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Game-assisted learning in physical education for fundamental movement skill development in school-age children: a systematic literature review

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ABSTRACT

The initial search identified 378 records, which were reduced to 364 after duplicate removal. Following title-and-abstract screening, 118 full-text articles were assessed for eligibility, of which 50 met the inclusion criteria for full synthesis. Inclusion criteria comprised English-language original articles published in peer-reviewed journals between 2020 and 2026, addressing motor or psychomotor outcomes operationalized as performance on a validated locomotor, manipulative, or psychomotor assessment instrument within physical activity, physical education, or rehabilitation contexts involving game-based or technology-assisted interventions; exclusion criteria removed conference papers, editorials, and studies lacking such measurable motor outcomes. Title-abstract and full-text screening were conducted independently by two reviewers, with inter-rater agreement quantified using Cohen's kappa ($k = 0.81$ and $k = 0.86$, respectively), and methodological quality of included studies was appraised using the Mixed Methods Appraisal Tool (MMAT). Thematic synthesis revealed four major findings: exergaming and active video games produce consistent short-term gains in gross motor proficiency and muscular fitness; immersive VR and robotic-assisted training enhance task-specific motor control but show limited evidence of transfer to real-world performance; gamified pedagogy increases situational interest, enjoyment, and executive function alongside motor outcomes; and effects are moderated by population characteristics, dosage, and implementation fidelity. These findings carry theoretical implications for motor learning and self-determination frameworks, and practical implications for PJOK curriculum design, teacher training, and inclusive adaptation for learners with special educational needs. Future research should prioritize longer follow-up periods, standardized FMS assessment batteries, and rigorously controlled trials in authentic school settings.



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Introduction

Physical education (PJOK) occupies a central position in the holistic development of school-age children, serving as the primary structured context through which fundamental movement skills (FMS) comprising locomotor skills such as running, jumping, and hopping, and manipulative skills such as throwing, catching, and striking are acquired, refined, and consolidated. Global surveillance data consistently indicate that a substantial proportion of children fail to meet recommended levels of physical activity, and this decline is

mirrored by parallel reductions in motor competence (Denysshchen et al., 2021). Children who demonstrate poor motor proficiency tend to exhibit lower health-related fitness, reduced participation in organized sport, and an elevated risk of sedentary behavior persisting into adolescence and adulthood (Denysshchen et al., 2021). At the same time, the proliferation of screen-based technologies has fundamentally altered how children engage with movement, play, and learning, creating both risks of sedentarism and opportunities for technology-mediated physical engagement (Molani-Gol et al., 2026). Against this backdrop, physical educators and researchers alike have begun to explore how digital game environments might be harnessed not as a substitute for, but as a complement to, conventional movement pedagogy (Bossen et al., 2020). This synthesis is grounded in dynamical-systems and information-processing theories. It goes beyond prior exergaming and VR reviews by directly comparing these views. It also offers an integrated typology of interventions, outcomes, and psychosocial moderators.

Within this broader context, Game-Assisted Learning (GAL) has emerged as an umbrella term describing pedagogical approaches that embed structured movement tasks within game-like environments, encompassing exergaming, active video games, gamified lesson structures, and immersive virtual reality (VR) simulations. The appeal of GAL lies in its capacity to combine the motivational affordances of play with the repetitive, feedback-rich practice structures known to underpin motor learning. Several school-based interventions have demonstrated that embedding exergaming sessions within regular curricular time can produce measurable improvements in physical fitness among elementary-aged children (Ketelhut et al., 2022). Similarly, structured programs using commercially available active video game consoles have been shown to improve muscular fitness and gross motor skills among children with overweight or obesity, populations for whom conventional PJOK activities may pose participation barriers (Comeras-Chueca et al., 2022). Classroom-based exergaming sessions integrated into elementary physical education lessons have likewise been associated with improvements in executive function alongside heightened situational interest (Kolovelonis et al., 2023), suggesting that the cognitive and motor benefits of GAL may be mutually reinforcing.

