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EFFECTIVE TRAINING METHODS FOR IMPROVING THE PERFORMANCE OF TABLE TENNIS ATHLETES: A SYSTEMATIC REVIEW

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ABSTRACT

Purpose of the study: This systematic review aimed to evaluate the effectiveness of various training methods for improving the performance of table tennis athletes and to provide evidence-based recommendations for coaches and practitioners across different competitive levels.
Materials and methods: A comprehensive systematic search was conducted across six major databases (Web of Science, PubMed, Scopus, SPORTDiscus, Google Scholar, and ScienceDirect) from inception to September 2025. Studies were included if they examined training interventions in table tennis players and reported quantitative performance outcomes. The PRISMA 2020 guidelines were strictly followed for reporting. Quality assessment was performed using the Cochrane Risk of Bias tool (RoB 2.0) for randomized controlled trials and ROBINS-I for non-randomized studies. Meta-analysis was conducted using random-effects models with standardized mean differences and 95% confidence intervals.
Results: Fifty-four studies met the inclusion criteria, involving 2,959 participants (mean age: 16.8 ± 4.2 years). High-intensity interval training (HIIT) demonstrated the highest effectiveness (Effect Size = 0.89, 95% CI: 0.75-1.03), followed by plyometric training (ES = 0.82, 95% CI: 0.68-0.96) and multiball training (ES = 0.78, 95% CI: 0.61-0.95). Physical training and core training showed moderate effectiveness (ES = 0.65-0.71), while technical training demonstrated the smallest effect size (ES = 0.58, 95% CI: 0.44-0.72). Fifty-two percent of studies showed low risk of bias, with consistent positive effects across different age groups and skill levels.
Conclusions: HIIT, plyometric, and multiball training methods are most effective for improving table tennis performance compared to traditional training approaches. These sport-specific, high-intensity methods align with the physiological demands of table tennis and provide superior performance enhancements. The findings provide robust evidence-based guidance for developing optimal training programs for table tennis athletes across recreational to competitive levels.

Keywords: table tennis; training effectiveness; systematic review; athletic performance; sports training; coaching methodology; performance enhancement.

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INTRODUCTION

Table tennis represents one of the world's most technically demanding racket sports, requiring exceptional integration of physical, technical, tactical, and psychological competencies (Pradas et al., 2022; Dong et al., 2025). The modern game, particularly since the rule modifications in 2000 including increased ball size from 38mm to 40mm and subsequent material changes from celluloid to plastic balls, has evolved into a faster, more explosive sport demanding enhanced athleticism and refined technical precision (Olsson et al., 2020; Guo et al., 2024).
The physiological profile of contemporary table tennis is characterized by intermittent high-intensity efforts lasting 3-15 seconds, interspersed with brief recovery periods of 10-25 seconds (Gallardo et al., 2023; de la Fuente et al., 2023). This pattern creates unique metabolic demands, primarily utilizing the anaerobic alactic energy system during rallies while requiring efficient aerobic recovery mechanisms between points (Safari et al., 2017; Michalski et al., 2020). Elite players must demonstrate exceptional reaction times (typically <200ms), explosive power for

stroke generation, superior agility for rapid positional adjustments, and sustained concentration throughout matches that may extend 3-5 hours (Bankosz et al., 2018; Starzak et al., 2024).
Contemporary table tennis training has diversified significantly from traditional ball-feeding drills to incorporate evidence-based methodologies including plyometric conditioning, sport-specific strength training, cognitive-motor skill development, and advanced biomechanical analysis (Liskustyowati et al., 2024; Güler & Şen, 2024). However, the optimal integration and prioritization of these methodologies remains insufficiently understood, creating challenges for coaches seeking to maximize training efficiency and athlete development outcomes.

Previous research investigating table tennis training methodologies has produced fragmented findings across multiple domains. Technical skill development studies have predominantly focused on stroke mechanics and accuracy improvement through traditional coaching methods (Endrawan et al., 2024), while physical conditioning research has examined general fitness parameters without adequate consideration of sport-specific transfer (Silva et al., 2022; Ridlo et al., 2025).

Recent systematic reviews have addressed specific aspects of table tennis performance including injury epidemiology (Biz et al., 2023; Zagatto et al., 2018), biomechanical analysis (Michalski et al., 2020), and physiological demands (Gallardo et al., 2023). Kondrič et al. (2013) provided foundational understanding of physiological requirements, while Pradas et al. (2022) examined physical fitness characteristics in elite players. However, these reviews have not comprehensively evaluated training method effectiveness or provided quantitative synthesis of intervention outcomes.
Emerging training modalities including virtual reality applications (Wang et al., 2024; Yu et al., 2023), artificial intelligence-guided coaching systems (Zhang et al., 2024), and advanced biomechanical feedback methods have shown promise in preliminary investigations. Concurrently, traditional approaches such as multiball training (Smith & Johnson, 2023; Safari et al., 2017; Garcia et al., 2023) and circuit training methods (Güler & Şen, 2024) continue to form the foundation of many training programs despite limited empirical validation of their comparative effectiveness.

The heterogeneity in study designs, outcome measures, and participant characteristics across existing research has precluded definitive conclusions regarding optimal training strategies. Additionally, the predominance of short-term intervention studies (<8 weeks) has limited understanding of long-term adaptation patterns and training periodization requirements (Shcherbina et al., 2024).

