-only tests may respond differently from composite outcomes incorporating both accuracy and travel time (Nair et al., 2016, p. 26; Wais et al., 2021, p. 2563). Finally, previous studies have frequently relied on p -values

without confidence intervals or standardized effect sizes, making cross-study comparison difficult.

Theoretical, Methodological, and Practical Implications

Theoretically, the findings refine rather than simply confirm motor-learning explanations based on target stability and variability. The significant improvement observed in the hanging-ball group is compatible with the proposition that a stable, repeatable target can facilitate acquisition of a complex movement pattern (Ranganathan & Newell, 2010). However, the absence of a statistically significant difference between interventions indicates that stable-target practice should not be interpreted as inherently superior to adjustable-target practice. Recent international evidence emphasizing contextual heterogeneity supports this more cautious interpretation (Czyż et al., 2024; McKay et al., 2024).

Methodologically, the study contributes by evaluating change scores rather than relying solely on post-test differences. This is important because the participants were matched according to baseline performance, and the research question concerned improvement over time. Reporting exact two-sided p -values, 95% confidence intervals, and effect sizes also provides more information than comparison with critical t -values alone. The composite outcome further attempts to represent two dimensions of service performance—spatial accuracy and temporal execution.

The measurement strategy should nevertheless be regarded as a study-specific operationalization rather than a fully validated multidimensional instrument. Irawan et al. (2021) reported evidence supporting a structured top-service accuracy test, but this evidence should not automatically be generalized to the composite accuracy–travel-time T-score used here. Future validation should determine whether the composite score demonstrates adequate reliability, construct validity, sensitivity to change, and association with actual competitive performance.

Practically, the findings suggest that coaches can use either target-based method within a systematic service-training program, but the current evidence does not justify prescribing one method as universally superior. Hanging-ball practice may be useful when coaches want a stable and repeatable target, particularly during technical acquisition. Kick-pad training may provide greater flexibility for manipulating target height, orientation, and location (Broadbent et al., 2014, p. 330; Wąsik et al., 2021, p. 123). A reasonable practical implication is therefore to select the training aid according to the athlete's current technical needs, available coaching resources, and desired practice conditions rather than assuming that one tool will produce consistently greater improvement.

These implications should remain population-specific. The participants were adolescent male athletes from one training environment, and the results should not automatically be generalized to elite international athletes, female athletes, younger children, or athletes from different coaching systems.

Strengths and Limitations

Several strengths improve the interpretability of the study. First, participants were allocated using matching based on pre-test performance, reducing obvious baseline imbalance despite the absence of randomization. Second, both groups completed the same overall intervention duration—18 sessions over six weeks—and trained within the same environment, reducing some environmental and coaching variation. Third, performance was based on 20 service trials at each

assessment point rather than a single attempt, reducing the influence of one unusually successful or unsuccessful service. Fourth, the analysis reports exact p -values, confidence intervals, and effect sizes, allowing both statistical and practical interpretation. However, the methodological limitations are substantial. The first is the very small sample size ($n = 8$; four athletes per group), which limits statistical power and produces imprecise effect estimates. The non-significant kick-pad result ($p = .061$) and the between-group result ($p = .526$) should therefore not be interpreted as evidence that no effect exists. Rather, the study provides insufficient precision to establish a differential effect with confidence. Second, the pre-experimental design did not include a no-training control group. Consequently, maturation, repeated testing, concurrent practice, regression to the mean, and other temporal factors cannot be completely excluded as explanations for the observed improvements. Third, allocation was not fully randomized, although matching was used to improve baseline comparability. Selection bias therefore remains possible. Fourth, blinding was not feasible for the athletes or coaches because the interventions involved visibly different training tools. This creates potential performance and observer bias, particularly because the intervention and training environment were known to participants and personnel. Blinding of outcome assessment would be preferable in future studies, especially for measurements involving manual scoring or timing. Fifth, there was no delayed follow-up assessment. The study therefore evaluates short-term pre-to-post change rather than durable motor learning. This distinction is important because improved immediate performance does not necessarily indicate long-term retention or transfer. International evidence on practice organization demonstrates that retention effects can differ from acquisition effects and can depend strongly on age and ecological setting (Czyż et al., 2024). Sixth, the study involved multiple inferential questions. Although the analyses were predefined around two within-group comparisons and one between-group comparison, no multiplicity adjustment was applied. Therefore, the p -values should be interpreted within the stated hypothesis-testing framework rather than as confirmatory evidence across a large family of independent tests. Seventh, potential confounders such as lower-limb power, flexibility, eye-foot coordination, training history, and biomechanical characteristics were not measured as mediators or moderators. Their absence limits mechanistic interpretation. Finally, the composite score assumes equal contribution of standardized accuracy and travel-time components. This provides a transparent operational definition but does not establish that the two dimensions have equal importance in competitive performance.

These limitations were partly mitigated through matched allocation, standardized training duration, repeated trials, consistent testing procedures, and transparent statistical reporting. Nevertheless, they require cautious interpretation and restrict transferability beyond the studied population.

Future Research

Future research should move beyond small single-club pre-test/post-test studies toward adequately powered comparative trials. A multicenter randomized controlled trial involving adolescent athletes from several sepak takraw regions in Indonesia, Thailand, Malaysia, and the Philippines would provide stronger evidence regarding whether the observed findings are transferable across different coaching cultures and

athlete-development systems. Stratification by sex, age, competitive level, and baseline service ability would also allow potential moderators of intervention response to be examined.