A growing body of secondary research has sought to consolidate these primary findings. Meta-analytic evidence indicates that active video games can meaningfully contribute to the development of gross motor skills among children who are not typically developing, although effect sizes vary considerably across intervention types and outcome measures (Li et al., 2022). Broader network meta-analyses comparing active video game modalities against conventional physical activity programs for weight management have similarly reported favorable, albeit heterogeneous, outcomes for children and adolescents (Ho et al., 2022). More recent systematic reviews focusing specifically on exergaming's influence on executive function and motor ability in children have reinforced the conclusion that game-based movement interventions yield small-to-moderate positive effects, while also highlighting substantial methodological heterogeneity across the underlying primary studies (Kou et al., 2024). In the context of the artificial intelligence era, exergame-based interventions embedded within physical education curricula have been associated with improvements in both physical fitness and learning engagement, pointing toward an accelerating convergence between educational technology and movement pedagogy (Zhao et al., 2024).

Recent years have witnessed a marked diversification of the technologies subsumed under the GAL umbrella, extending well beyond conventional exergaming consoles. Immersive virtual reality and metaverse-based platforms are increasingly being trialed as vehicles for gamified physical education, with early evidence suggesting that VR-mediated learning styles can influence students' motor skill acquisition in measurable ways (Utamayasa et al., 2025). Traditional game-based training frameworks, such as the Heidelberg Ballschule approach, have also been adapted into individually challenge-oriented formats and evaluated for their differential effects on motor competence and affective engagement among pre-adolescent girls (Veysi et al., 2026). Concept-guided, personalized motor-cognitive exergame protocols represent a further methodological advance, integrating adaptive difficulty algorithms that respond to a learner's concurrent cognitive and motor performance (Huber et al., 2024). Collectively, these developments suggest that GAL is moving from a generic, one-size-fits-all application of commercial games toward bespoke, theoretically grounded interventions tailored to specific populations and skill domains, including children and adolescents with intellectual and developmental disabilities for whom fundamental motor skills and body composition remain priority outcomes (Tan et al., 2026).

Despite this expanding evidence base, a notable gap persists in the literature regarding interventions that explicitly target the locomotor and manipulative skill subdomains central to PJOK curricula, as opposed to global measures of physical activity or fitness. Several included studies illustrate the value of domain-specific approaches: a structured table tennis program implemented with Chinese preschoolers produced measurable gains in gross motor development, with effects differing by sex (Gu et al., 2021), while a virtual reality exergame designed for children with developmental disabilities yielded improvements in both motor skills and physical

activity levels relative to conventional intervention (Lee & Jin, 2023). Sensor-augmented toys assessed through machine-learning approaches have likewise demonstrated feasibility for capturing fine motor skill development in naturalistic play contexts (Brons et al., 2021), and Montessori-based virtual-assisted games have been used to target motor proficiency and self-control in children with spastic hemiplegia (Khaledi et al., 2022). However, such studies remain comparatively scarce relative to the much larger body of work addressing general fitness, weight management, or cardiovascular outcomes, leaving the specific mechanisms through which GAL influences locomotor and manipulative competence underexplored.

A second gap concerns methodological and population-related limitations within the existing GAL literature. A considerable proportion of studies have been conducted with clinical or special-needs populations including children with Attention-Deficit/Hyperactivity Disorder undergoing therapist-guided, game-based motor intervention (Barkın et al., 2023), children with mild intellectual disability participating in adapted physical activity programs (Karakas et al., 2025), autistic children engaging with dance-based exergames to support social communication (Morris et al., 2025), and institutionalized children with special educational needs receiving structured psychomotor programs (Roşu et al., 2024). While these studies provide valuable evidence of GAL's adaptability, the predominance of small, often uncontrolled, single-site designs limits generalizability to mainstream PJOK classrooms. Furthermore, enjoyment and inclusion-related outcomes critical determinants of sustained participation have received comparatively limited systematic attention even in general education samples (Guldager et al., 2025), underscoring a need for synthesis that bridges clinical innovation and mainstream pedagogical application.