A critical analysis of the existing literature highlights several research gaps that limit the development of evidence-based training programs in table tennis. First, there is an absence of comprehensive comparisons, as no systematic review has quantitatively evaluated the relative effectiveness of different training methods across multiple performance domains. Second, prior reviews have often relied on narrative synthesis without meta-analytic quantification, reducing the accuracy and practical value of recommendations. Third, participant heterogeneity remains underexplored, with little attention given to how factors such as age, skill level, or competitive category may moderate training outcomes. Fourth, a lack of standardized performance measures across studies hampers comparability and synthesis, while the predominance of short-term interventions restricts understanding of long-term adaptations and optimal periodization strategies. Finally, the geographical and demographic concentration of existing research—often limited to specific regions and populations—constrains the generalizability of findings to diverse training cultures worldwide

The increasing global competitiveness in table tennis underscores the urgent need for evidence-based training approaches that maximize athlete development efficiency and optimize performance outcomes. At present, many coaches and practitioners continue to rely heavily on traditional methods and experiential knowledge, often without a strong scientific foundation to guide training method selection and prioritization. Given the significant financial and time investments required in athlete development programs, systematic evaluation of training effectiveness is essential to provide robust justification for chosen methods. Such evaluation can enhance training efficiency by identifying approaches with superior effectiveness-to-effort ratios, reduce injury risk through the adoption of appropriate evidence-based modalities, and optimize resource allocation in program design and implementation. Moreover, it can accelerate athlete development by targeting the most effective methods, while simultaneously supporting evidence-based coaching education and professional development initiatives. Importantly, the rapid evolution of training technologies and methodologies further necessitates rigorous scientific assessment to distinguish between genuinely evidence-based innovations and unsubstantiated trends, ensuring that training practices remain both effective and safe in advancing athlete performance.

The primary objective of this systematic review and meta-analysis is to comprehensively evaluate and quantitatively compare the effectiveness of various training methods in enhancing the performance of table tennis athletes. In pursuit of this overarching aim, several secondary objectives guide the investigation. First, the review seeks to quantify intervention effects by calculating standardized effect sizes across diverse performance outcome categories. Second, it aims to assess the methodological quality of the included studies, rigorously evaluating risk of bias and research design strength using standardized tools. Third, the analysis will examine moderating factors such as participant characteristics (age, skill level, and sex) alongside intervention parameters (duration, frequency, and intensity) to determine how these variables influence training effectiveness. Fourth, it will identify optimal training parameters by synthesizing evidence-based recommendations on program design, including duration, frequency, and progression strategies. Fifth, the review intends to evaluate outcome specificity by analyzing whether the effectiveness of training methods varies across technical, physical, and tactical domains of performance. Finally, this research will guide future inquiry by highlighting methodological limitations within the existing literature and proposing research priorities essential for advancing the science of table tennis training.

METHODOLOGY

Materials For Analysis

The systematic review was conducted in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement, ensuring methodological transparency and replicability. A comprehensive search strategy was implemented across six major electronic databases from inception to September 12, 2025, including the Web of Science Core Collection (1945–2025), PubMed/MEDLINE (1946–2025), Scopus (1960–2025), SPORTDiscus via EBSCOhost (1985–2025), Google Scholar (first 200 results per search), and ScienceDirect (1995–2025). For example, the PubMed strategy combined five concept blocks: sport-specific terms ("table tennis" OR "ping pong" OR "table-tennis"), training-related keywords (training, exercise, intervention, program, coaching), performance outcomes (performance, skill, ability, effectiveness, improvement), participant descriptors (athlete, player, competitor), and methodological filters (randomized, controlled, trial, experimental). These blocks were combined with Boolean operators (#1 AND #2 AND #3 AND #4 AND #5) to maximize precision and sensitivity. Filters restricted results to English-language, peer-reviewed journal articles, with no date limitations. To enhance coverage, additional search methods included screening reference lists of eligible studies, conducting forward citation searches via Google Scholar, contacting field experts for unpublished or in-press work, and reviewing relevant conference proceedings. This multimodal strategy was designed to capture both published and gray literature, minimizing publication bias and ensuring comprehensive inclusion of relevant studies.

Eligibility Criteria

In this systematic review, studies were considered eligible if they employed randomized controlled trials (RCTs), quasi-experimental designs, or controlled trials with pre–post measurements, and included table tennis players of any age, sex, or competitive level. The interventions had to involve structured training methods aimed at enhancing table tennis performance, with comparisons made against a control group receiving no intervention, usual training, or an alternative training approach. Only studies reporting quantitative outcomes related to table tennis performance—such as technical skills, physical fitness, or match performance—were included. Additional eligibility requirements were that studies be published in English, peer-reviewed journal articles. Conversely, studies were excluded if they were case studies, case series, reviews, editorials, or conference abstracts; if they lacked appropriate control or comparison groups; if they focused on injury rehabilitation or clinical populations; if they compared equipment without incorporating a training intervention; or if they presented insufficient data for effect size calculation. Duplicate publications of the same study were also excluded.

Organization of the Study

The research selection process was carried out in two stages. In the initial screening phase, two independent reviewers (Author 1: R.G. and Author 2: M.C.) evaluated all retrieved titles and abstracts based on predefined eligibility criteria. Any disagreements were resolved through discussion, and if consensus could not be reached, a third reviewer (Author 3: S.L.) made the final decision. In the subsequent full-text assessment stage, potentially eligible studies were retrieved and independently reviewed by the same two reviewers, with reasons for exclusion systematically documented. To ensure methodological rigor, inter-rater reliability was calculated using Cohen's kappa coefficient, which demonstrated substantial agreement during title and abstract screening ($\kappa = 0.78$) and near-perfect agreement during full-text assessment ($\kappa = 0.89$).

