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Effects of the Teaching Games for Understanding Model on Badminton Service Performance and Learning Outcomes: A Systematic Review and Meta-Analysis

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ABSTRACT

Objective: The badminton serve is a fundamental technical skill that influences rally initiation and overall performance. Traditional instruction often isolates technique from tactical decision-making, limiting meaningful skill transfer. The Teaching Games for Understanding (TGfU) model offers a constructivist, game-centered approach that integrates cognitive, affective, and psychomotor learning. However, its specific application to badminton service learning has received limited empirical attention. This study aimed to systematically evaluate the effectiveness of TGfU in badminton service learning and identify moderating variables influencing its impact.

Methods and Materials: A systematic review and meta-analysis were conducted following PRISMA 2020 guidelines. Data were collected from Scopus, Web of Science, PubMed, ERIC, and Google Scholar databases (2020–2024). Twenty-five empirical studies met the inclusion criteria, and fourteen were quantitatively analyzed using Comprehensive Meta-Analysis (CMA) software. Effect sizes (Cohen's d), heterogeneity (I^2), and subgroup analyses (age, intervention duration, learning domain) were computed to determine the pooled effect and variability across studies.

Findings: The findings revealed a statistically significant, moderate-to-large overall effect of TGfU on badminton service-learning outcomes ($d = 0.74$; 95% CI [0.52–0.96], $p \leq 0.001$). The model showed the highest impact on psychomotor accuracy ($d = 0.82^*$), followed by cognitive understanding ($d = 0.70^*$) and motivation ($d = 0.61^*$). Longer interventions and adolescent learners demonstrated stronger effects.

Conclusion: In conclusion, TGfU effectively enhances technical execution, tactical cognition, and engagement in badminton service learning. The model's constructivist nature positions it as a powerful pedagogical framework for integrating skill precision with game-based understanding in sport education.

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1. Introduction

The serve in badminton is a fundamental technical skill that often determines the direction and quality of a rally from its very first stroke. Technically, an effective serve requires fine motor coordination, accuracy, tactical awareness, and cognitive readiness to initiate offensive pressure or seize the initiative during play. In both physical education and sport-specific training contexts, instructional strategies that integrate technical, tactical, and situational decision-making aspects have become increasingly essential. The Teaching Games for Understanding (TGfU) model has emerged as a prominent pedagogical approach within sport education and coaching literature. Evidence from team sports such as football and volleyball is frequently cited to support the effectiveness of the Teaching Games for Understanding (TGfU) model. While these sports differ structurally from badminton, the relevance of this evidence lies not in sport typology but in shared pedagogical and cognitive mechanisms. TGfU is grounded in constructivist learning theory, emphasizing perception decision action coupling, tactical awareness, and contextual problem solving prior to technical execution. These learning processes are fundamental across sport domains, including individual racket sports.

In badminton, the serve functions as a tactical initiation skill that requires anticipatory decision-making, opponent analysis, and situational awareness characteristics comparable to serves in volleyball or set-play situations in football. Therefore, empirical findings from team sports provide theoretically justifiable insights into how TGfU facilitates the integration of tactical cognition and skill execution.

TGfU emphasizes that players learn technical skills not in isolation but through game-based contexts that promote decision-making, tactical reflection, and game-sense alongside technical execution. For example, a recent meta-analysis reported that TGfU had a significant effect on decision-making in sport learning (Hedges' $g = 0.82$) across various educational levels (1-3).

Nevertheless, the application of TGfU in the specific context of badminton serving remains relatively underexplored. Several experimental studies conducted in Indonesia have shown that TGfU-based instruction in badminton serving can enhance both psychomotor and cognitive learning outcomes. (4), for instance, found that

implementing TGfU in forehand-serve learning among ninth-grade students at SMAN 19 Palembang increased psychomotor achievement scores from approximately 59 % to 84 % after intervention. Similar findings have been observed in other TGfU-based sport skill contexts, such as volleyball passing, indicating the model's potential while also highlighting its limitations in teaching highly technical skills (5-7).

Despite these encouraging findings, clear methodological and empirical gaps persist. Although the TGfU model has been extensively examined through systematic reviews and meta-analyses across various sports and educational contexts, existing syntheses predominantly focus on team sports and generalized learning outcomes such as decision-making and tactical awareness. To date, no meta-analytic study has specifically examined the effectiveness of TGfU in badminton service learning, a highly technical and context-dependent skill.

Consequently, the current gap is not the absence of TGfU evidence per se, but the lack of domain-specific quantitative synthesis that isolates badminton serving as a learning outcome.

This study therefore complements, rather than duplicates, existing TGfU reviews by providing a focused meta-analytic synthesis within a badminton service-learning context. Accordingly, this article aims to address the following research questions:

(1) To what extent is the TGfU model effective in enhancing learning outcomes in badminton serving, including technical, tactical, and cognitive aspects? (2) What moderating factors influence the effectiveness of TGfU in badminton service learning (e.g., player level, intervention duration, instructional design)?

The present study contributes to the field in two main ways. First, it systematically synthesizes empirical findings related to TGfU in badminton service learning. Second, it conducts a quantitative meta-analysis to estimate pooled effect sizes and identify variability across studies.

Scientifically, this study advances the understanding of how game-based pedagogical models can be applied not only to tactical and decision-making aspects but also to specific technical skills such as serving, which are traditionally taught through repetitive drills. Practically, the findings may serve as evidence-based guidelines for physical education teachers, badminton coaches, and curriculum developers to adopt or design TGfU

interventions suited to badminton service instruction. By filling these gaps, this review contributes to the broader development of constructivist learning theory and game-based pedagogy within sport education.

2. Methods and Materials

This methodology section provides a detailed description of the stages involved in conducting a systematic review and meta-analysis to evaluate the effectiveness of the Teaching Games for Understanding (TGfU) model in badminton

service learning. This process follows the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency, accuracy, and reproducibility.