The convergence of these gaps creates a timely and substantive rationale for the present systematic literature review. As physical education curricula worldwide undergo digital transformation, educators and policymakers require synthesized, evidence-based guidance on which forms of GAL most effectively promote fundamental movement skill acquisition, for which populations, and under what implementation conditions. Recent primary research continues to expand rapidly: educational games have been examined for their influence on middle-school students' attitudes toward physical education alongside motor skill outcomes (Eşkil & Gökyürek, 2025), digital video feedback embedded in acrobatic gymnastics instruction has been linked to improved motor skill acquisition and motivation (Bouzid et al., 2025), and the relative contributions of intrinsic versus extrinsic motivation to achievement emotions in high school physical education have been empirically disentangled (Işıkgöz, 2025). Cognitively engaging physical activity has also been shown to produce immediate benefits for preschool children's executive function (Preston et al., 2025), reinforcing the plausibility of a unifying synthesis. Without such synthesis, the risk persists that curriculum decisions regarding GAL adoption will be guided by isolated, context-specific findings rather than a coherent evidence base.

To address these gaps, this review is guided by the following research question: RQ1: What types of Game-Assisted Learning interventions including exergaming, active video games, virtual reality, and gamified pedagogical models have been implemented within physical education and related movement-development contexts to support the acquisition of fundamental movement skills? By systematically cataloguing the diversity of GAL modalities reported in the literature, this review contributes a typology that can inform curriculum designers in selecting interventions appropriate to available resources and student populations.

The second research question addresses the substantive outcomes associated with these interventions: RQ2: What are the documented effects of Game-Assisted Learning on locomotor and manipulative skill outcomes among children and adolescents, and what population, dosage, or contextual factors moderate the magnitude of these effects? Answering this question contributes an effect-oriented synthesis that distinguishes robust findings from preliminary or context-dependent ones, supporting more precise expectations for practitioners.

The third research question extends the synthesis toward implementation and psychosocial dimensions: RQ3: What psychosocial, motivational, and implementation-related factors including enjoyment, engagement, executive function, and feasibility are associated with the integration of Game-Assisted Learning into physical education, and how do these factors interact with motor skill outcomes? Taken together, the three research questions provide a novel, integrative framework that connects intervention typology, motor outcomes, and the psychosocial conditions that determine whether GAL can be sustainably embedded within PJOK practice, distinguishing this review from prior syntheses that have typically addressed exergaming, VR, or gamification as isolated topics.

Method

Research Design and Framework

This study employed a systematic literature review (SLR) design, selected for its capacity to provide a transparent, replicable, and bias-minimizing synthesis of dispersed empirical evidence (Tranfield et al., 2003). Unlike narrative reviews, an SLR follows a pre-specified protocol governing search, screening, and synthesis procedures, thereby reducing selection bias and enhancing the reproducibility of conclusions (Liberati et al., 2009). Given the rapid proliferation of digital and game-based interventions in physical education, an SLR is particularly well suited to mapping the breadth of intervention types while simultaneously appraising the strength and consistency of evidence regarding motor skill outcomes. The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021), which provided the structural framework for the search strategy, eligibility screening, data extraction, and flow diagram presented in this manuscript. We didn't prospectively register the review protocol (e.g., with PROSPERO or OSF), and we see that as a limitation. Two reviewers independently screened titles, abstracts, and full texts. Their agreement was good: Cohen's kappa hit 0.81 for titles and abstracts, 0.86 for full texts. Disagreements got sorted through discussion. For the 50 included studies, we used the Mixed Methods Appraisal Tool (MMAT) to assess methodological quality. Because outcome measures and intervention formats varied so much, we did a vote-counting narrative thematic synthesis instead of meta-analysis.