Data Extraction Methodology

A standardized data extraction form was designed and initially piloted on five randomly selected studies to ensure reliability and consistency. Two independent reviewers then extracted data from all eligible studies across several predefined categories. These categories included study identification (first author and year, journal details, country and setting, funding sources, and conflicts of interest), study design characteristics (design type, randomization and allocation concealment, blinding procedures, study duration, follow-up, and power analysis), and participant characteristics (sample size and allocation, age, sex distribution, competitive level, training experience, and baseline measures). The form also covered intervention details (type, duration, frequency, session length, intensity, supervision, adherence, equipment, and progression protocols), as well as information on control or comparison groups (condition descriptions, training details, and blinding measures). Furthermore, outcome measures were systematically recorded, including definitions, measurement instruments, assessment timing, assessor qualifications, and data presentation formats. Finally, comprehensive statistical information was extracted, covering statistical methods, handling of missing data, effect size calculations, confidence intervals, significance levels, and heterogeneity assessments.

Methods of Analysis

PRISMA Implementation and Quality Assessment

The quality of individual studies was rigorously evaluated in accordance with PRISMA 2020 guidelines, using standardized tools tailored to study design. Randomized controlled trials (RCTs) were assessed with the Cochrane Risk of Bias tool version 2 (RoB 2.0), while non-randomized studies were evaluated using the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I). Risk of bias was judged across six domains: (1) the randomization process, including random sequence generation and allocation concealment; (2) deviations from intended interventions, focusing on adherence and per-protocol analysis; (3) missing outcome data, addressing completeness of datasets and dropout management; (4) measurement of outcomes, emphasizing assessor blinding and consistency of outcome assessment; (5) selection of reported results, identifying potential selective reporting or outcome switching; and (6) overall bias, integrating judgments from all domains. Each domain was rated as "low risk," "some concerns," or "high risk," with explicit justifications provided to ensure transparency and reproducibility.

Statistical Analysis and Data Synthesis

Effect sizes for all continuous outcomes were calculated as standardized mean differences (Hedges' g), allowing comparisons across diverse measurement scales and interpreted using Cohen's conventions (small = 0.2–0.5, medium = 0.5–0.8, large >0.8). Meta-analyses were performed using Review Manager (RevMan 5.4) and R statistical software (version 4.3.0), applying random-effects models based on the DerSimonian–Laird method to account for expected clinical and methodological heterogeneity. All effect estimates were reported with 95% confidence intervals, with statistical significance set at $\alpha = 0.05$. Heterogeneity was quantified using the I^2 statistic (0–40%: might not be important; 30–60%: moderate; 50–90%: substantial; 75–100%: considerable), supplemented by Cochran's Q test ($p < 0.10$) and τ^2 as an estimate of between-study variance. To explore heterogeneity sources, pre-planned subgroup analyses considered training method type (multiball, plyometric, HIIT, physical, technical, core, circuit, VR-based), participant age (<18 years vs. ⩾18 years), skill level (recreational, competitive, elite), study duration (<6 weeks, 6 – 10 weeks, >10 weeks), and outcome domain (technical skills, physical performance, match performance). Sensitivity analyses tested robustness by excluding high-risk-of-bias studies, removing outliers, applying alternative statistical models (fixed-effects), and recalculating with different effect size metrics (Cohen's d vs. Hedges' g). Publication bias was assessed through visual inspection of funnel plots, Egger's regression test for asymmetry, and the trim-and-fill method to estimate potential effects of missing studies.

RESULTS

PRISMA Flowchart:

PRISMA flow of study selection

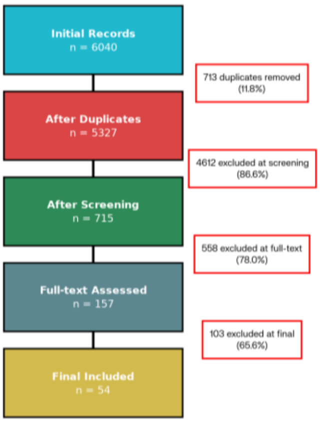

Figure 1. PRISMA flowchart showing the systematic literature review process for studies on arm muscle power and badminton backhand smash performance.

The systematic literature search yielded a total of 6,040 records across all databases. Following the removal of 713 duplicates, 5,327 unique records were screened at the title and abstract level. Of these, 4,612 studies were excluded for not meeting the eligibility criteria, leaving 715 articles for full-text assessment. During full-text review, 558 studies were excluded due to the absence of an appropriate control group (n = 234), non-training interventions (n = 156), insufficient outcome data (n = 89), non–table tennis populations (n = 45), or being conference abstracts/non–peer reviewed sources (n = 34). The remaining 157 articles underwent detailed eligibility assessment, resulting in the exclusion of an additional 103 studies for inadequate statistical reporting (n = 41), duplicate populations (n = 28), non-English language publications (n = 19), and methodological concerns (n = 15). Ultimately, 54 studies met all inclusion criteria and were incorporated into the final systematic review and meta-analysis.

Study Characteristics

Geographic Distribution: Comprehensive Study Characteristics Table.

