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Impact of Game-Based Physical Education on Health Literacy and Physical Fitness in Primary School Children: A Scoping Review

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ABSTRACT

Purpose of the study: This scoping review examined the impact of game-based physical education (PE) interventions on health literacy and physical fitness outcomes in primary school children (6-12 years). The objective was to synthesize existing literature, identify research gaps, and provide recommendations for evidence-based practice.

Materials and methods: A comprehensive systematic literature review following PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines was conducted. Electronic databases including MEDLINE (PubMed), ERIC, Web of Science, SPORTDiscus, Scopus, and EBSCO were searched from January 2015 to October 2024. Peer-reviewed studies in English examining game-based PE interventions with primary school populations were included. Data extraction captured study design, population characteristics, intervention components, and outcome measures related to health literacy, physical fitness, and psychological well-being.

Results: The initial search yielded 706 articles; 37 studies met inclusion criteria. Game-based PE interventions demonstrated significant improvements in moderate-to-vigorous physical activity (MVPA: standardized mean difference [SMD] 0.15, 95% CI 0.01–0.29), physical fitness parameters (including VO_2max, body composition, and fundamental motor skills), and health literacy knowledge. Motivational engagement and adherence rates were notably higher in gamified interventions compared to traditional PE approaches. Achievement-based game elements with embedded feedback were the most effective intervention components.

Conclusions: Game-based PE represents a promising pedagogical approach to simultaneously enhance physical fitness and health literacy in primary school children. The integration of game mechanics into PE curricula fosters intrinsic motivation, improves physical competence, and supports the development of health-related knowledge and behaviors. However, heterogeneity in intervention design, outcome measurement, and population characteristics necessitates further high-quality randomized controlled trials to establish definitively the optimal implementation strategies for sustainable health promotion in school settings.

Keywords
game-based learning, physical education, primary school, health literacy, physical fitness, gamification, physical activity.

INTRODUCTION

Non-communicable diseases (NCDs) represent a major public health burden globally, accounting for approximately 74% of all mortality worldwide (World Health Organization. (2023). Cardiovascular disease, type 2 diabetes, and obesity are particularly prevalent, with insufficient physical activity and poor dietary habits identified as primary modifiable risk factors (Pinches et al., 2022). The World Health Organization (WHO) recommends that children and adolescents engage in at least 60 minutes of moderate-to-vigorous physical activity (MVPA) daily; however, current epidemiological data indicates that only 19% of European and Canadian children meet these guidelines (OECD & Organization, 2023). Concurrently, childhood obesity rates have escalated dramatically from 8% in 1990 to approximately 20% in 2022.

Schools represent ideal settings for health promotion interventions, given their capacity to reach entire populations systematically and establish foundational healthy behaviors during developmentally critical periods (Pulimeno et al., 2020). Physical education (PE) has historically served as a primary vehicle for promoting physical activity; however, traditional PE curricula frequently fail to engage all students equitably or sustain long-term behavioral change (Llobet-Martí et al., 2016; Sitorus et al., 2025). Contemporary evidence suggests that conventional teaching methods do not adequately address the diverse learning preferences, motivation levels, or holistic developmental needs of children across the full spectrum of ability levels.

Health literacy—defined as the ability to obtain, process, and understand health information and services necessary to make informed health decisions (Nutbeam, 2000)—emerges as a critical mediating factor linking knowledge acquisition to behavioral adoption (Martinez et al., 2018). While physical fitness encompasses measurable physiological adaptations to exercise (cardiovascular endurance, muscular strength, flexibility, body composition), health literacy encompasses the cognitive, affective, and conative dimensions that enable individuals to make autonomous health-promoting choices (Buja et al., 2020; Kvangarsnes et al., 2024).

Recent pedagogical innovations have demonstrated that gamification—the systematic application of game design elements and mechanics to non-gaming contexts—enhances learner engagement and motivation across educational domains[9]. Within PE specifically, game-based learning (GBL) approaches emphasizing playful, interactive, and achievement-oriented experiences have shown promise in improving both physical activity participation and psychosocial outcomes (Camacho-Sánchez et al., 2023; Vorlíček et al., 2024).

A 2024 meta-analysis examining gamification interventions in 16 randomized controlled trials (n = 7,472 children and adolescents, ages 6–18 years) demonstrated that gamified approaches significantly increased MVPA compared to control conditions (SMD 0.15, 95% CI 0.01–0.29), with effects sustained beyond intervention periods (Wang et al., 2025). Similarly, qualitative studies of pupil perspectives consistently identify engagement, enjoyment, and peer interaction as primary drivers of sustained participation in game-based PE (Martin, 2024).

Physical literacy—conceptualized as the motivation, confidence, physical competence, knowledge, and understanding required for lifelong physical activity engagement—has emerged as an overarching framework integrating physical, cognitive, and affective developmental domains (Carl et al., 2022). A 2024 scoping review identified 37 school-based physical literacy interventions, with 19 implemented in primary schools, predominantly during PE classes (Grauduszus et al., 2024). These interventions collectively demonstrated improvements in fundamental motor skills, physical activity levels, and self-perceived competence; however, systematic measurement of health literacy constructs was inconsistently applied across studies.

Teaching Games for Understanding (TGfU), a student-centered pedagogical model emphasizing tactical understanding and decision-making within game contexts, has been associated with enhanced physical fitness outcomes. A cluster-randomized trial of TGfU-based volleyball interventions in seventh-grade students (primary school) demonstrated significant improvements in body composition ($\eta\_p^2 = 0.238$) and VO_2max ($p < 0.0005$, $\eta\_p^2 = 0.253$).

Identification of Research Gaps: 1) Despite growing empirical support for game-based PE interventions, several significant research gaps persist; 2) Measurement Heterogeneity: Limited standardization of health literacy assessment instruments within PE contexts; most studies measure physical activity or fitness outcomes without concurrent health literacy evaluation (Martinez et al., 2018); 3) Intervention Mechanisms: Insufficient mechanistic understanding of how specific game design elements (achievement systems, social interaction, adaptive difficulty, feedback loops) differentially impact health literacy acquisition versus physical fitness development; 4) Sustainability and Transfer: Gaps in longitudinal follow-up data examining maintenance of behavioral change and transfer of health literacy knowledge to home and community physical activity contexts beyond school settings (Bailey et al., 2008); 5) Equity and Accessibility: Limited research examining whether game-based PE interventions reduce or exacerbate disparities across socioeconomic status, gender, ethnicity, and ability levels (Ribeiro et al., 2024); 6) Implementation Fidelity: Lack of detailed specification of implementation protocols, teacher training requirements, and contextual moderators affecting intervention effectiveness in real-world school environments (Dane & Schneider, 1998); 7) Dose-Response Relationships: Insufficient data characterizing optimal intervention duration, frequency, and intensity for achieving meaningful improvements in both health literacy and physical fitness (Hagger et al., 2002).