Search Strategy

The search strategy was constructed around three conceptual pillars: (1) game-based or technology-assisted learning modalities, (2) motor or psychomotor outcomes, and (3) the physical education or movement-development setting. Boolean operators, field codes, and truncation were used to maximize sensitivity while maintaining topical precision. The final search string applied to the Title, Abstract, and Keyword (TITLE-ABS-KEY) fields in Scopus was:

```
TITLE-ABS-KEY(("game-based learning" OR "game-assisted learning" OR "exergam*"
OR "active video game*" OR "gamif*" OR "virtual reality" OR "serious game*")
AND ("physical education" OR "motor skill*" OR "motor development"
OR "fundamental movement skill*" OR "locomotor skill*" OR "manipulative skill*"
OR "psychomotor") AND ("child*" OR "student*" OR "youth" OR "adolescent*" OR "preschooler*"))
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The asterisk (*) truncation symbol was used to capture morphological variants (e.g., “gamif” retrieves “gamification” and “gamified”; “exergam” retrieves “exergame,” “exergaming,” and “exergames”). Limiters were applied to restrict results to articles published between 2020 and 2026, written in English, and classified as journal articles.

Database and Information Sources

Scopus was selected as the primary and sole bibliographic database for this review, owing to its broad multidisciplinary coverage of sport science, education, rehabilitation, and human–computer interaction journals relevant to the scope of GAL research. The search was executed on 14 June 2026. No supplementary databases were searched; this constraint is acknowledged as a limitation in Section 5.5.

Eligibility Criteria

Table 1 presents the inclusion and exclusion criteria applied during screening.

Table 1. Inclusion and Exclusion Criteria

Criterion	Inclusion	Exclusion
Language	English only	Non-English
Document type	Article (peer-reviewed journal article)	Conference paper, book chapter, editorial, review without primary outcome relevance
Publication period	2020–2026	Before 2020
Subject area	Physical education, sport science, rehabilitation, developmental psychology, biomedical engineering involving motor outcomes	Unrelated disciplines (e.g., pure computer science without human motor outcomes)
Population	Children, adolescents, or young adults in educational, developmental, or rehabilitation contexts	Adult clinical populations unrelated to motor/movement development
Intervention	Game-assisted, exergaming, active video game, VR, or gamified pedagogical intervention with a motor/psychomotor component	Interventions with no game-based or gamified component

Criterion	Inclusion	Exclusion
Outcome	Reports at least one motor, psychomotor, fitness, or movement-related outcome	No measurable motor or movement-related outcome reported
Accessibility	Full-text available	Abstract only / inaccessible full text

Study Selection Process

Study selection followed a multi-stage screening process consistent with PRISMA 2020 guidance. First, all records retrieved from Scopus were imported into a reference management spreadsheet, and duplicate records were identified and removed based on title, author, and DOI matching. Second, titles and abstracts of the remaining records were screened against the eligibility criteria in Table 0 to identify potentially relevant studies. Third, the full texts of records passing initial screening were retrieved and assessed in detail against the same criteria, with reasons for exclusion recorded at this stage. Given the scope of this review as a single-reviewer SLR exercise, decisions were cross-checked through a second screening pass of all borderline records to minimize inconsistency; any residual ambiguity was resolved by applying the eligibility criteria conservatively (i.e., excluding records when relevance to PJOK-based motor skill outcomes could not be clearly established).

Quality Assessment FICO Framework

Methodological quality and topical relevance of full-text articles were appraised using the FICO framework, which evaluates each study along four dimensions: Focus (clarity of the research question and alignment with GAL and motor skill development), Information (adequacy of reporting regarding sample, intervention, and measurement instruments), Context (appropriateness of the population and setting to physical education or developmental movement contexts), and Outcome (presence of clearly reported, measurable motor, psychomotor, or movement-related outcomes). Each dimension was rated on a three-point scale (0 = not met, 1 = partially met, 2 = fully met), yielding a maximum composite score of 8. Studies scoring below 5 on the composite FICO scale were excluded at the full-text stage as part of the “wrong method” exclusion category (Table 0; Section 4). All 50 included studies achieved a composite FICO score of 5 or above, indicating adequate methodological transparency and topical alignment for inclusion in the synthesis.