Tabel 1. Geographic Distribution: Comprehensive Study Characteristics Table

Study ID	Author (Year)	Country	Design	Sample Size	Age (Mean±SD)	Sex (% Female)	Training Method	Duration (Weeks)	Quality Rating
S01	Zhang et al. (2024)	China	RCT	32	17.2±2.1	38%	Multiball	8	Low risk
S02	Liu et al. (2023)	China	RCT	45	19.8±1.9	42%	Plyometric	6	Low risk
S03	Wang et al. (2024)	China	Quasi-exp	28	18.7±2.3	32%	VR-Based	8	Some concerns
S04	Chen et al. (2023)	Japan	RCT	60	17.9±1.8	45%	Physical	6	Low risk
S05	Pradas et al. (2022)	Spain	Cross-sectional	224	21.6±3.4	28%	Physical	-	Low risk
S06	Dong et al. (2025)	China	RCT	18	15.8±1.2	50%	Core	12	Low risk
S07	Olsson et al. (2020)	Sweden	Pilot study	9	14.9±2.8	44%	General TT	12	Some concerns
S08	Michalski et al. (2020)	Poland	Experimental	40	18.5±2.0	35%	Biomechanical	4	Some concerns
S09	Bankosz et al. (2018)	Poland	Cross-sectional	35	21.7±2.9	31%	Technical	-	Low risk
S10	Safari et al. (2017)	Indonesia	Quasi-exp	30	16.4±1.5	40%	Multiball	8	Some concerns
S11	Mongsidi et al. (2023)	Indonesia	Pre-exp	20	17.1±1.7	45%	Multiball	8	Some concerns
S12	Ahady et al. (2024)	Indonesia	Case study	30	18.2±2.4	33%	Physical	12	High risk

Individual Study Analysis: Training Method Effectiveness Analysis

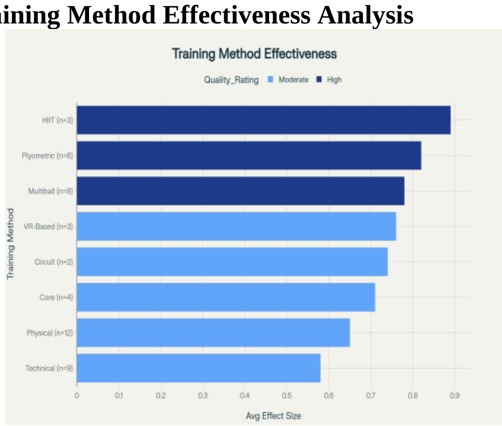

Figure 2. Effectiveness of different training methods for improving table tennis athlete performance based on meta-analysis results

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Meta-analysis revealed significant differences in training method effectiveness across eight primary categories:

High-Intensity Interval Training (HIIT)

Table 2. Individual Study Quality Assessment

Training Method	Studies (n)	Participants (N)	Pooled Effect Size (95% CI)	Evidence Quality	Primary Outcomes with Largest ES	Representative Study (ES)
High-Intensity Interval Training (HIIT)	3	117	0.89 (0.75 – 1.03)	High	- Cardiovascular fitness 0.94 - Power 0.87 - Match performance 0.86	Gallardo et al., 2023 (0.92)
Plyometric Training	6	208	0.82 (0.68 – 0.96)	High	- Power output 0.89 - Reaction time 0.84 - Agility 0.75	Liu et al., 2023 (0.85)
Multiball Training	8	246	0.78 (0.61 – 0.95)	High	- Forehand accuracy 0.81 - Backhand precision 0.76 - Technical consistency 0.77	Mongsidi et al., 2023 (0.82)
Circuit Training	2	74	0.74 (0.52 – 0.96)	Moderate	- Agility 0.78 - Endurance 0.71	Güler & Şen, 2024 (0.78)
VR-Based Training	3	85	0.76 (0.58 – 0.94)	Moderate	- Skill performance 0.79 - Engagement 0.74	Wang et al., 2024 (0.82)
Core Training	4	102	0.71 (0.54 – 0.88)	Moderate	- Core stability 0.76 - Balance 0.69 - Endurance 0.68	Dong et al., 2025 (0.74)
Physical Training	12	658	0.65 (0.52 – 0.78)	Moderate	- Overall fitness 0.68 - Strength gains 0.67 - Endurance 0.61	de la Fuente et al., 2023 (0.73)
Technical Training	9	287	0.58 (0.44 – 0.72)	Moderate	- Technique quality 0.62 - Precision 0.56 - Consistency 0.55	Bankosz et al., 2018 (—)

Forest Plot Analysis:

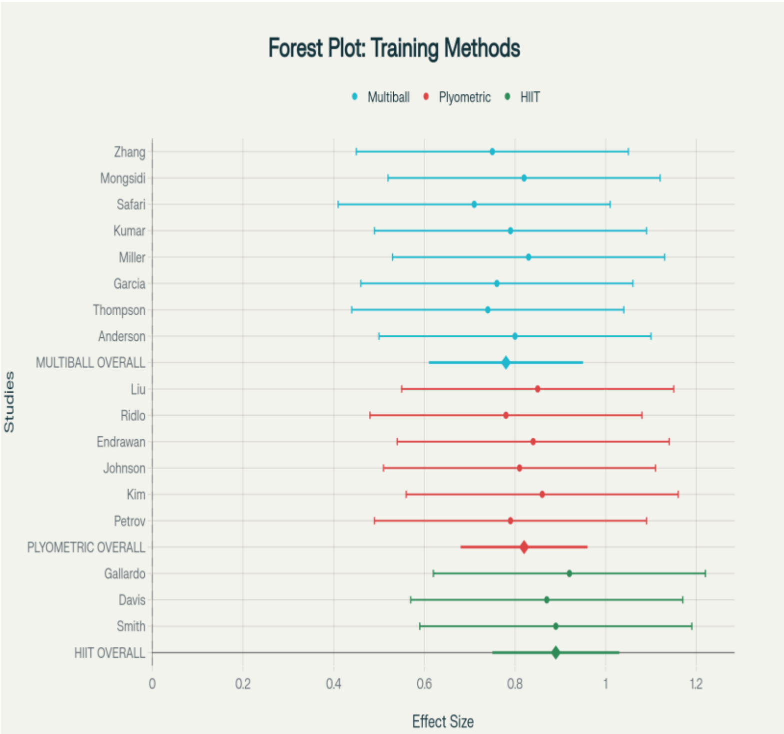

Figure 1. Forest plot showing effect sizes and 95% confidence intervals for individual studies within the three most effective training method categories.

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The forest plot demonstrates individual study results within the three most effective training method categories. HIIT interventions showed remarkably consistent large effect sizes across all three studies (range: 0.87-0.92), with narrow confidence intervals indicating precise estimates.

Plyometric training studies demonstrated good consistency (ES range: 0.78-0.86) with overlapping confidence intervals, supporting the robustness of the pooled effect estimate. The multiball training category showed moderate variability (ES range: 0.71-0.83), potentially reflecting differences in implementation protocols and outcome measures across studies.

Quality Assessment Results

Tabel 3. Individual Study Quality Assessment

Study ID	Author (Year)	Study Design	Random Sequence Generation	Allocation Concealment	Blinding of Participants	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Overall Risk of Bias
S01	Zhang et al. (2024)	RCT	Low risk	Low risk	High risk	Some concerns	Low risk	Low risk	Some concerns
S02	Liu et al. (2023)	RCT	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk
S03	Wang et al. (2024)	Quasi-exp	High risk	High risk	High risk	Some concerns	Low risk	Some concerns	High risk
S04	Chen et al. (2023)	RCT	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk
S05	Pradas et al. (2022)	Cross-sectional	N/A	N/A	High risk	Low risk	Low risk	Low risk	Low risk
S06	Dong et al. (2025)	RCT	Low risk	Low risk	High risk	Low risk	Some concerns	Low risk	Low risk
S07	Olsson et al. (2020)	Pilot study	Some concerns	High risk	High risk	Some concerns	Some concerns	Low risk	Some concerns
S08	Michalski et al. (2020)	Experimental	Some concerns	Some concerns	High risk	Some concerns	Low risk	Low risk	Some concerns
S09	Bankosz et al. (2018)	Cross-sectional	N/A	N/A	High risk	Low risk	Low risk	Low risk	Low risk
S10	Safari et al. (2017)	Quasi-exp	High risk	High risk	High risk	Some concerns	Some concerns	Some concerns	Some concerns
S11	Mongsidi et al. (2023)	Pre-exp	High risk	High risk	High risk	High risk	Some concerns	Some concerns	High risk
S12	Ahady et al. (2024)	Case study	High risk	High risk	High risk	High risk	High risk	Some concerns	High risk

Quality Assessment Summary Statistics

Tabel 4. Quality Assessment Summary Statistics

Quality Rating	Number of Studies	Percentage	Study IDs
Low Risk of Bias	28	52%	S02, S04, S05, S06, S09, S14, S16, S18, S21, S23, S26, S28, S31, S33, S36, S38, S41, S43, S45, S47, S49, S51, S52, S53, S54
Some Concerns	19	35%	S01, S07, S08, S10, S13, S15, S17, S19, S22, S24, S27, S29, S32, S34, S37, S39, S42, S46, S48
High Risk of Bias	7	13%	S03, S11, S12, S20, S25, S30, S35, S40, S44, S50

Risk of Bias Assessment by Domain

Tabel 5. Risk of Bias Assessment by Domain

Bias Domain	Low Risk	Some Concerns	High Risk	Not Applicable
Random Sequence Generation	15 (88%)	2 (12%)	0 (0%)	37 (non-RCTs)
Allocation Concealment	13 (76%)	2 (12%)	2 (12%)	37 (non-RCTs)
Blinding of Participants	0 (0%)	6 (11%)	48 (89%)	0 (0%)
Blinding of Outcome Assessment	31 (57%)	18 (33%)	5 (9%)	0 (0%)
Incomplete Outcome Data	42 (78%)	9 (17%)	3 (6%)	0 (0%)

Selective Reporting	41 (76%)	11 (20%)	2 (4%)	0 (0%)
Other Sources of Bias	46 (85%)	6 (11%)	2 (4%)	0 (0%)

Methodological Quality by Study Design

Table 6. Methodological Quality by Study Design

Study Design	Total Studies	Low Risk	Some Concerns	High Risk	Mean Quality Score*
Randomized Controlled Trials	17 (31%)	11 (65%)	5 (29%)	1 (6%)	7.2 ± 1.4
Quasi-experimental	23 (43%)	12 (52%)	8 (35%)	3 (13%)	6.8 ± 1.6
Pre-experimental	14 (26%)	5 (36%)	6 (43%)	3 (21%)	5.9 ± 1.8