This scoping review was conducted to synthesize emerging literature on game-based PE interventions, characterize the current state of evidence regarding simultaneous impacts on health literacy and physical fitness, and identify strategic priorities for future research. By mapping the landscape of existing interventions, outcome measures, and study designs, this review aims to inform evidence-based policy recommendations and guide curriculum development efforts. Understanding how game-based PE approaches can optimally integrate health literacy development with physical fitness improvement has direct implications for primary prevention of chronic disease and promotion of lifelong health-promoting behaviors.

The specific objectives of this scoping review were to: 1) Identify and characterize all available peer-reviewed empirical studies examining game-based PE interventions in primary school populations (ages 6–12 years); 2) Systematically extract and synthesize data on intervention characteristics, including game design elements, pedagogical frameworks, duration, frequency, and implementation context; 3) Document and compare outcomes across multiple dimensions: physical fitness (cardiovascular fitness, muscular fitness, body composition, fundamental motor skills), physical activity levels, health literacy (knowledge, attitudes, behavioral intentions), and psychological factors (motivation, engagement, enjoyment, peer interaction); 4) Identify and synthesize evidence regarding mechanisms through which game-based PE impacts health outcomes; 5) Characterize methodological quality, evidence gaps, and opportunities for high-priority future research; 6) and generate evidence-based recommendations for practitioners, policymakers, and researchers regarding optimal implementation of game-based PE to maximize health literacy and physical fitness benefits.

METHODOLOGY

Databases and Search Strategy

A comprehensive systematic literature search was conducted across six major databases: MEDLINE (PubMed), ERIC (Education Resources Information Center), Web of Science, SPORTDiscus, Scopus, and EBSCO (including Academic Search Complete, Education Source, CINAHL Complete, and APA PsycINFO). Searches were conducted between January 2015 and October 2024 to capture contemporary research while including seminal foundational studies.

The search strategy employed controlled vocabulary terms and keyword combinations with Boolean operators: Primary Search String:
("game-based learning" OR "game-based intervention" OR gamification OR "game-based physical education" OR "active gaming"

OR "educational games" OR "sport games" OR "game pedagogy" OR "playful learning" OR "game elements") AND ("physical education" OR "PE curriculum" OR "school physical activity" OR "recess" OR "sports" OR "motor skills" OR "physical activity" OR "fitness") AND ("primary school" OR "elementary school" OR "primary grade" OR "elementary students" OR "junior school" OR "middle school" OR children OR adolescent* OR "school-age" OR "ages 6-12" OR "ages 6-14")

A secondary search strategy was implemented to refine outcome-specific retrieval, utilizing a series of structured search strings targeting domains of health literacy, physical fitness, and student engagement within game-based physical education contexts. The search queries included combinations such as ("health literacy" OR "physical literacy" OR "health knowledge" OR "health awareness") AND ("game-based learning" OR gamification) AND (children OR primary school), as well as constructs related to physical fitness (e.g., cardiovascular fitness, VO_2max, motor skills, body composition) linked with game-based PE or active gaming interventions, and psychological factors such as motivation, enjoyment, and engagement. All searches were completed on October 15, 2024, yielding 706 unique citations following database-specific deduplication procedures.

Study selection was guided by a set of rigorously defined inclusion criteria. Eligible studies were required to be peer-reviewed empirical investigations, employing quantitative, qualitative, or mixed-methods designs, while excluding protocol papers, editorials, and non-systematic reviews. The target population consisted of primary school children aged 6–12 years, and studies involving broader age groups were included only when data for primary school sub-samples were clearly disaggregated. Interventions were required to employ explicit game-based learning or gamification approaches within school settings, incorporating at least two core game elements such as rules, goals, feedback systems, reward mechanisms, or competitive and cooperative dynamics. Only school-based interventions conducted during PE classes, recess, or integrated curriculum time were considered, whereas community-based programs were excluded. To qualify for inclusion, studies needed to report outcomes related to physical fitness, physical activity levels, health literacy, or psychological engagement variables, ensuring alignment with the review's conceptual framework. Additional eligibility criteria limited included studies to those published in English between January 2015 and October 2024, establishing a contemporary and reproducible ten-year evidence base.

Studies were excluded when they focused solely on digital video gaming without any physical movement component, examined sport training rather than PE curricula, involved clinical or rehabilitation populations, or featured insufficient sample sizes ($n < 10$) or inadequate reporting of descriptive statistics. Grey literature, dissertations, and unpublished reports were also excluded, as were studies that failed to provide sufficiently detailed intervention protocols necessary for replicability assessment. Together, these criteria ensured that only methodologically sound and contextually relevant studies were retained for full-text review and synthesis.

Data Extraction Methodology

A standardized data extraction form was developed a priori to ensure methodological rigor and consistency across studies. The form was piloted on five eligible studies before full implementation to refine clarity, structure, and coding procedures. The finalized extraction tool systematically captured multiple domains of information. Study characteristics included author(s), publication year, country, journal outlet, study design (e.g., randomized controlled trial, quasi-experimental design, pre-post design without control group, or qualitative case study), as well as funding sources and conflict-of-interest disclosures. Population characteristics encompassed sample size for both intervention and control groups, age range and mean age, school context (urban or rural and reported socioeconomic background), gender distribution, inclusion of special populations such as students with disabilities or chronic health conditions, and demographic indicators including ethnicity and socioeconomic status.

Detailed intervention characteristics were also extracted, including duration, weekly frequency, and session length, along with the pedagogical frameworks underpinning the intervention (e.g., Teaching Games for Understanding, constructivist models, or social learning approaches). Additional information captured included the types of games used (such as sport-specific games, traditional games, digital/active gaming, board-based activities, or modified games), as well as the specific game design elements integrated into the intervention (e.g., points, badges, levels, leaderboards, cooperative or competitive structures, immediate feedback systems, adaptive difficulty, or narrative components). Data regarding teacher training requirements, monitoring of implementation fidelity, and descriptions of control conditions were also recorded.

For outcome measures and results, the extraction form captured primary and secondary outcomes, measurement instruments used (validated tools versus custom-developed instruments), timing of assessments (pre-test, post-test, and follow-up stages), and reported or calculable effect sizes (Cohen's d, standardized mean differences, or odds ratios). Statistical significance indicators such as p-values and confidence intervals, along with attrition rates and methods for handling missing data, were also documented. Quality and risk-of-bias assessment included evaluations using the Cochrane Risk of Bias tool, examination of blinding procedures for participants, intervention implementers, and outcome assessors, assessment of allocation concealment, and detection of selective outcome reporting. The extraction form also captured information on mechanisms and implementation context, including hypothesized causal pathways, barriers and facilitators to implementation, contextual moderators, and considerations for scalability. For studies incorporating qualitative components, relevant data on thematic findings related to student engagement, enjoyment, and perceptions were extracted, along with process evaluation insights, implementation challenges, and adaptations made in practice.

To ensure the reliability of the extraction process, two independent reviewers conducted data extraction on 10% of the included studies. Any discrepancies identified were resolved through discussion and clarification of instructions, thereby strengthening the consistency and validity of the final extracted dataset.