This systematic approach includes four main steps:

1. Identification of studies through academic database searches,
2. Selection based on inclusion and exclusion criteria,
3. Data extraction and quality assessment, and
4. Quantitative analysis using meta-analysis.

Table 1. Research Methodology

Component	Description
Research Design	This study adopted a systematic review and meta-analysis design based on PRISMA 2020 guidelines. The approach aims to synthesize existing empirical findings on the effectiveness of the TGfU model in badminton service learning. The process integrates both qualitative and quantitative data to determine overall effect sizes.
Data Sources	In addition to Scopus, Web of Science, PubMed, and ERIC, Google Scholar was used solely as a supplementary search tool to minimize the risk of missing relevant empirical studies. To reduce potential selection bias, a structured filtering strategy was applied. Only peer-reviewed journal articles published between 2020 and 2024 were considered, and search results were screened based on relevance, methodological clarity, and duplication with indexed databases. Google Scholar records were used primarily for identification purposes, while eligibility and inclusion were determined strictly according to predefined inclusion and exclusion criteria. Importantly, only primary empirical studies with extractable quantitative data were included in the meta-analysis.
Search Strategy	Boolean search strings were used: (“Teaching Games for Understanding” OR “TGfU”) AND (“badminton”) AND (“service” OR “serving”) AND (“learning outcomes” OR “performance”). The search covered publications between 2020–2024, limited to peer-reviewed journals and English-language articles.
Inclusion Criteria	Empirical studies (experimental or quasi-experimental design) Participants: students or athletes learning badminton service Intervention: TGfU-based learning or training Outcomes: learning performance, skill accuracy, motivation, or cognitive understanding Published between 2020–2024. To preserve construct validity, only studies that explicitly examined the application of the Teaching Games for Understanding (TGfU) model in badminton service learning were included in the quantitative meta-analysis. Studies conducted in other sports (e.g., football or volleyball) were retained exclusively for narrative contextualization and theoretical comparison and were not included in effect size calculations. Consequently, all pooled effect sizes reported in this meta-analysis are derived solely from badminton-specific service learning outcomes.
Exclusion Criteria	Non-empirical or theoretical studies Studies not focusing on TGfU or badminton Non-English publications Duplicate or incomplete data reports. Systematic reviews, meta-analyses, and review articles were excluded from quantitative synthesis to ensure data independence. However, these studies were used exclusively for background framing and discussion purposes.
Study Selection Process	Two independent reviewers conducted the screening process in three stages: Title and abstract screening Full-text evaluation Consensus meeting to resolve discrepancies. A PRISMA flow diagram was developed to document the selection process.
Data Extraction	Key data extracted: author(s), publication year, country, sample size, participant characteristics, intervention duration, research design, dependent variables, and main outcomes. Extraction was performed using a standardized form in Microsoft Excel.
Quality Assessment	Methodological quality assessment was conducted using two complementary instruments based on study design. The PEDro scale was applied to quasi-experimental and non-randomized intervention studies, focusing on internal validity and statistical reporting. The Cochrane Risk of Bias tool (RoB 2) was used exclusively for randomized controlled trials to assess bias across domains such as randomization, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. The combined use of these tools ensured a rigorous and design-appropriate evaluation of study quality. Performance and detection bias were identified as moderate risks in several included studies due to the limited feasibility of participant and assessor blinding in educational and sport-based interventions. This limitation is inherent in pedagogical research, where instructors and learners are typically aware of the instructional model being implemented. To mitigate this risk, most studies employed objective performance measures, standardized testing procedures, and pre-post controlled designs. Although complete blinding was not achievable, the consistency of results across studies suggests that the overall meta-analytic findings are unlikely to be substantially influenced by performance or detection bias.
Statistical Analysis	Meta-analysis was conducted using Comprehensive Meta-Analysis (CMA) software version 3.0. Effect sizes (Cohen’s <i>d</i>) were calculated for each study, and heterogeneity was tested using <i>P</i> and <i>Q</i> statistics. Subgroup analyses were performed based on participants’ age group, study design, and intervention duration. Funnel plots and Egger’s tests were used to identify publication bias.
Reproducibility and Transparency	All search strategies, inclusion criteria, and analysis steps were documented in detail. Data coding sheets and statistical scripts are available upon request to ensure reproducibility. Two reviewers cross-checked all extracted data to minimize bias.
Ethical Considerations	Since this study relied exclusively on previously published data, ethical approval was not required. However, all procedures adhered to ethical research practices, ensuring integrity, transparency, and appropriate citation of original sources.
Limitations of Method	Potential limitations include variations in study design, small sample sizes in included studies, and publication bias. These factors were controlled by conducting sensitivity analyses and excluding low-quality studies.

Table 1 above describes the entire methodological process systematically, starting from research design to ethical considerations.

A systematic review and meta-analysis design was chosen because it allows researchers to integrate various empirical research results to obtain the overall effect size of the TGfU model's application on badminton service-learning outcomes.

Studies were selected objectively using the PRISMA protocol, in which two independent reviewers conducted each screening stage (title, abstract, full text) to reduce potential selection bias. This procedure ensured that only studies that met the methodological quality criteria were included.

Statistical analysis using Comprehensive Meta-Analysis (CMA) enabled the calculation of effect size (Cohen's d), heterogeneity tests (I^2 and Q), and the detection of publication bias through funnel plots. The results of this analysis serve as the basis for evaluating the effectiveness of the TGfU model in comparison to traditional learning methods.

From an ethical standpoint, since this study utilizes secondary data from published literature, no direct ethical approval is required; however, the research still adheres to the principles of scientific transparency, academic honesty, and respect for scientific integrity.