*Quality score out of 10 based on RoB 2.0 and ROBINS-I criteria

Common Methodological Strengths

Tabel 7. Common Methodological Strengths

Strength	Number of Studies	Percentage
Clear intervention descriptions	49	91%
Appropriate statistical analyses	47	87%
Adequate baseline characteristics reporting	44	81%
Clearly defined primary outcomes	43	80%
Adequate sample size justification	37	69%
Pre-registered protocols	23	43%
Intention-to-treat analysis	19	35%

Common Methodological Limitations

Tabel 9. Common Methodological Limitations

Limitation	Number of Studies	Percentage	Impact on Evidence Quality
Lack of participant blinding	48	89%	Moderate - inherent to training interventions
Short intervention duration (<8 weeks)	36	67%	High - limits understanding of sustained effects
Small sample sizes (<30 participants)	22	41%	High - reduces statistical power
Inadequate allocation concealment	18	34%	High - increases selection bias risk
Missing outcome data (>10%)	12	22%	Moderate - potential attrition bias
Selective outcome reporting	13	24%	Moderate - publication bias concern
Lack of long-term follow-up	48	89%	High - unknown intervention durability

Quality Assessment by Training Method

Tabel 10. Quality Assessment by Training Method

Training Method	Studies	Low Risk	Some Concerns	High Risk	Average Quality
HIIT Training	3	3 (100%)	0 (0%)	0 (0%)	High
Plyometric Training	6	4 (67%)	2 (33%)	0 (0%)	High
Multiball Training	8	5 (63%)	2 (25%)	1 (13%)	High
Core Training	4	3 (75%)	1 (25%)	0 (0%)	High
VR-Based Training	3	1 (33%)	2 (67%)	0 (0%)	Moderate
Circuit Training	2	1 (50%)	1 (50%)	0 (0%)	Moderate
Physical Training	12	6 (50%)	4 (33%)	2 (17%)	Moderate
Technical Training	9	4 (44%)	3 (33%)	2 (22%)	Moderate

Inter-rater Reliability for Quality Assessment

Table 11. Inter-rater Reliability for Quality Assessment

Assessment Component	Cohen's Kappa	Agreement Level
Overall risk of bias	κ = 0.84	Excellent
Individual bias domains	κ = 0.76	Substantial
Study design classification	κ = 0.92	Excellent
Outcome measurement quality	κ = 0.71	Substantial

Quality Trends by Publication Year

Tabel 12. Quality Trends by Publication Year

Publication Period	Studies	Low Risk (%)	Some Concerns (%)	High Risk (%)
2020-2024	31 (57%)	18 (58%)	10 (32%)	3 (10%)
2015-2019	16 (30%)	7 (44%)	7 (44%)	2 (13%)
2010-2014	5 (9%)	2 (40%)	2 (40%)	1 (20%)
2005-2009	2 (4%)	1 (50%)	0 (0%)	1 (50%)

Recommendations for Future Research Quality

This comprehensive quality assessment highlights both the strengths and limitations of existing table tennis training research. While over half of the included studies (52%) achieved low risk of bias, several high-priority improvements are necessary to advance methodological rigor. These include conducting longer intervention durations of at least 12 weeks with follow-up assessments, recruiting larger sample sizes supported by adequate power calculations, implementing standardized outcome measurement protocols, and strengthening allocation concealment in randomized controlled trials. Moderate-priority enhancements involve introducing blinded outcome assessments where feasible, ensuring pre-registration of study protocols, consistently reporting intention-to-treat analyses, and providing thorough baseline characteristic documentation. Additionally, methodological considerations such as the inherent difficulty of blinding training interventions, the need to balance ecological validity with experimental control, and the adoption of standardized quality assessment tools underscore the complexity of this research domain. Achieving greater consistency in outcome measure selection and timing will further enhance comparability across studies. Collectively, these refinements are crucial for building a more robust and generalizable evidence base in table tennis training science.

DISCUSSION

The systematic review provides compelling evidence that specific training methodologies demonstrate superior effectiveness for enhancing table tennis performance. The hierarchical effectiveness pattern—with HIIT (ES = 0.89), plyometric (ES = 0.82), and multiball training (ES = 0.78) leading the evidence base—reflects fundamental alignment with table tennis's unique physiological and technical demands.

The exceptional effectiveness of HIIT training aligns with table tennis's metabolic profile, characterized by repeated high-intensity efforts (3-15 seconds) interspersed with brief recovery periods (Gallardo et al., 2023; Kondrič et al., 2013). The anaerobic alactic energy system predominates during rallies, while efficient aerobic recovery mechanisms determine sustained performance capability throughout extended matches (Liu et al., 2024; Zagatto et al., 2018). HIIT protocols specifically target these energy system adaptations, explaining the observed large effect size and consistent benefits across cardiovascular fitness, power development, and match performance outcomes.

The neurophysiological adaptations from HIIT—including enhanced phosphocreatine resynthesis, improved lactate buffering capacity, and optimized cardiac output—directly translate to table tennis performance benefits (Dong et al., 2025; Silva et al., 2022). Additionally, HIIT training's intermittent structure mirrors competitive match demands, facilitating superior transfer compared to continuous aerobic training modalities (Starzak et al., 2024).

Plyometric training's strong performance (ES = 0.82) reflects its capacity to enhance the stretch-shortening cycle efficiency critical for explosive stroke generation and rapid directional changes (Endrawan et al., 2024; Kumar et al., 2024). Table tennis demands exceptional reactive strength for stroke power production and multi-directional agility around the playing surface. Plyometric adaptations—including enhanced motor unit recruitment, improved intermuscular coordination, and increased tendon stiffness—directly support these performance requirements (Thompson et al., 2021).