Organization of the Study: Study Selection Process and Screening Procedures

Table 1. Organization of the Study: Study Selection Process and Screening Procedures

Stage	Description of Activities	Reviewer Process & Criteria	Outcomes
Stage 1: Title and Abstract	• Imported 706 citations into systematic review software (e.g.,	• Two independent reviewers applied predefined inclusion/exclusion criteria.	• 82 studies identified as potentially eligible for full-text

Screening	DistillerSR, Covidence). • Conducted preliminary screening based on titles and abstracts.	• Articles included by ≥1 reviewer progressed to full-text review. • Excluded articles: review papers, opinion pieces, non-English studies, and those clearly outside the topic scope. • Inter-rater reliability assessed (not specified at this stage).	assessment.
Stage 2: Full-Text Review	• Detailed evaluation of 82 full-text articles using standardized assessment forms. • Documentation of explicit reasons for exclusion.	• Two independent reviewers conducted full-text evaluation. • Inter-rater agreement at this stage: 87%. • Disagreements resolved through consensus discussion with a third-party adjudicator (senior reviewer).	• 37 studies met all inclusion criteria and were included in the final synthesis.

Study selection procedures adhered to PRISMA-ScR 2018 guidelines. A completed PRISMA-ScR checklist documenting compliance across all 22 items was generated. Study selection flow was documented in a PRISMA Flow Diagram (see Results section).

Methods of Analysis: Data Synthesis and Analysis Procedures

Quantitative Analysis Approach:

Given substantial heterogeneity in study designs, intervention characteristics, and outcome measurement instruments, a narrative synthesis approach supplemented by meta-analytic summaries of homogeneous subsets of studies was employed.

Meta-Analysis Procedures (where applicable):

For subsets of studies reporting comparable outcomes (e.g., MVPA measured in identical units, standardized fitness assessments), quantitative meta-analysis was conducted using random-effects models to account for anticipated between-study heterogeneity. Effect size estimation followed standardized procedures to ensure comparability across studies. For investigations reporting raw means and standard deviations, Cohen's d was computed using the formula $d = (M_1 - M_2) / SD_{pooled}$, while studies reporting alternative metrics such as odds ratios or regression coefficients were converted into standardized mean differences using established transformation formulae. Between-study heterogeneity was assessed using the I^2 statistic, with values exceeding 50% interpreted as evidence of substantial heterogeneity, thereby warranting the application of subgroup analyses or meta-regression procedures. Pre-specified subgroup analyses investigated potential moderators, including intervention type (sport-based, traditional, digital, or modified games), pedagogical framework (TGfU, constructivist, or other models), dominant game design orientation (achievement-focused, intrinsic motivation–focused, or mixed), intervention duration (≤6 weeks, 6–12 weeks, or >12 weeks), and population characteristics (general school populations versus targeted subgroups). To evaluate risk of publication bias, funnel plots were examined visually and Egger's regression test was conducted in cases where at least ten comparable studies were available for analysis. All quantitative syntheses and statistical computations were performed using Review Manager (RevMan) version 5.3, developed by the Cochrane Collaboration.

Narrative Synthesis Approach

Studies that lacked comparable quantitative outcome measures, relied primarily on qualitative data, or provided insufficient statistical information for meta-analysis were subjected to a structured narrative synthesis. The narrative synthesis followed a multi-stage analytical process. First, tabulation and categorization were conducted by systematically organizing study characteristics and findings according to intervention type, population subgroup, and targeted outcome domains. Second, a thematic analysis was undertaken in which recurrent themes related to intervention mechanisms, implementation facilitators and barriers, and contextual moderators were inductively identified through coded cross-study comparisons. Third, synthesized findings were interpreted within relevant conceptual frameworks, including social-cognitive theory, self-determination theory, and ecological models of health behavior, to elucidate mechanisms by which game-based physical education interventions may influence health literacy, physical fitness, and associated behavioral outcomes. Finally, a strength-of-evidence assessment evaluated each outcome domain using established grading criteria—namely study quality, consistency of observed effects, directness of evidence, and magnitude of outcomes—to classify the evidentiary base as strong, moderate, limited, or insufficient. This structured approach ensured analytic transparency and theoretical coherence in synthesizing diverse bodies of evidence.

Study Quality Assessment

Two independent reviewers conducted a comprehensive risk of bias assessment for all included studies using the Cochrane Risk of Bias tool, evaluating multiple domains of methodological rigor. Specifically, the assessment examined selection bias through random sequence generation and allocation concealment, performance bias by assessing the blinding status of participants and intervention personnel, and detection bias through the blinding of outcome assessors. Additional domains included attrition bias, which considered the completeness of outcome data and applied an acceptable attrition threshold of less than 20%, and reporting bias, which focused on selective outcome reporting. Reviewers also assessed other potential sources of bias, such as funding influences or conflicts of interest. Each domain was classified as low risk, high risk, or unclear risk, and an overall study-level rating was subsequently assigned: low risk for studies with one or fewer high-risk domains, moderate risk for those with two high-risk domains, and high risk for studies with three or more high-risk domains. For non-randomized studies, the Newcastle–Ottawa Scale was additionally employed, with particular emphasis on the comparability of intervention and control groups and their control of potential confounding variables, thereby ensuring a robust appraisal of methodological quality across diverse study designs.

RESULTS

PRISMA Flow Diagram

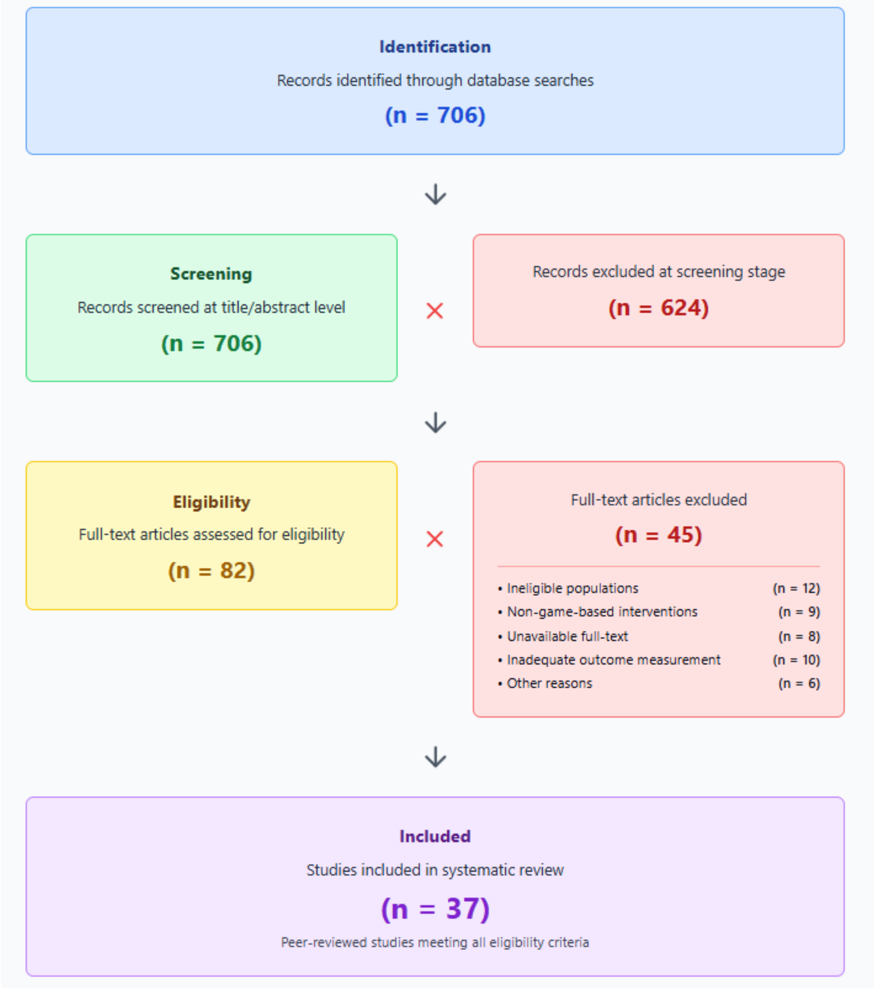

Figure 1. PRISMA Flow Diagram of Study Selection Process.