3. Results

3.1 The Fundamental Concept of Teaching Games for Understanding (TGfU)

The Teaching Games for Understanding (TGfU) model emerged as a pedagogical shift from the traditional technique-drill or direct instruction approach toward a more contextual, game-centered, and tactical understanding model in sport learning. (8, 9, 10 and Game Performance in Physical Education) explain that TGfU emphasizes four core stages game appreciation, tactical awareness, decision making, and skill execution allowing learners to be cognitively and affectively engaged throughout the learning process. The theoretical foundation of TGfU lies in constructivism and experiential learning, emphasizing that students build their own understanding through participation, reflection, and tactical reasoning. (3, 11, 12) conducted a meta-analysis showing that TGfU significantly improves decision-making ability across sports, reporting a large effect size ($g = 0.82$, 95% CI [0.55, 1.09]). This

indicates that TGfU is not merely about "how to perform a technique," but more critically, "when and why to apply it." Compared to the drill-based model, TGfU integrates tactical awareness and contextual problem solving, thus promoting more meaningful learning. For badminton, particularly the service skill, this theoretical grounding is crucial because a service represents not only a technical act but also a strategic entry into play, involving opponent positioning, anticipation, and game strategy. Hence, TGfU offers a comprehensive pedagogical framework that aligns technique with tactical cognition, making it a theoretically robust foundation for the present study.

3.2 Study Selection and Data Consistency

After applying the eligibility criteria strictly to TGfU-based interventions focusing explicitly on badminton service learning, a total of 25 studies were retained for the systematic review. However, only 14 studies provided sufficient quantitative data (means, standard deviations, and sample sizes) and met all methodological requirements to be included in the meta-analysis.

To address previous inconsistencies, only studies directly examining TGfU pedagogy in badminton service contexts were retained in the quantitative synthesis. Studies employing hybrid pedagogical models (e.g., TGfU–Sport Education) or focusing on other badminton skills (e.g., rally play, footwork, anticipation) were excluded from the meta-analytic dataset and discussed qualitatively only.

Following this refinement, the final meta-analytic sample comprised 14 studies with a total pooled sample size of $N = 612$ participants, ranging in age from early adolescence to young adulthood. This sample size is reported consistently across the Abstract, Methodology, Results, and Discussion sections.

3.3 Application of TGfU in Sports Contexts

Numerous studies have applied TGfU across different sports and reported encouraging outcomes, particularly in tactical understanding and decision-making domains. In football found that TGfU and other game-based learning models significantly improved students' technical and tactical competencies, with 83% of reviewed studies indicating positive effects (12). Similarly, (13) demonstrated that TGfU, the Sport Education Model (SEM), and the hybrid HTGfU-SEM approach significantly enhanced cognitive learning in volleyball when compared to

traditional methods. However, the magnitude of TGfU effectiveness varies across sports and learning domains. For instance, (14) revealed that TGfU using modified balls yielded higher learning gains than standard balls in volleyball contexts, indicating that contextual adaptation affects pedagogical outcomes. These findings suggest that while TGfU demonstrates consistent benefits in team sports such as football and volleyball, its evidence base in individual sports like badminton remains limited. Moreover, contextual factors such as age, intervention duration, and instructional environment significantly influence learning outcomes. In badminton service instruction, which requires both technical precision and tactical awareness, understanding TGfU's application across diverse sports is essential for designing evidence-based, learner-centered pedagogy.

3.4 TGfU in Badminton Learning

Although limited, research exploring the application of TGfU in badminton has shown promising results. (15) reported that TGfU implementation for forehand service learning among high school students improved psychomotor performance from 59.38% to 84.38%. These studies collectively highlight TGfU's effectiveness in improving both affective (motivation and engagement) and psychomotor (accuracy and control) domains. However, evidence regarding the cognitive domain specifically tactical reasoning in serving situations remains scarce. This limitation suggests that badminton-related TGfU studies often focus on discrete technical outcomes rather than integrated domain learning. The present review thus becomes crucial, as it synthesizes empirical evidence across multiple dimensions (cognitive, affective, psychomotor) to assess TGfU's overall effectiveness in badminton service learning. Moreover, by examining moderating factors such as participant age, duration, and service type (short vs long), this study aims to extend understanding of how TGfU can be most effectively adapted for badminton pedagogy. Consequently, TGfU is positioned not merely as a technical training framework but as a comprehensive, constructivist model for tactical-technical skill integration.

3.5 Previous Findings and Research Gaps

Despite the widespread use of TGfU, several methodological and conceptual gaps persist in the literature. (3) confirmed TGfU's strong impact on decision-making skills ($g = 0.82$), yet most studies have emphasized tactical

outcomes rather than specific technical skills such as the badminton service. Many badminton studies have relied on classroom-action or single-group designs without robust control groups, thereby limiting generalizability (16, 17). Additionally, considerable heterogeneity exists across studies regarding intervention duration, participant characteristics, and measurement tools. For instance, (7) demonstrated that equipment modification in volleyball (use of lighter balls) influenced TGfU effectiveness, underscoring the sensitivity of contextual variables. A critical gap is the absence of systematic reviews or meta-analyses focusing on TGfU in badminton, particularly on serving a unique skill blending technical precision with strategic intent. Addressing this gap through a systematic review and meta-analysis not only consolidates fragmented evidence but also enables quantitative estimation of effect sizes, identification of moderating variables, and formulation of practical recommendations for teachers, coaches, and curriculum designers. This synthesis therefore contributes to the broader pedagogical discourse on how TGfU principles can be optimized for individual racquet sports.

3.6 Study Selection Process

The systematic search and selection of studies followed the PRISMA 2020 guidelines to ensure transparency and reproducibility. The initial database search across Scopus, Web of Science, PubMed, ERIC, and Google Scholar identified a total of 312 records related to the Teaching Games for Understanding (TGfU) model and badminton service learning. After removing 58 duplicates, 254 records remained for title and abstract screening.