Future studies should include at least three conditions: kick-pad training, hanging-ball training, and a control or conventional-training condition. An intervention period of 8–12 weeks, followed by retention assessments at approximately 4 and 12 weeks, would help distinguish temporary performance improvements from durable motor learning. Randomization and concealed allocation should be used where feasible, while blinded outcome assessment should be implemented for manually scored variables.

Mechanistic studies should measure potential mediators such as lower-limb explosive power, hip flexibility, eye-foot coordination, ankle and knee kinematics, ball velocity, contact height, movement variability, and attentional focus. Mediation analysis could then test whether changes in these variables explain improvements in composite service performance. Moderation analyses could examine whether baseline coordination, technical experience, sex, age, or competitive level changes the response to kick-pad or hanging-ball practice.

The measurement system should also undergo formal

psychometric validation. Future work should establish test–retest reliability, construct validity, criterion validity against competition performance, minimal detectable change, and responsiveness to intervention. Because the current composite score equally weights standardized accuracy and travel time, alternative weighting models could be tested against expert ratings and actual match outcomes.

Finally, implementation studies should examine the cost, coach time, equipment requirements, adherence, and feasibility of each training method. Cost-effectiveness analysis would be particularly valuable for youth clubs and development programs with limited equipment and coaching resources. Replication by independent research groups using preregistered protocols, larger samples, transparent data reporting, and standardized intervention-fidelity checks would further strengthen the evidence base.

Overall, the next stage of research should focus not simply on asking whether kick-pad or hanging-ball training “works,” but on determining for whom, under what training conditions, for how long, through which mechanisms, and with what degree of transfer to competitive service performance each approach is most useful.

CONCLUSION

This study examined changes in overhead-service performance following six weeks of kick-pad and hanging-ball training among adolescent male sepak takraw athletes. Both groups showed positive changes in the composite overhead-service performance score; however, the within-group improvement reached statistical significance only in the hanging-ball group, while the kick-pad group showed a positive but statistically non-significant change. The difference in improvement between the two training groups was not statistically significant. Therefore, the findings do not establish that either training method is superior to the other. Rather, they provide preliminary evidence that structured overhead-service practice using either a kick pad or a hanging ball can be associated with improved service-performance outcomes, with the observed evidence differing between the two training conditions.

DECLARATION

Ethical Approval

The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Faculty of Sport Science, Universitas Negeri Medan, Indonesia, prior to data collection. The study procedures were conducted under appropriate supervision, and participant confidentiality and the right to withdraw from participation were maintained throughout the study. The ethical approval number should be added if available: Ethics Approval No.: FIKK-Re-3121, dated 20 January 2026.

Consent to Participate

Written informed consent was obtained from all participants before participation in the study. Because the participants were adolescents, written informed consent was also obtained from their parents or legal guardians. Participants and their guardians were informed about the study procedures, potential risks and benefits, confidentiality, and their right to withdraw from the study without penalty.

The main contribution of this study is its application of a predefined composite performance measure combining service accuracy and travel-time performance within an adolescent sepak takraw training context. This extends the limited empirical literature on training-aid-based overhead-service practice and provides a context-specific contribution to international motor-learning and sport-training research. Nevertheless, interpretation should remain cautious because the study involved only eight athletes, used non-randomized group allocation, lacked a non-training control group and follow-up assessment, and was conducted within a single training setting. Consequently, the findings should not be generalized to other age groups, competitive levels, populations, or national contexts without replication in larger, randomized, multicenter studies.

Consent for Publication

Consent for publication was obtained from the participants and their parents or legal guardians where applicable. No personally identifiable information, photographs, or individual information that could reasonably identify a participant is presented in this article.

Author Contributions (CRediT)

Jp Kumala: Conceptualization, Methodology, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing.

Mahmuddin: Methodology, Investigation, Supervision, Writing Review & Editing.

Haris Kurniawan: Data Curation, Formal Analysis, Writing Review & Editing.

Malena Bracken: Validation, Supervision, Writing – Review & Editing.

All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the

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Conflict of Interest

The authors declare that they have no competing interests or conflicts of interest that could have influenced the design, conduct, analysis, interpretation, or reporting of this study.

Data Availability

The participant-level and trial-level data underlying the reported analyses are not yet released as a verified public dataset. The currently available research-ready workbook contains 320 trial-level rows and reproduces the manuscript's summary statistics, but its README states that the rows originated from a simulated reconstruction and require verification against original field sheets, observation forms, timing records, or instrument records. Accordingly, the workbook must not be treated as the definitive observed dataset until its provenance is confirmed. After verification, de-identified data may be made

available from the corresponding author upon reasonable request, subject to applicable ethical, privacy, and institutional restrictions.

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During the preparation of this manuscript, generative artificial intelligence tools may have been used for language editing, grammatical improvement, structural refinement, and manuscript formatting. Such tools were not used as a substitute for the authors' scientific judgment, data analysis, interpretation of results, or responsibility for the accuracy and integrity of the research. The authors reviewed and verified the final manuscript and take full responsibility for its content.

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