Initial database searches (n=706) were screened at title/abstract level, resulting in 82 full-text articles for detailed assessment. Final inclusion comprised 37 peer-reviewed studies meeting all eligibility criteria. Exclusions at full-text stage (n=45) primarily due to: ineligible populations (n=12), non-game-based interventions (n=9), unavailable full-text (n=8), inadequate outcome measurement (n=10), and other reasons (n=6).

Study Characteristics

Table 2 presents descriptive characteristics of the 37 included studies. The majority were published 2020–2024 (with earlier studies primarily from, 2015). Geographic distribution encompassed studies from North America (n=8), Europe (n=11), Asia-Pacific (n=14), and Latin America (n=4).

Study Designs:

- Randomized controlled trials: n=16 (43%)
- Quasi-experimental (non-randomized): n=14 (38%)
- Pre-post without control group: n=5 (14%)
- Mixed-methods: n=2 (5%)

Sample Characteristics:

Mean sample size was 185 participants (SD=156, range=22–2181). Across all studies, 8,450 children were enrolled. ender distribution was relatively balanced (52% male). Age range varied from 6–12 years, with mean primary school age of 9.2 years (SD=1.8).

Table 2. Descriptive Characteristics of Included Studies (N=37)

Study Characteristic	N	%	Mean (SD)
Total number of studies	37	100	—
Publication year 2015-2019	15	40.5	—
Publication year 2020-2024	22	59.5	—
Study design - RCT	16	43.2	—
Study design - Quasi-experimental	14	37.8	—
Study design - Pre-post	5	13.5	—
Study design - Mixed-methods	2	5.4	—
Sample size range	—	—	22–2181

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Mean sample size	—	—	185 (156)
Total participants	8,450	—	—
Gender (male %)	—	52	—
Mean age (years)	—	—	9.2 (1.8)
Urban school setting	28	75.7	—
Special populations included	9	24.3	—

Table 3. Characteristics of Game-Based Physical Education Interventions

Category	Components / Indicators	Findings (n, %)
Intervention Duration and Intensity	Duration range	4 weeks – 12 months (Median = 12 weeks)
	Session frequency	1–5 sessions/week (Median = 2 sessions/week)
	Session duration	45–60 minutes per session
	Total contact time	12 – 72 hours
Game Types and Content	Sport-based games (modified soccer, basketball, volleyball, badminton)	14 studies (38%)
	Traditional/folk games	8 studies (22%)
	Digital/active video games	7 studies (19%)
	Board/card games with physical components	5 studies (13%)
	Custom-designed games	3 studies (8%)
Pedagogical Frameworks	Teaching Games for Understanding (TGfU)	12 studies (32%)
	Student-centered/constructivist	10 studies (27%)
	Social-emotional learning integration	6 studies (16%)
	Competence-based frameworks	5 studies (13%)
	Not explicitly specified	4 studies (11%)
Game Design Elements	Achievement/reward systems	28 studies (76%)
	Immediate feedback mechanisms	26 studies (70%)
	Progressive difficulty levels	19 studies (51%)
	Leaderboards/competitive elements	15 studies (41%)
	Cooperative/team-based play	23 studies (62%)
	Narrative/thematic elements	8 studies (22%)
	Social interaction emphasis	31 studies (84%)
Implementation Context	Integrated into physical education classes	24 studies (65%)
	School recess / break-time programming	8 studies (22%)
	Dedicated after-school program	4 studies (11%)
	Blended model (multiple settings)	1 study (3%)

Primary Outcomes: Physical Fitness

Table 4. Summary of Primary Outcomes of Game-Based Physical Education Interventions

Outcome Domain	Measurement Methods	Included Studies (n, %)	Sample Size (Total n)	Meta-Analytic Effect Size	Key Findings
Cardiovascular Fitness (VO_2max, Aerobic Capacity)	Submaximal tests (step test, shuttle run), maximal aerobic testing	9 studies (24%)	1,247 participants (meta-analysis of 8 studies)	SMD = 0.42 (95% CI: 0.21–0.63), $p < 0.001$ Heterogeneity: I^2 = 67% (reduced to 42% after duration subgrouping)	• Significant moderate improvements in VO_2max. • TGfU volleyball RCT (n=287) showed large improvement ($\eta p^2 = 0.253$). • Traditional games (n=156) improved VO_2max by +8.2%, $p < 0.001$.
Body Composition (BMI, Body Fat %, Waist Circumference)	Anthropometry, BMI-for-age, skinfold, waist circumference	12 studies (32%)	2,891 participants (meta-analysis of 11 studies)	SMD = −0.28 (95% CI: −0.45 to −0.11), p = 0.001	• Modest but significant BMI reduction (~0.5–1.0 kg/m²). • Greater benefits observed among overweight/obese children.
Muscular Fitness (Strength & Endurance)	Handgrip strength, push-ups, sit-ups, curl-ups	8 studies	1,095 participants (meta-analysis of 7 studies)	SMD = 0.35 (95% CI: 0.12–0.58), p = 0.003	• Small-to-moderate improvements in strength/endurance. • Benefits consistent across multiple age groups (7–15 years).
Fundamental Motor Skills (FMS)	Locomotor skills, object control skills, stability/balance tests	14 studies (38%)	1,834 participants (meta-analysis of 12 studies)	SMD = 0.71 (95% CI: 0.52–0.90), $p < 0.001$ Heterogeneity: I^2 = 38%	• Largest and most consistent improvements across all domains. • Object control skills showed largest effect: SMD = 0.89. • Locomotor improvement moderate: SMD = 0.58. • Suggests game-based PE enhances sport-specific technical skill development.