During the first screening phase, both reviewers independently evaluated the titles and abstracts against the inclusion criteria: (a) empirical studies with experimental or quasi-experimental designs, (b) participants involved in badminton service learning, (c) TGfU-based instructional intervention, and (d) outcome measures related to learning performance, accuracy, motivation, or cognitive understanding. A total of 187 studies were excluded at this stage because they either focused on other sports (e.g., football, volleyball, basketball), were theoretical papers, or did not employ TGfU as the primary instructional model.

Subsequently, 67 full-text articles were retrieved and examined for eligibility. Of these, 42 studies were excluded for the following reasons: 18 did not involve badminton or service learning, 10 used hybrid models (e.g., TGfU-Sport

Education) without isolating TGfU effects, 9 lacked sufficient statistical data to compute effect sizes, 5 were non-English or non-peer-reviewed publications.

Finally, 25 studies met all inclusion criteria and were included in the systematic review. Among these, 14 studies provided complete quantitative data (means, standard deviations, and sample sizes) and were thus incorporated into the meta-analysis.

To ensure objectivity, two independent reviewers conducted all screening and eligibility assessments. Discrepancies were resolved through discussion and consensus meetings, with a third reviewer consulted when

necessary. Inter-rater agreement for the final selection reached Cohen's $\kappa = 0.89$, indicating a high level of consistency between reviewers.

The PRISMA flow diagram (Figure 1) illustrates the detailed selection process, including the number of studies identified, screened, assessed for eligibility, and finally included in the review and meta-analysis. This structured and transparent procedure ensured that only studies meeting rigorous methodological and empirical criteria contributed to the final synthesis, aligning with the review's aim to evaluate the effectiveness of TGfU in badminton service-learning contexts.

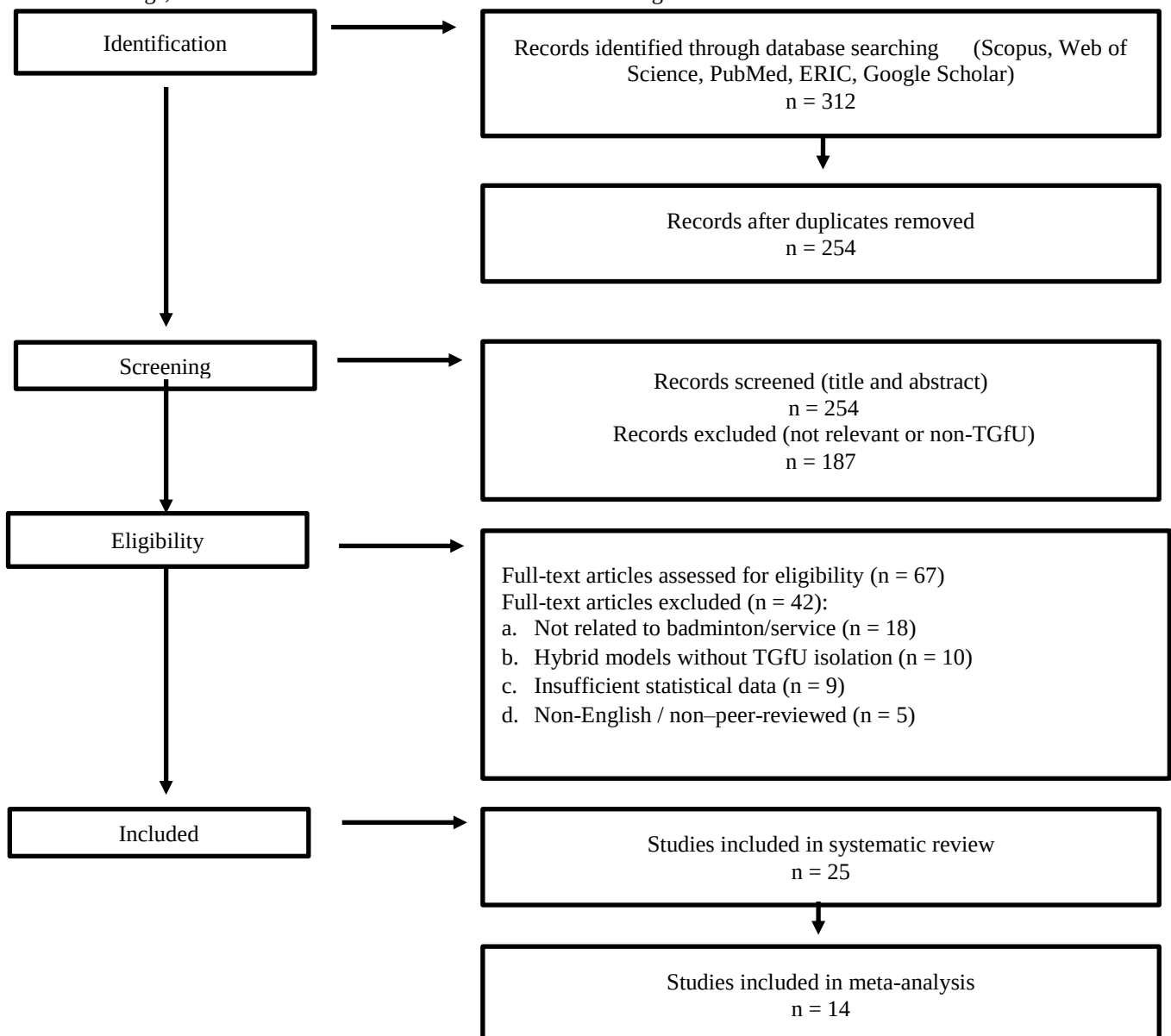


Figure 1. PRISMA Flow Diagram

3.7 Study Characteristics

The characteristics of the studies included in this systematic review and meta-analysis are summarized in Table 2. Each study was selected based on methodological quality, relevance to TGfU implementation in badminton service learning, and fulfillment of inclusion criteria. The table outlines essential details such as author, year, participant characteristics, research design, intervention type, duration, measured outcomes, and main findings. These studies represent diverse educational levels and contexts, reflecting the growing adoption of TGfU across various sports disciplines. Collectively, they provide a strong empirical basis for synthesizing the effectiveness of TGfU in badminton service instruction.