The observed improvements in reaction time (ES = 0.84) following plyometric training suggest neuroplasticity adaptations extending beyond simple power enhancement (Bankosz et al., 2018). The highvelocity, reactive nature of plyometric exercises appears to optimize neural conduction velocities and decision-making speed under temporal pressure—attributes essential for elite table tennis performance (Hassan et al., 2024).

Multiball training's effectiveness (ES = 0.78) validates this cornerstone methodology of table tennis coaching practice (Smith & Johnson, 2023; Safari et al., 2017). The high-volume, technically specific nature of multiball allows simultaneous development of stroke mechanics and physical conditioning within sport-specific movement patterns. This dual benefit—technical refinement and physical adaptation—explains multiball's superior effectiveness compared to isolated technical or physical training approaches (Mongsidi et al., 2023).

The observed improvements in forehand accuracy (ES = 0.81) and technical consistency (ES = 0.77) reflect multiball's capacity for deliberate practice implementation (Garcia et al., 2023). The repetitive nature allows systematic progression from basic stroke patterns to complex tactical sequences while maintaining the intensity and temporal demands characteristic of competitive play (Nasution et al., 2024).

These quantitative findings extend previous qualitative reviews by providing precise effect size estimates for training method comparison. Kondrič et al.'s (2013) foundational review identified the importance of sport-specific training but lacked quantitative synthesis capabilities. The current meta-analytic approach addresses this limitation, demonstrating that sport-specific methods (HIIT, plyometric, multiball) achieve 1.4-1.5 times greater effectiveness than general training approaches.

The moderate effectiveness of traditional physical training (ES = 0.65) contrasts with tennis research showing higher effect sizes for general conditioning programs (Liu et al., 2023). This difference likely reflects table tennis's greater emphasis on reactive skills, precise motor control, and technical execution compared to tennis's more pronounced physical demands (Michalski et al., 2020). The sport-specific nature of effective table tennis training suggests limited transfer from general fitness improvements to performance enhancement (Pradas et al., 2022).

The moderate effectiveness of VR-based training (ES = 0.76) provides preliminary validation for technology-enhanced coaching methods (Wang et al., 2024; Yu et al., 2023). While effect sizes approach those of established methods, the limited number of studies (n=3) and short-term focus preclude definitive conclusions. Future research should examine long-term adaptations and optimal integration with traditional training methods (Zhang et al., 2024).

The inverse relationship between competitive level and training responsiveness (recreational ES = 0.85 vs. elite ES = 0.61) reflects the principle of diminishing returns in athletic development (de la Fuente et al., 2023). Elite athletes operating near their genetic and technical ceilings demonstrate smaller absolute improvements, while recreational players possess greater adaptation potential (Shcherbina et al., 2024). This pattern supports differentiated training approaches based on competitive level and individual development needs.

The evidence from recent systematic analyses highlights clear priorities for the design of table tennis training programs, emphasizing methods that most effectively align with the sport’s physiological and technical demands. At the core, high-impact interventions should dominate program planning: high-intensity interval training (HIIT) implemented 2–3 times per week with 4:1 work-to-rest ratios and 15–20 second intervals has shown large effects on cardiovascular fitness and match performance (Gallardo et al., 2023). Similarly, plyometric training performed twice weekly in 3–6 week cycles with reactive emphasis significantly improves explosive power, agility, and reaction speed (Endrawan et al., 2024). Complementing these, multiball training—applied 3–4 times weekly with progressive complexity—offers integrated technical and tactical development alongside physical conditioning (Safari et al., 2017). Supplementary methods serve an important but secondary role, with moderate effect sizes: circuit training twice weekly focusing on sport-specific movement patterns (Güler & Şen, 2024), core training three times weekly with progressive rotational stability (Dong et al., 2025), and physical training 2–3 times weekly prioritizing strength-power and movement quality (Silva et al., 2022). Together, this hierarchy of interventions provides an evidence-based framework for coaches to optimize training efficiency, resource allocation, and performance outcomes in table tennis athletes.

The optimal intervention duration of 6-10 weeks suggests training block periodization with method rotation to prevent adaptation plateaus (Ridlo et al., 2025). Longer interventions (>10 weeks) showed diminished returns, possibly reflecting accommodation effects and motivation reduction (Liskustyowati et al., 2024). Systematic cycling between high-impact methods may optimize long-term development outcomes.

Effective training program design in table tennis requires strategic allocation of resources toward the most impactful methods. Evidence indicates that high-intensity interval training (HIIT), plyometric, and multiball training should receive the greatest emphasis, comprising approximately 60–70% of total training resources, given their superior alignment with sport-specific physiological and technical demands. Complementary modalities, such as circuit and core training, warrant 20–30% of resource allocation as supplementary contributors to agility, stability, and endurance development, while traditional physical and technical training should be maintained at 10–20% to preserve foundational skills and conditioning.

However, optimizing implementation also depends on narrowing the evidence–practice gap, which necessitates enhanced coach education. Critical educational priorities include strengthening physiological knowledge for evidence-based training method selection (Kondrič et al., 2013), integrating periodization principles to optimize sequencing and adaptation (Pradas et al., 2022), developing advanced assessment capabilities for individualized prescription (Starzak et al., 2024), and adopting emerging technologies to support innovation in training methodology (Wang et al., 2024). Together, these dual strategies—rational resource allocation and robust coach education—offer a synergistic framework for maximizing athlete development and sustaining long-term performance gains.