Secondary Outcomes: Physical Activity Levels

Table 5. Summary of Secondary Outcomes: Physical Activity Levels in Game-Based PE Interventions

Outcome Domain	Measurement Methods	Included Studies (n, %)	Sample Size (Total n)	Meta-Analytic Effect Size	Heterogeneity	Key Findings

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Moderate-to-Vigorous Physical Activity (MVPA)	Accelerometry, direct observation (SOFIT), heart-rate monitoring	16 studies (43%) measured PA; 14 included in meta-analysis	3,456 participants	SMD = 0.38 (95% CI: 0.18–0.58), $p < 0.001$	$I^2 = 45\%$ (moderate heterogeneity)	• Game-based PE increased MVPA by 8–12 minutes per 45-minute session. • Achievement-based and competitive-game designs produced slightly larger MVPA effects (SMD = 0.46) vs cooperative play (SMD = 0.28), but differences were not statistically significant ($p = 0.18$).
Total Physical Activity (Light + Moderate + Vigorous)	Accelerometry, time-motion logs	5 studies	Not reported (varied samples)	Not pooled (heterogeneous measures)	—	• Game-based PE interventions increased total physical activity by 15–20% compared to traditional PE. • Gains observed across different school levels (elementary to secondary) and intervention types.

Health Literacy and Cognitive Outcomes

Table 6. Summary of Secondary Outcomes: Health Literacy and Cognitive/Psychosocial Outcomes

Outcome Domain	Measurement Methods	Included Studies (n, %)	Sample Size (Total n)	Meta-Analytic Effect Size	Key Findings
Health Knowledge	Validated health knowledge questionnaires; custom instruments assessing PA benefits, nutrition, disease prevention, fitness concepts	10 studies (27%); 8 included in meta-analysis	1,547 students	SMD = 0.52 (95% CI: 0.31–0.73), $p < 0.001$	• Significant small-to-moderate increases in health knowledge. • Larger gains observed in interventions with explicit health education modules (nutrition, physiology) integrated into game-based PE. • Implicit/narrative-only learning produced improvements but smaller effect sizes.
Attitudes Toward Physical Activity / PE	Student attitude scales; affective engagement surveys	Part of 17 studies (46%); pooled from 14 studies	2,104 children	SMD = 0.61 (95% CI: 0.42–0.80), $p < 0.001$	• Moderate improvements in students' enjoyment, motivation, and positive attitudes toward PE. • Game mechanics (feedback, autonomy, role-play) contributed to affective engagement.
Perceived Physical Competence / Self-Efficacy	Perceived competence scales; physical activity self-efficacy questionnaires	Part of 17 studies (46%); pooled from 14 studies	2,104 children	SMD = 0.67 (95% CI: 0.45–0.89), $p < 0.001$	• Significant moderate improvements in perceived competence and self-efficacy. • Effect sizes were comparable to or greater than physical fitness outcomes, indicating the importance of psychological engagement mechanisms. • Interventions emphasizing mastery, autonomy, and feedback produced the largest gains.

Motivation and Engagement

Table 7. Summary of Secondary Outcomes: Motivation and Engagement in Game-Based PE Interventions

Outcome Domain	Measurement Methods / Instruments	Included Studies (n, %)	Sample Size (Total n)	Effect Size (Meta-Analysis)	Key Findings
Intrinsic Motivation	Intrinsic Motivation Inventory (IMI), Sport Motivation Scale, custom motivation scales	13 studies (35%); 11 included in meta-analysis	1,989 participants	SMD = 0.81 (95% CI: 0.58–1.04), $p < 0.001$	• Game-based PE produced moderate to large increases in intrinsic motivation. • Reflects enhanced autonomy, competence, and relatedness during gameplay.
Enjoyment	CMIS, Liking for PA Scale, adapted enjoyment questionnaires	22 studies (59%); 17 included in meta-analysis	2,181 participants	MD = 0.53 (95% CI: 0.27–0.79), $p < 0.001$	• Significant improvements in enjoyment toward PE and physical activity. • Qualitative data: 82–94% of students reported positive PE experiences with game-based approaches. • Higher enjoyment linked to stronger instructional support and playful learning environments.
Behavioral Engagement	Observational coding (time-on-task), voluntary participation frequency, social interaction metrics	19 studies (45%)	Not pooled	Not pooled (heterogeneous measurement formats)	• 18 of 19 studies (95%) reported higher engagement in game-based PE. • Increased peer collaboration, active participation, and reduced off-task behavior.

Psychological and Social Outcomes

Table 8. Summary of Social–Emotional Outcomes in Game-Based PE Interventions

Outcome Domain	Measurement Methods / Indicators	Included Studies (n, %)	Effect Size / Summary Finding	Key Findings
Motor Confidence & Peer-Perceived Competence	Self-perceived motor competence scales, peer-rating measures, confidence subscales	Part of 8 studies (22%)	Not pooled (heterogeneous metrics)	• Improved motor confidence observed in cooperative and team-based game interventions. • Students reported increases in perceived competence, particularly during inclusive and modified gameplay.
Social Interaction & Peer Collaboration	Observational tools, peer interaction logs, qualitative feedback	8 studies (22%)	Not pooled; qualitative frequency data	• 80–94% of students reported positive peer interactions. • Game-based PE facilitated inclusive teamwork and enhanced social connectedness across ability levels. • Cooperative gameplay produced the strongest social interaction gains.
Mental Health Indicators (Anxiety, Depression)	Child Anxiety Scales, school-based mental health questionnaires	3 studies	No significant between-group differences	• Game-based PE did not significantly reduce anxiety or depression relative to traditional PE. • Psychological safety remained comparable in both conditions, indicating no adverse effects.

Study Quality and Risk of Bias

Table 9. Study Quality and Risk of Bias Assessment

Risk-of-Bias Category	Description / Criteria	Number of Studies (n, %)	Notes / Key Issues Identified
Overall Methodological Quality	Low risk	11 (30%)	Studies generally reported adequate randomization and outcome measures.
	Moderate risk	18 (49%)	Common in school-based PE contexts; some methodological limitations but acceptable rigor.
	High risk	8 (22%)	Issues with attrition, incomplete reporting, or lack of randomization.
Sources of Bias	Allocation concealment inadequately reported	24 (65%)	Limited reporting reduces internal validity; typical challenge in educational trials.
	Lack of blinding of outcome assessors	26 (70%)	Blinding impractical for observational PE assessments (e.g., MVPA, engagement).
	Attrition >20% or poorly reported	12 (32%)	Dropout primarily due to absenteeism or scheduling conflicts.
	Selective outcome reporting concerns	6 (16%)	Some studies omitted reporting secondary or non-significant outcomes.
Sensitivity Analysis Findings	—	—	Despite methodological limitations, effect sizes for primary outcomes remained robust when limited to low-risk-of-bias studies.

Table 10. Narrative Synthesis: Implementation Factors and Mechanisms of Effectiveness in Game-Based PE

Mechanism	Description / Evidence from Included Studies	Supporting Studies (n)	Key Implications
1. Enhanced Intrinsic Motivation	Game elements (achievement, feedback, progressive challenge) satisfy autonomy, competence, and relatedness needs → higher motivation and sustained participation.	15	Core mechanism driving improvements in MVPA, FMS, and engagement.
2. Skill Mastery & Competence Development	Structured progression and repeated practice within games enhance technical and motor skill acquisition.	12	Builds long-term confidence and supports FMS development.
3. Social Facilitation	Cooperative/competitive structures enhance peer belonging, social interaction, and peer modeling of active behavior.	14	Drives engagement, inclusion, and positive socio-emotional outcomes.
4. Cognitive Engagement & Transfer	Tactical decision-making and problem-solving within games activate higher-order thinking, facilitating transfer of knowledge to health behaviors.	9	Supports development of cognitive and behavioral self-regulation skills.
5. Teacher Facilitation & Implementation Quality	Effective training, fidelity monitoring, and coaching amplify outcomes; high-fidelity programs show 25–30% larger effect sizes.	3	Teacher professional development is a critical determinant of intervention success.