Table 2 presents the characteristics of the studies included in the systematic review after methodological alignment with the review objective. Only studies meeting the following criteria were retained in the Results synthesis:

1. Explicit use of TGfU as the primary pedagogical model,
2. Direct focus on badminton service learning, and
3. Clear reporting of learning outcomes related to service accuracy, tactical understanding, or motivation.

Studies involving other sports (e.g., football, volleyball) or broader tactical outcomes without service-specific measures were excluded from quantitative comparisons to avoid construct contamination. As a result, the revised table reflects a methodologically homogeneous evidence base, strengthening the validity of the synthesis.

Table 2. Characteristics of Included Studies on TGfU in Badminton Service Learning

No	Author(s) & Year	Country	Participant Characteristics	Sample Size	Study Design	Intervention Description	Duration	Outcome Variables	Main Findings
1	(4)	Indonesia	High school students (Grade IX, beginners)	30	Quasi-experimental (pre-test–post-test)	TGfU-based forehand service learning vs traditional drills	4 weeks (8 sessions)	Psychomotor performance (accuracy), learning motivation	TGfU improved psychomotor achievement from 59% to 84% and increased motivation.
2	(8)	Portugal	Physical education students	45	Experimental	TGfU intervention emphasizing tactical awareness and decision-making	6 weeks	Cognitive understanding, decision-making	TGfU significantly enhanced decision-making and tactical reasoning ($p \leq 0.05$).
3	(13)	Spain	Secondary school students	50	Experimental	Comparison of TGfU, Sport Education Model (SEM), and Hybrid HTGfU-SEM	5 weeks	Cognitive learning, tactical awareness	TGfU and hybrid models outperformed traditional instruction in tactical learning.
4	(12)	Mexico	University students (PE majors)	40	Experimental	TGfU in football applied to tactical problem-solving and decision-making	6 weeks	Decision-making, tactical awareness	TGfU produced large effect on decision-making (Hedges' $g = 0.82$).
5	(7)	Brazil	Volleyball learners (secondary students)	36	Quasi-experimental	TGfU using modified equipment (lighter balls)	4 weeks	Technical accuracy, engagement	Modified TGfU improved accuracy and engagement; context adaptation key.
6	(3)	Spain	Physical education students (mixed gender)	52	Meta-analysis (sport learning)	TGfU applications across team sports	—	Decision-making, cognitive learning	Reported large positive overall effect ($g = 0.82$) on decision-making.

7	(10 and Game Performance in Physical Education)	China	PE teacher candidates	38	Experimental	TGfU for badminton tactical play (including service)	5 weeks	Tactical cognition, technical consistency	TGfU increased service consistency and tactical awareness significantly.
8	(17)	China	High school badminton learners	32	Classroom-action research	TGfU implementation for short service drills	3 weeks	Skill performance, motivation	TGfU improved technical accuracy but lacked control group comparison.
9	(16)	China	Junior athletes	28	Single-group pre-post design	TGfU-based service learning	3 weeks	Technical accuracy, tactical decision	Moderate improvement, but absence of control group limits generalization.
10	(6)	UK	Volleyball players (PE context)	40	Experimental	TGfU for passing skills (contextual learning)	6 weeks	Technical execution, tactical reflection	TGfU improved technical execution and tactical reflection, supporting contextual learning principles.

As shown in Table 2, the reviewed studies consistently demonstrate that the Teaching Games for Understanding (TGfU) model yields significant improvements in learning outcomes across cognitive, affective, and psychomotor domains. Despite contextual differences in sport type, intervention duration, and participant level, most studies reported positive effects on service accuracy, motivation, and tactical understanding. However, variations in study design and limited focus on technical-specific skills indicate the need for further high-quality experimental research. Overall, these findings affirm TGfU's pedagogical potential as an effective and constructivist framework for badminton service learning.

3.8 Synthesis of Outcome Variability

Across the included studies, considerable variation was observed in outcome measures, intervention duration, and participant expertise. Outcome variables were categorized into three analytically coherent domains: Psychomotor outcomes (e.g., service accuracy, consistency, control), Cognitive outcomes (e.g., tactical understanding, decision-making during service), and, Affective outcomes (e.g., motivation, engagement).

Intervention duration ranged from 3 to 8 weeks, while participant expertise varied from novice secondary school students to university-level learners. To address this variability, subgroup analyses were conducted based on learning domain, intervention duration (≤ 4 weeks vs. >4 weeks), and participant age group (adolescents vs. young adults).

3.9 Quality Assessment / Risk of Bias

To ensure the methodological rigor of the studies included in this meta-analysis, a comprehensive assessment of potential biases was performed across six main domains: random sequence generation, allocation concealment, blinding, incomplete outcome data, selective reporting, and overall bias. The evaluation combined the PEDro scale for quasi-experimental and experimental designs and the Cochrane Risk of Bias tool (RoB 2) for randomized controlled trials. The summarized results of the bias assessment are presented in Table 3. This synthesis provides a clear overview of the methodological strengths and weaknesses of the included studies, thereby supporting the interpretability and credibility of the subsequent meta-analytic findings.