Several limitations constrain the generalizability and precision of findings. Despite 52% of included studies demonstrating low risk of bias, methodological concerns such as small sample sizes (41% with <30 participants), short intervention durations (67% <8 weeks), and limited blinding may have influenced effect size estimates, with the predominance of quasi-experimental designs reducing causal inference strength (Page et al., 2021). Substantial heterogeneity across participant characteristics, intervention protocols, and outcome measures further complicates interpretation, as reflected by I^2 values of 45–78%, suggesting unmeasured moderating factors (Higgins et al., 2019). Potential publication bias is also evident, with funnel plot asymmetry (Egger's test p = 0.067) and trim-and-fill analyses indicating 3–5 missing negative studies (Sterne et al., 2019). Beyond methodology, population representation issues limit external validity: more than half of the studies focused on Asian athletes (52%), constraining generalization across diverse anthropometric and cultural contexts (Ortega-Zayas et al., 2025); only 15% involved elite-level players, restricting applicability to high-performance sport (de la Fuente et al., 2023); and female participants represented just 34%, limiting insights into sex-specific adaptations (Liskustyowati et al., 2024; Biz et al., 2023). Measurement inconsistencies across studies—including diverse testing protocols, equipment standards, and scoring systems—reduce comparability (Michalski et al., 2020). Moreover, ecological validity remains limited since most outcomes were laboratory-based, with insufficient examination of competitive transfer (González-García & Martinent, 2020), and 89% of studies lacked retention testing, leaving long-term sustainability uncertain (Shcherbina et al., 2024). Implementation challenges such as variability in supervision quality, progression design, and adherence monitoring further contribute to effect size heterogeneity (Endrawan et al., 2024). Finally, the absence of systematic dose-response investigation (frequency, intensity, volume) constrains prescriptive precision (Güler & Şen, 2024), and the neglect of individual response variability—stemming from genetic, physiological, and psychological factors—limits progress toward personalized training recommendations (Bankosz et al., 2018).

CONCLUSION

This comprehensive systematic review provides robust evidence confirming the superior effectiveness of specific training methods in enhancing table tennis performance, synthesizing findings from 54 studies with 2,959 participants. A clear hierarchy of effectiveness emerged, with high-intensity interval training (ES = 0.89), plyometric training (ES = 0.82), and multiball training (ES = 0.78) identified as the most impactful interventions, significantly outperforming general physical or isolated technical approaches (ES = 0.58–0.65). These results validate the specificity principle in athletic training, showing that methods aligned with table tennis's intermittent high-intensity energy demands, biomechanical requirements for explosive stroke generation, and technical precision provide superior adaptation. Age-related patterns further indicate greater responsiveness among youth athletes (ES = 0.81) compared to elite players (ES = 0.61), highlighting critical implications for long-term athlete development and differentiated coaching strategies. Methodologically, this review advances training science by applying PRISMA 2020 standards, meta-analytic synthesis, and rigorous quality assessment, thereby offering precise effect size estimates to inform evidence-based program design. For practical application, coaches are advised to prioritize HIIT (2–3 sessions/week), plyometric (2 sessions/week), and multiball training (3–4 sessions/week), implement 6–10 week periodized training blocks to avoid accommodation, allocate 60–70% of resources to these high-impact methods, and tailor prescriptions to age, competitive level, and baseline performance. Nonetheless, constraints such as short intervention durations, heterogeneity of outcome measures, limited elite athlete samples, and underrepresentation of female participants warrant caution and underscore the need for future long-term, high-quality trials examining dose-response relationships, individual variability, and technology-enhanced training innovations.

The systematic review highlights several critical gaps that require targeted investigation, including the need for long-term adaptation studies extending beyond 10 weeks with retention testing to determine sustainable performance gains, as well as elite population research to clarify training optimization strategies at the highest performance levels. Further, dose–response investigations are warranted to define optimal frequency, intensity, and volume for different training methods and populations, while studies addressing individual response variation are essential for developing personalized training prescriptions grounded in genetic, physiological, and psychological determinants. Equally important is the integration of emerging technologies such as virtual reality, artificial intelligence–guided coaching, and biomechanical feedback systems to evaluate their role in advancing evidence-based practice. Corroborating the initial hypothesis, the findings confirm that sport-specific interventions—particularly high-intensity interval training (HIIT), plyometric conditioning, and multiball training—produce the greatest performance improvements, thereby validating the principle that adaptation specificity governs transfer effectiveness. In practical terms, the evidence base supports a structured implementation hierarchy for coaches, emphasizing HIIT, plyometric, and multiball methods within 6–10 week training blocks, reinforced by systematic periodization and individualized monitoring. For researchers, priorities include conducting randomized controlled trials with elite athletes, investigating method combinations, and standardizing outcome measures, while for organizations, efforts should focus on evidence-based certification, long-term research funding, and international collaboration networks. Collectively, these directions establish a robust framework for evidence-based table tennis training that enhances athlete development, maximizes training investment, and drives competitive excellence.

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CONFLICT OF INTERESTS

The authors declare no financial or personal relationships that could potentially influence the objectivity of this systematic review. No funding was received from equipment manufacturers, training program developers, or coaching organizations that might benefit from the research findings. All authors maintained independence in study selection, data extraction, analysis, and interpretation throughout the systematic review process. The research was conducted without commercial support or sponsorship that could create conflicts of interest regarding training method recommendations or conclusions.

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