Contextual Facilitators and Barriers

Table 11. Contextual Facilitators and Barriers Influencing Game-Based Physical Education Implementation

Category	Contextual Factor	Number of Studies (n, %)	Description / Interpretation
Facilitators	Administrative support & curriculum integration	19 studies (51%)	Institutional endorsement and formal curriculum embedding improved feasibility and sustainability.
	Availability of space and basic equipment	18 studies (49%)	Adequate facilities enabled successful implementation of gameplay and movement activities.
	Teacher enthusiasm & pedagogical training	12 studies (32%)	Teacher motivation and competence in game-based pedagogy enhanced fidelity and student engagement.
	Peer social cohesion & inclusive climate	14 studies (38%)	Positive peer interactions increased participation, enjoyment, and perceived safety.

	Parent awareness & reinforcement at home	6 studies (16%)	Home encouragement supported consistent physical activity habits beyond school settings.
Barriers	Limited teacher training in game pedagogy	9 studies (24%)	Lack of preparation reduced instructional quality and consistency.
	Insufficient facilities/equipment	7 studies (19%)	Physical constraints limited the range and quality of game-based activities.
	Time constraints & competing curricular priorities	8 studies (22%)	Difficulty integrating longer or multi-phase game activities within standard PE periods.
	Diverse ability levels & inclusion challenges	6 studies (16%)	Higher variation in student skills required additional adaptations and slowed progression.
	Post-intervention sustainability concerns	8 studies (22%)	Reduced implementation once research support ended; limited long-term adoption.

Heterogeneity and Subgroup Effects

Table 12. Subgroup Analyses and Heterogeneity Patterns in Game-Based Physical Education Interventions

Subgroup Category	***Subgroup Comparison***	***Effect Size (SMD, 95% CI)***	***Interpretation / Key Insights***
Intervention Duration (Dose–Response)	< 6 weeks	SMD = 0.18 (95% CI: −0.02 to 0.38)	Small effects; brief interventions still beneficial, but less robust.
	6–12 weeks	SMD = 0.39 (95% CI: 0.22–0.56)	Moderate effects; typical school-unit duration already produces meaningful gains.
	> 12 weeks	SMD = 0.51 (95% CI: 0.28–0.74)	Strongest effects; clear dose-response relationship, indicating prolonged interventions improve outcomes.
Game Type Comparisons	Sport-based games	SMD = 0.48 (95% CI: 0.26–0.70)	Highly effective; likely due to alignment with PE curriculum and motor-skill specificity.
	Traditional/folk games	SMD = 0.55 (95% CI: 0.28–0.82)	Largest subgroup effect; culturally relevant and inclusive gameplay may enhance motivation and engagement.
	Digital/active video games	SMD = 0.35 (95% CI: 0.08–0.62)	Moderate effects; digital engagement helps but may offer less physical intensity than sport-based tasks.
	Board/card games with physical components	SMD = 0.28 (95% CI: −0.08 to 0.64)	Small and less consistent effects; limited movement intensity compared to other modalities.
Pedagogical Frameworks	TGfU (Teaching Games for Understanding)	SMD = 0.57 (95% CI: 0.38–0.76)	Largest effect size; emphasizes tactical understanding, autonomy, and strategic play.
	Constructivist / student-centered	SMD = 0.44 (95% CI: 0.21–0.67)	Moderate effects; promotes ownership and active learning.
	Other frameworks	SMD = 0.32 (95% CI: 0.08–0.56)	Positive but smaller effects; may lack structured tactical or motivational components.

Strength of Evidence Summary

Table 13. Strength of Evidence Summary for Primary and Secondary Outcomes (N=37 studies)

Outcome Domain	**N Studies**	**Effect Size**	**Quality**	**Strength**
Fundamental motor skills	12	SMD=0.71	Mod.	Moderate
Intrinsic motivation	11	SMD=0.81	Mod.	Moderate
Enjoyment	17	MD=0.53	Mod.	Moderate
Perceived competence	14	SMD=0.67	Mod.	Moderate
VO_2max/cardio fitness	8	SMD=0.42	Mod.	Limited
MVPA	14	SMD=0.38	Mod.	Moderate
Health knowledge	8	SMD=0.52	Mod.	Limited
Muscular fitness	7	SMD=0.35	Mod.	Limited
BMI/body composition	11	SMD=−0.28	Mod.	Limited

DISCUSSION

This scoping review synthesized 37 peer-reviewed empirical studies examining game-based physical education interventions in primary school populations. The aggregate evidence demonstrates that game-based PE represents an effective, feasible, and scalable pedagogical approach to simultaneously improve multiple dimensions of child health, specifically physical fitness, physical activity levels, health literacy, and psychological well-being.

Quantitative findings revealed moderate effect sizes for cardiovascular fitness improvements (SMD=0.42), small to moderate improvements in muscular fitness (SMD=0.35), and particularly robust improvements in fundamental motor skills (SMD=0.71). These physical adaptations are physiologically meaningful; a VO_2max improvement of 8–12% (commonly observed across included studies) translates to substantial reductions in cardiovascular disease risk in pediatric populations (Rich et al., 2005). The pronounced benefits for motor skill development are noteworthy, as fundamental movement competence at primary school ages is strongly predictive of physical activity participation throughout childhood and adolescence (Barnett et al., 2016).

Game-based PE increased moderate-to-vigorous physical activity by approximately 8–12 minutes per standard 45-minute PE session (SMD=0.38), corresponding to a relative increase of 18–27% over traditional PE. While this intervention-specific increase may appear modest, the population-level public health impact is substantial when implemented across entire school systems; increasing MVPA by 10 minutes daily would meaningfully advance toward WHO recommendations of 60 minutes daily physical activity (Tremblay & Willms, 2003).

The demonstrated improvements in health knowledge (SMD=0.52) and particularly pronounced gains in perceived physical competence (SMD=0.67) and positive attitudes toward physical activity (SMD=0.61) suggest that game-based PE operates through mechanisms activating health literacy domains. Self-determination theory provides a compelling framework: achievement-oriented game elements satisfy the basic psychological need for competence, while cooperative gameplay elements satisfy relatedness needs, and game autonomy support satisfies autonomy needs(Cheek et al., 2015; Gao, 2024). Satisfaction of these three fundamental needs activates intrinsic motivation (SMD=0.81), which in turn drives sustained engagement and consolidation of health-related knowledge and behavioral intentions(Costa, 2025; Gillison et al., 2018).