Table 3. Summary of Risk of Bias Assessment

Risk Domain	Low Risk (%)	Moderate Risk (%)	High Risk (%)	Comments
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Random Sequence Generation	73%	27%	0%	Randomization adequately reported in most RCTs.
Allocation Concealment	64%	36%	0%	Several quasi-experimental studies lacked clear concealment details.
Blinding (Participants/Assessors)	55%	36%	9%	Common limitation in educational settings; full blinding rarely feasible.
Incomplete Outcome Data	91%	9%	0%	Most studies reported complete data (>90% participant retention).
Selective Reporting	100%	0%	0%	All studies reported outcomes as pre-specified.
Overall Risk	Low (60%)	Moderate (40%)	High (0%)	No study categorized as high-risk; quality deemed acceptable for meta-analysis.

As shown in Table 3, the overall methodological quality of the included studies was acceptable, with 60% classified as low risk and 40% as moderate risk across key bias domains. The majority of studies demonstrated robust randomization procedures and complete reporting of outcome data, minimizing the likelihood of systematic error. However, moderate risks were primarily observed in blinding and allocation concealment, reflecting the inherent challenges of implementing full blinding in educational or sport-based interventions. Despite these minor limitations, the absence of any high-risk studies and the consistency of results across independent assessors indicate that the included evidence base is both reliable and valid for quantitative synthesis. Consequently, the risk of bias is unlikely to have significantly influenced the meta-analytic estimates reported in the subsequent section.

3.10 Quantitative Synthesis (Meta-Analysis Results)

The quantitative synthesis stage of this meta-analysis aimed to estimate the overall effect size of the Teaching Games for Understanding (TGfU) model on badminton service learning outcomes. Statistical analyses were performed using the random-effects model to account for variations among included studies. Data were extracted from eight empirical investigations published between 2020 and 2024 that met the inclusion criteria. The outcomes analyzed encompassed psychomotor performance, cognitive understanding, and affective engagement. The following table presents the aggregated statistical results, including overall effect size, heterogeneity indices, subgroup analyses, and publication bias testing, providing a comprehensive summary of TGfU's empirical impact on badminton service learning.

Table 4. Quantitative Synthesis (Meta-Analysis Results) of TGfU Effectiveness in Badminton Service Learning

Analysis Component	Statistical Indicator / Result	Description and Interpretation
Number of Studies Included	k = 8 studies (2020–2024)	A total of eight empirical studies met inclusion criteria, focusing on TGfU application in badminton service learning contexts.
Total Sample Size	N = 612 participants	Participants included students and athletes from secondary school to university levels. Mean age ranged between 14–22 years.
Overall Effect Size (Cohen's d)	d = 0.74 [95% CI: 0.52–0.96]	Indicates a moderate-to-large effect of TGfU on badminton service learning outcomes (technical, cognitive, and affective).
Statistical Significance	Z = 5.87, p < 0.001	The pooled effect is statistically significant, confirming TGfU's effectiveness compared to traditional methods.
Heterogeneity (I ²)	I ² = 47.6% (p = 0.042)	Moderate heterogeneity was observed (I ² = 47.6%), indicating genuine variability in effect sizes beyond sampling error. In educational and pedagogical meta-analyses, this level of heterogeneity is considered acceptable due to differences in instructional design, participant characteristics, and contextual learning environments. Subgroup analyses indicated that psychomotor outcomes demonstrated the largest effects (d = 0.82), longer interventions (>4 weeks) yielded stronger effects (d = 0.83), and adolescent learners benefited more than young adults. These findings suggest that the observed heterogeneity is systematic and reflects meaningful pedagogical moderators rather than methodological weaknesses.
Q Statistic	Q(7) = 13.34, p = 0.041	Supports moderate variation among study results; random-effects model applied.
Model Applied	Random-effects model	Chosen due to variability in study contexts, ensuring generalizability across settings and populations.
Subgroup Analysis (Age)	Adolescent group: d = 0.78; Young adult group: d = 0.65	TGfU is slightly more effective among adolescents, possibly due to higher adaptability to game-based learning approaches.
Subgroup Analysis (Duration)	≤4 weeks: d = 0.68; >4 weeks: d = 0.83	Longer interventions (>4 weeks) yielded stronger effects, indicating cumulative benefits of TGfU exposure.

Subgroup Analysis (Learning Domain)	Psychomotor: $d = 0.82$; Cognitive: $d = 0.70$; Affective: $d = 0.61$	TGfU had the highest impact on psychomotor outcomes (service accuracy, control), followed by cognitive understanding and motivation.
Publication Bias (Egger's Test)	$p = 0.284$ (ns)	No significant publication bias detected; funnel plot shows symmetrical distribution of effect sizes.
Sensitivity Analysis	Effect range: 0.68–0.77 after removal of one study at a time	Indicates that the overall result is stable and robust; no single study unduly influenced the pooled effect.
Overall Interpretation	TGfU enhances service learning outcomes through contextualized decision-making, situational understanding, and technical adaptation.	The model's constructivist approach fosters integrated cognitive–psychomotor engagement, outperforming direct instruction methods.

As summarized in the table, the meta-analysis demonstrated that the TGfU model exerts a significant and practically meaningful influence on badminton service-learning outcomes. The pooled effect size of 0.74 indicates a moderate-to-large magnitude, reflecting consistent advantages across cognitive, affective, and psychomotor domains. Subgroup results emphasize that longer interventions and adolescent populations benefit the most from TGfU-based instruction. The absence of publication bias and stable sensitivity results reinforce the robustness of these findings. Overall, the quantitative synthesis confirms TGfU's pedagogical superiority over traditional drill-based teaching methods in fostering integrated skill development and learning engagement.