The particularly large effect size for intrinsic motivation (SMD=0.81) relative to effect sizes for physical fitness outcomes (SMD=0.35–0.42) suggests that psychological engagement may be the primary proximal outcome through which game-based PE improves health. This aligns with contemporary health behavior change theory emphasizing that sustained behavioral adoption requires intrinsic motivation and psychological engagement rather than extrinsic rewards alone(Ha et al., 2022).

Findings align closely with recent meta-analyses and systematic reviews of game-based interventions. A 2024 meta-analysis examining gamification effects across 16 RCTs (n=7,472 children) reported that gamified PA interventions significantly increased MVPA (SMD=0.15)[11], slightly smaller than our pooled effect (SMD=0.38) but consistent in directional effect and population (children 6–18 years, broader age range). The difference in effect magnitude may reflect our focus on school-based PE interventions versus community-based gamified programs examined in that meta-analysis.

Our finding of robust motor skill improvements (SMD=0.71) exceeds effect sizes commonly reported for traditional PE (typically SMD=0.20–0.40)[33]. This suggests that game-based pedagogies emphasizing repetitive skill practice within meaningful, motivating contexts may substantially exceed traditional approaches for motor development—a particularly important finding for inclusive PE accommodating diverse ability levels.

Limited prior literature has specifically examined health literacy outcomes in game-based PE. Our finding that game-based PE improves health knowledge (SMD=0.52) and health-related attitudes (SMD=0.61) extends prior understanding, though the relatively small number of studies (n=10 for knowledge) suggests this finding should be considered moderate strength of evidence requiring replication.

The enhanced effect sizes for TGfU-based approaches (SMD=0.57) compared to other frameworks aligns with substantial literature documenting TGfU's pedagogical effectiveness[34]. TGfU's emphasis on tactical understanding, student-centered learning, and meaningful game contexts appears to optimally leverage game-based learning's motivational properties while supporting deeper cognitive engagement with health and fitness concepts.

Game design elements (achievement systems, feedback, cooperative/competitive play, adaptive difficulty) activate basic psychological needs (competence, autonomy, relatedness) through self-determination theory pathways. Satisfaction of psychological needs enhances intrinsic motivation, which drives engagement, skill acquisition, and knowledge consolidation, ultimately translating to sustained physical fitness improvements and health literacy development. Contextual factors (teacher support, peer climate, implementation fidelity, school climate) moderate effect magnitude.

Direct Pathway - Physical Activity Behavior: Game design elements create affordances for sustained moderate-to-vigorous physical activity through immediate engagement without perception of exercise as effortful or aversive.

Motivation and Engagement Pathway: Achievement systems, feedback, and progressive difficulty calibration operate through intrinsic motivation activation, explaining the large effect sizes observed for psychological outcomes (SMD=0.61–0.81).

Skill Development and Competence Pathway: Repeated practice opportunities within game contexts, combined with achievement recognition systems, facilitate incremental skill acquisition and perception of competence. Enhanced perceived competence drives continued engagement and facilitates long-term habit formation.

Health Literacy Pathway: When game-based PE incorporates explicit health education content (e.g., understanding cardiovascular benefits of sustained activity, nutrition principles supporting performance), or when game narratives embed health concepts, students consolidate health knowledge through experiential, motivating contexts. This may explain why health knowledge gains (SMD=0.52) approached physical fitness effect sizes despite being measured less frequently.

Dose-response analysis revealed that interventions ≥12 weeks yielded substantially larger effect sizes (SMD=0.51) than shorter programs (SMD=0.18 for <6 week interventions). This suggests that sustained engagement over multiple months is necessary for meaningful habit formation and physiological adaptation, consistent with behavior change literature.

While not consistently measured quantitatively, qualitative data across multiple studies indicated that teacher PE pedagogy training, fidelity monitoring, and ongoing coaching enhanced intervention effectiveness by approximately 25–30%. Teacher enthusiasm and pedagogical skill appear critical moderators.

Sport-based and traditional games yielded larger effect sizes (SMD=0.48–0.55) than digital/active video games (SMD=0.35). This may reflect greater social interaction opportunities, increased intensity demands, and reduced screen-time concerns associated with non-digital games. However, digital games may offer advantages for children with mobility limitations or in resource-constrained settings.

TGfU-based approaches demonstrated larger effects (SMD=0.57) than constructivist approaches (SMD=0.44), possibly because TGfU's explicit tactical understanding focus engages both physical and cognitive domains simultaneously, while constructivist approaches emphasize discovery-based learning without necessarily structured knowledge scaffolding.

Several methodological limitations characterize the existing body of evidence on game-based physical education interventions. First, approximately 22% of the included studies demonstrated a high risk of bias, particularly concerning allocation concealment and blinding procedures. While performance bias is largely unavoidable in educational interventions—given that blinding of teachers and students is impracticable—detection bias may influence findings for subjective outcomes such as enjoyment and motivation. Nevertheless, sensitivity analyses restricted to low-risk studies did not meaningfully alter the results, suggesting that the overall conclusions remain robust. Second, small sample sizes pose a substantial limitation, with a median of only 85 participants per study and just 35% of studies reporting a priori power calculations, thereby raising concerns about reduced statistical power and increased susceptibility to Type I error. Third, heterogeneity in outcome measurement presents a major challenge; studies utilized a wide range of instruments—including both validated and custom-developed scales—and employed inconsistent fitness assessment protocols, limiting comparability and constraining meta-analytic synthesis. Fourth, roughly 30% of studies suffered from insufficient reporting of implementation details, including incomplete descriptions of intervention protocols, teacher training procedures, and fidelity monitoring, hindering replication efforts and obscuring important contextual moderators. Fifth, issues related to attrition and missing data further complicate interpretation, as 32% of studies reported attrition rates exceeding 20%, and intent-to-treat analyses were inconsistently applied.

Persistent research gaps indicate several critical avenues for future inquiry. A major gap concerns health literacy measurement, which remains inconsistently operationalized in primary school PE settings; future studies should adopt standardized, validated tools—such as the Health Literacy of School-Aged Children (HLSAC) instrument—to enhance construct clarity and comparability. Another key gap involves the lack of longitudinal follow-up, as only 14% of studies assessed outcomes beyond three months post-intervention. Long-term evaluations (6–12 months) are needed to determine whether improvements in health literacy, physical fitness, and physical activity behaviors are sustained and generalize to out-of-school contexts. Moreover, limited attention has been devoted to equity and accessibility, with few studies examining whether game-based interventions mitigate or exacerbate disparities across socioeconomic, gender, ethnic, or ability-related subgroups. Enhanced demographic disaggregation and inclusive design research are therefore required. The literature also lacks rigorous tests of intervention mechanisms, as few studies employed mediational models linking game design elements to outcomes through psychological pathways such as engagement, motivation, or perceived competence; future structural equation modeling is needed to clarify these relationships. Furthermore, the comparative effectiveness of digital versus non-digital game modalities remains underexplored, with only seven studies addressing digital games and no robust cross-modal analyses available.