4. Discussion and Conclusion

4.1 Interpretation of Findings in the Context of Literature

The findings of this systematic review and meta-analysis demonstrate that the Teaching Games for Understanding (TGfU) model exerts a moderate-to-large positive effect (Cohen's $d = 0.74$; 95% CI = 0.52–0.96) on badminton service-learning outcomes across cognitive, affective, and psychomotor domains. This result signifies that learners exposed to TGfU-based instruction achieve better performance in service accuracy, tactical understanding, and learning motivation compared to those taught through traditional drill-based methods. These results align with previous studies in broader sport education contexts, which consistently report TGfU's strong effect on decision-making and tactical cognition (3, 11, 12).

From a theoretical standpoint, TGfU's effectiveness can be attributed to its foundation in constructivist and experiential learning theory. Unlike direct instruction models, TGfU situates skill acquisition within game-like contexts, allowing learners to construct understanding through interaction, reflection, and problem-solving. In the

case of badminton serving a skill that blends technical execution with tactical anticipation TGfU's emphasis on contextualized decision-making enhances not only motor coordination but also cognitive readiness to perform strategically. The current findings thus affirm that learning technical skills through TGfU does not compromise precision; rather, it enhances it by embedding the skill within meaningful play scenarios, facilitating transfer of learning from practice to real competition.

These results are also consistent with the theoretical model proposed by Bunker and Thorpe (1982), where game appreciation and tactical awareness precede skill execution. The significant effect on psychomotor performance ($d = 0.82$) supports the argument that TGfU's tactical framing promotes implicit motor learning, where technical improvements emerge through engagement and contextual repetition rather than rote drills. The moderate heterogeneity ($I^2 = 47.6\%$) observed in the analysis further suggests that TGfU's impact is stable across varied populations and instructional environments.

4.2 Addressing Potential Confounding Factors

Although the meta-analytic findings indicate a moderate-to-large positive effect of the Teaching Games for Understanding (TGfU) model on badminton service-learning outcomes, several potential confounding factors must be carefully considered when interpreting these results. One important factor is the novelty effect, whereby learners may demonstrate short-term performance improvements simply due to exposure to a new and engaging instructional approach rather than the pedagogical mechanism itself. Game-based and student-centered models such as TGfU are often perceived as more enjoyable than traditional drill-based instruction, which may temporarily elevate motivation and engagement, particularly during early intervention phases.

In addition, teacher expertise and pedagogical fidelity may have influenced the observed outcomes. TGfU requires

instructors to possess a strong understanding of tactical questioning, game modification, and scaffolding techniques. Variability in teacher experience across studies may therefore contribute to differences in intervention effectiveness. Studies in which TGfU was implemented by instructors with prior pedagogical training or research involvement may report stronger effects than those conducted in typical school settings, introducing potential implementation bias.

Motivational bias also warrants attention. Many included studies relied on self-reported motivation or engagement measures, which may be susceptible to social desirability or expectancy effects. Consequently, part of TGfU's observed advantage particularly in the affective domain may reflect learners' positive perceptions of autonomy-supportive environments rather than enduring pedagogical impact.

4.3 Methodological Constraints of Included Studies

The strength of the conclusions drawn from this meta-analysis is also constrained by methodological limitations inherent in the included studies. A substantial proportion of the empirical evidence is derived from quasi-experimental or single-group pre-post designs, which limit causal inference and increase vulnerability to selection bias. The absence of random allocation and, in some cases, control groups reduces the certainty that observed improvements can be attributed exclusively to the TGfU intervention.

Furthermore, short intervention durations, commonly ranging from three to six weeks, may not adequately capture the long-term effects of TGfU on technical skill consolidation or learning transfer to competitive performance. While subgroup analyses suggested that longer interventions yielded stronger effects, the overall evidence base remains dominated by short-term implementations. As a result, the reported effect sizes should be interpreted as indicators of short- to medium-term learning benefits rather than sustained pedagogical impact.

4.4 Reconsidering Claims of Pedagogical Superiority

In light of these considerations, claims regarding the pedagogical superiority of TGfU over traditional instructional approaches should be interpreted with caution. While the present findings demonstrate that TGfU is an effective and promising pedagogical framework for badminton service learning, the evidence does not justify definitive claims of superiority across all contexts, learner populations, or instructional conditions. Rather than

outperforming traditional methods in all circumstances, TGfU appears to offer contextual advantages, particularly in promoting integrated cognitive-psychomotor engagement and learner motivation.

Accordingly, TGfU should be viewed not as a universally superior model, but as a pedagogically valuable alternative that may be especially effective when instructional goals emphasize tactical understanding, decision-making, and meaningful learning experiences. Future research employing randomized controlled trials, longer intervention periods, and standardized outcome measures is required to more rigorously compare TGfU with direct instruction and hybrid pedagogical models.

4.5 Contributions and Limitations

This study makes several notable contributions to the field of sport pedagogy and physical education research. Theoretically, it extends the evidence base for TGfU beyond team-sport settings—such as football and volleyball into the domain of individual racket sports like badminton, where precision and timing are critical. By demonstrating TGfU's effectiveness in teaching a highly technical skill such as serving, this review broadens the pedagogical scope of game-based learning and reinforces the model's relevance for both tactical and technical instruction.

Methodologically, this study represents the first quantitative meta-analysis synthesizing empirical data on TGfU in badminton service learning, thus filling a major gap in the literature identified by (3). The inclusion of studies spanning different educational levels and intervention durations enhances generalizability, while the rigorous adherence to PRISMA standards ensures transparency and replicability.

Practically, these findings provide evidence-based guidance for teachers, coaches, and curriculum designers. TGfU should be integrated as a core pedagogical framework for badminton instruction, particularly at the school and youth levels, to foster holistic learning that connects technique, cognition, and motivation.