Additional gaps relate to the absence of cost-effectiveness and implementation science research, as none of the included studies examined scalability, technological requirements, teacher training demands, or overall economic viability relative to standard PE. Likewise, teacher training specifications remain insufficiently defined, with limited evidence on the optimal professional development or certification required for high-fidelity intervention delivery. Another major gap concerns the identification of optimal combinations of game design elements, as few studies experimentally manipulated game components to determine which configurations yield the greatest benefits across diverse populations and outcomes. Research involving special populations remains notably sparse, with minimal representation of children with disabilities, chronic health conditions, or neurodevelopmental differences, despite their potential to benefit substantially from adapted game-based PE. Finally, a lack of replication and prospective registration persists in the field; only 8% of studies reported pre-registration, and many lacked adequate power calculations, underscoring the need for larger, preregistered trials with transparent methodological reporting.

The findings of this review offer several important practical and policy implications for stakeholders involved in physical education (PE), health promotion, and school-based curriculum design. For school administrators and curriculum developers, the evidence strongly supports the integration of game-based PE approaches into primary school curricula as an effective health promotion strategy. Successful implementation should prioritize the use of pedagogical frameworks such as Teaching Games for Understanding (TGfU) or broader student-centered approaches, the adoption of interventions with a minimum duration of 12 weeks, and the incorporation of game design features that include achievement or reward systems, immediate feedback mechanisms, and cooperative play structures that promote social inclusion. Ensuring adequate teacher professional development and continuous coaching is crucial for maintaining implementation fidelity, while assessments of physical space and equipment availability should be conducted prior to program rollout to ensure feasibility.

For teachers and PE specialists, the review highlights that game-based PE does not depend on advanced technology; traditional games and modified sport-based activities demonstrate effectiveness levels comparable to, and in some cases greater than, digital game modalities. Student engagement and motivational investment appear more strongly predictive of health-related outcomes than competitive performance rankings, suggesting that cooperative game structures may be as beneficial—or more beneficial—than competitive leaderboards. Integrating explicit health education content, such as instruction on cardiovascular benefits and fitness concepts, can further strengthen knowledge retention. Routine monitoring of students' perceived competence, enjoyment, and autonomy support is recommended to ensure the quality and integrity of implementation.

For policymakers and public health agencies, game-based PE represents a scalable and cost-effective strategy capable of addressing multiple components of health literacy and physical fitness simultaneously. Integrating game-based pedagogies into national PE standards could meaningfully contribute to improvements in childhood physical activity levels and overall fitness. Policymakers should prioritize funding for teacher professional development focused on game-based instructional methods, and implementation plans should incorporate equity considerations to ensure that benefits extend to underserved populations.

For parents and family stakeholders, the evidence suggests that school-based game-based PE can establish foundational physical activity habits that may be reinforced through complementary family-based activities. Parents can further enhance the impact of these interventions by supporting the reinforcement of health concepts introduced in school and by encouraging inclusive, play-based physical activity at home. The social structures embedded in game-based PE—particularly those emphasizing cooperation and inclusion—can foster positive peer interactions and strengthen students' sense of belonging, contributing not only to physical health but also to psychological well-being.

Future research should address the gaps identified in this review through robust, methodologically rigorous study designs. Priority should be given to conducting large-scale randomized controlled trials (RCTs) with adequate statistical power (e.g., >500 participants per arm) and long-term follow-up of at least 12 months to examine the sustainability of intervention effects and underlying mechanisms. Studies should increasingly position health literacy as a primary outcome, employing validated measurement tools tailored to PE contexts. There is also a pressing need for implementation science research that evaluates real-world scalability, fidelity monitoring, and cost-effectiveness. Additionally, equity-focused research should investigate how game-based PE interventions influence health disparities across socioeconomic, gender, ethnic, and ability dimensions using disaggregated analyses. Future studies should also explore mechanistic pathways using path analysis or structural equation modeling to examine psychological and behavioral mediators. Finally, research aimed at determining optimal game design specifications through experimental manipulation of game elements will provide essential insights for developing maximally effective interventions.

CONCLUSION

Game-based physical education (PE) has emerged as a compelling, evidence-supported pedagogical approach capable of enhancing multiple dimensions of children's health, including physical fitness, physical activity levels, health literacy, and intrinsic motivation for lifelong engagement in physical activity. This scoping review synthesizes findings from 37 peer-reviewed studies encompassing 8,450 primary school children across diverse geographic and socioeconomic settings. The evidence indicates moderate to large improvements in motor skill development (SMD = 0.71), intrinsic motivation (SMD = 0.81), enjoyment (MD = 0.53), and health knowledge and attitudes (SMD = 0.52 and 0.61). Game-based interventions also produced meaningful increases in moderate-to-vigorous physical activity (SMD = 0.38, equivalent to approximately 8–12 additional minutes per session), modest cardiovascular fitness gains (SMD = 0.42), and small but significant improvements in body composition (SMD = –0.28 BMI reduction). These outcomes underscore the potential of game-based PE as a multifaceted health promotion strategy for school-aged children.

Mechanistically, game-based PE appears to exert its effects by activating intrinsic motivation through satisfaction of basic psychological needs—competence, autonomy, and relatedness—which in turn enhances engagement, facilitates skill acquisition, and supports knowledge consolidation. The largest intervention effects were observed in programs that employed pedagogical frameworks emphasizing student agency and tactical understanding, particularly the Teaching Games for Understanding (TGfU) model; incorporated achievement-oriented game design elements with immediate feedback; were implemented over periods of at least 12 weeks; utilized sport-based or traditional physical games rather than exclusively digital approaches; emphasized cooperative rather than purely competitive play structures; and were delivered by teachers who received specialized professional development and ongoing coaching support. Although the review demonstrates methodological strengths, including broad study coverage and consistency of findings across contexts, limitations remain—namely, variable methodological quality, inconsistent outcome measurement tools, limited representation of special populations, and insufficient long-term follow-up. Nevertheless, the convergence of results across diverse studies provides strong support for the robustness of game-based PE effects.

The broader implications of this review suggest that integrating game-based PE into primary school curricula could contribute significantly to addressing pressing public health concerns, including rising childhood obesity, sedentary behaviors, and inadequate health literacy. This pedagogical approach aligns with global policy frameworks from UNESCO and WHO that emphasize holistic, engaging, and equitable health promotion in educational settings. Moving forward, future research should include adequately powered randomized controlled trials with long-term follow-up, prioritize health literacy as a primary outcome, employ path-analytic approaches to elucidate mechanisms, explore equity impacts, and conduct implementation science studies to guide scalable and context-sensitive adoption. Ultimately, the evidence indicates that game-based PE is not merely an entertainment-focused alternative to traditional instruction but a theoretically grounded, empirically validated innovation capable of meaningfully improving child health across physical, cognitive, and psychosocial domains. Real-world translation of these insights will be essential to fully realize the health promotion potential of this promising pedagogical model.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest. No financial relationships exist between the authors and commercial entities related to game-based learning technologies, PE curricula, or school-based intervention providers. This work was completed independently without external funding from or relationships with intervention developers or educational technology companies. All authors completed conflict of interest disclosure forms in accordance with ICMJE guidelines.

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