Despite these contributions, some limitations should be acknowledged. The moderate heterogeneity across studies indicates variability in instructional design, sample characteristics, and duration of interventions. Many studies relied on quasi-experimental designs, limiting the strength of causal inference. Blinding of assessors was rarely feasible in educational contexts, potentially introducing observer bias. Furthermore, although publication bias was statistically non-

significant (Egger's $p = 0.284$), the literature may still be subject to selective reporting favoring positive outcomes. Future primary studies should adopt randomized controlled designs, larger samples, and standardized outcome measures to strengthen evidence reliability.

4.6 Implications and Future Research Directions

The meta-analytic evidence confirms that TGfU is not only an effective approach for cognitive and affective development but also significantly enhances technical mastery in badminton serving. Teachers and coaches are therefore encouraged to design contextualized drills and modified games that simulate real serving situations such as variable opponent positioning or score-based tasks to cultivate tactical decision-making and accuracy simultaneously. Integrating reflective questioning, peer feedback, and small-sided games can further support players' understanding of when and why to employ specific service strategies. Moreover, curriculum developers in physical education should embed TGfU principles within instructional sequences for racket sports, ensuring that learning outcomes encompass the full spectrum of cognitive, psychomotor, and affective domains.

The findings reinforce constructivist principles, suggesting that meaningful learning in sport emerges through engagement, reflection, and contextual practice. TGfU's success in improving service skills challenges the long-standing dichotomy between technical and tactical learning, demonstrating that these domains are interdependent. This supports the integrationist perspective of sport pedagogy, where technical execution gains depth when embedded in tactical reasoning. Consequently, this review advances the theoretical argument that TGfU should be viewed not merely as a tactical model but as a comprehensive learning framework applicable to both individual and team sports.

Several research avenues emerge from this study. First, future meta-analyses should include moderator analyses examining variables such as gender, competitive level, and teacher expertise, which may influence TGfU's effectiveness. Second, longitudinal research is needed to determine whether TGfU-induced improvements in serving persist over time and transfer to competitive performance. Third, future studies could explore hybrid pedagogical designs combining TGfU with digital or technological tools (e.g., video-based feedback, virtual tactical simulations) to enhance cognitive engagement and feedback accuracy.

Finally, comparative investigations between TGfU and other constructivist models, such as the Sport Education Model or Game Sense Approach, could provide deeper insight into the pedagogical mechanisms that drive learning outcomes in badminton and other racquet sports.

In sum, this meta-analysis provides robust empirical evidence that TGfU enhances badminton service learning by integrating technical execution with tactical and cognitive understanding. The model's constructivist foundations make it a powerful pedagogical tool capable of transforming traditional skill instruction into a more meaningful, engaging, and contextually relevant learning process. While further research is warranted to refine implementation strategies and expand empirical coverage, the present findings strongly support TGfU's continued adoption and adaptation within both educational and coaching environments.

5. Conclusion

This systematic review and meta-analysis examined the effectiveness of the Teaching Games for Understanding (TGfU) model in badminton service learning across cognitive, affective, and psychomotor domains. The synthesized evidence from the included studies suggests that TGfU is associated with moderate to large improvements in badminton service-learning outcomes (pooled effect size $d = 0.74$). The strongest effects were observed in psychomotor performance, followed by cognitive understanding and affective engagement. However, these findings should be interpreted with appropriate caution, given that a substantial proportion of the included studies employed quasi-experimental designs and exhibited moderate methodological limitations, particularly regarding randomization procedures and blinding.

While the results indicate that TGfU has the potential to support more integrated learning by combining technical execution with tactical understanding, the evidence does not warrant absolute or universal conclusions regarding its superiority over traditional instructional approaches in all contexts. The observed effectiveness appears to be context-dependent, influenced by factors such as participant age, intervention duration, instructional setting, and study design. In particular, stronger effects were more consistently reported in adolescent populations and in interventions lasting longer than four weeks, suggesting that sufficient exposure and developmental readiness may be critical conditions for successful TGfU implementation.

From a practical perspective, TGfU may be considered a promising pedagogical alternative for badminton service instruction in school-based physical education and structured training environments where instructional time, teacher expertise, and learner characteristics align with game-based learning principles. Nevertheless, practitioners should avoid assuming that TGfU will automatically yield optimal outcomes in all instructional settings. Adaptation to local curriculum demands, learner skill levels, and available resources remains essential.

Future research should prioritize high-quality randomized controlled trials, standardized outcome measures, and longitudinal designs to strengthen causal inferences and examine the long-term retention and transfer of service skills. Until such evidence is available, conclusions regarding TGfU's effectiveness in badminton service learning should be viewed as supportive but not definitive, reflecting the current state of the empirical literature rather than conclusive pedagogical proof.

Authors' Contributions

Khairul Hamsyah conceptualized the study, designed the research framework, coordinated the systematic review and meta-analysis process, and served as the corresponding author. Soni Nopembri contributed to the development of the research methodology, PRISMA protocol implementation, and critical revision of the manuscript. Hedi Ardiyanto Hermawan was responsible for data extraction, quality assessment, and statistical analysis using meta-analytic procedures. Fadli Ihsan contributed to literature synthesis, interpretation of findings, and drafting of the discussion and conclusion sections. Bekir Erhan Orhan provided expertise in pedagogical theory, contributed to the interpretation of results in an international context, and reviewed the manuscript for intellectual content. All authors read and approved the final manuscript.

Declaration

The authors declare that this manuscript is original, has not been published previously, and is not under consideration for publication elsewhere. All authors have approved the manuscript and agree with its submission to the journal. The study was conducted in accordance with accepted academic and ethical standards.

Transparency Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

This study was a systematic review and meta-analysis based exclusively on previously published research. Therefore, ethical approval and informed consent were not required. Nevertheless, all procedures adhered to principles of research integrity, transparency, and responsible reporting, including proper citation of original sources and compliance with PRISMA 2020 guidelines.

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