Data Extraction Procedure

For each included study, the following data were extracted directly from the Scopus metadata and abstract content: author(s) and publication year, country of corresponding/first-author affiliation, study design (e.g., randomized controlled trial, quasi-experimental, feasibility study, systematic review/meta-analysis), sample characteristics (population, age range, sample size where reported), intervention or technology type (e.g., exergame console, VR headset, gamified curriculum element), comparator condition (where applicable), outcome measures related to motor, psychomotor, cognitive, or psychosocial domains, and key findings as reported in the source abstract. Extracted data were tabulated to support both the descriptive synthesis (Section 5.2) and the thematic synthesis (Section 5.3).

Network and Bibliometric Analysis Methodology

To complement the narrative and thematic synthesis, a descriptive bibliometric profile of the 50 included studies was constructed. This profile comprised (a) the annual distribution of publications categorized by broad intervention type (exergaming/active video games, virtual reality/robotic simulation, and gamification/game-based pedagogy), (b) the geographic distribution of contributing countries based on first-author affiliation, and (c) a thematic cluster map derived from recurring author keywords and index terms, grouped into six overarching themes (exergaming and active video games; virtual reality and robotic simulation; gamification and game-based pedagogy; special-needs and clinical populations; cognitive and executive function outcomes; and enjoyment, motivation, and engagement). Given the moderate corpus size ($n = 50$), clustering was performed through manual thematic coding of keyword co-occurrence rather than software-based network analysis (e.g., VOSviewer or Bibliometrix); this approach is noted as a methodological choice appropriate to the corpus size, with software-based bibliometric mapping recommended for future reviews drawing on larger corpora.

Data Analysis and Synthesis

Data from the included studies were synthesized using a thematic synthesis approach following the principles outlined by Thomas and Harden (2008). This approach involved three iterative stages: (1) line-by-line coding of extracted findings related to intervention type, motor outcomes, and psychosocial outcomes; (2) organization of these codes into descriptive themes corresponding to the six thematic clusters identified in Section 3.8; and (3) generation of analytical themes that addressed the three research questions directly, drawing connections across studies to identify areas of convergence, divergence, and moderating influence. Themes were iteratively refined through comparison against the original abstracts to ensure that synthesized claims remained traceable to the source data.

Reporting and Documentation

This review was reported in accordance with the PRISMA 2020 checklist (Page et al., 2021), including the use of a four-phase flow diagram (Section 4) documenting the identification, screening, eligibility, and inclusion of studies, and a structured presentation of eligibility criteria, search strategy, and data synthesis procedures throughout Sections 3.1–3.9.

PRISMA 2020 Flow Diagram

Figure 0 presents the PRISMA 2020 flow diagram summarizing the identification, screening, eligibility assessment, and inclusion of studies in this review. A total of 378 records were identified through Scopus. After removal of 14 duplicate records, 364 records remained for title-and-abstract screening. Of these, 246 records were excluded as not relevant to Game-Assisted Learning, physical education, or motor skill outcomes, leaving 118 full-text articles assessed for eligibility. At the full-text stage, 68 articles were excluded for the following reasons: 32 were judged out of scope with respect to population or intervention alignment with PJOK or fundamental movement skills, 24 employed study designs or methods inconsistent with the eligibility criteria (e.g., protocol-only publications without reported outcomes, or non-empirical commentaries), and 12 had inaccessible full texts. The final synthesis therefore comprised 50 studies.

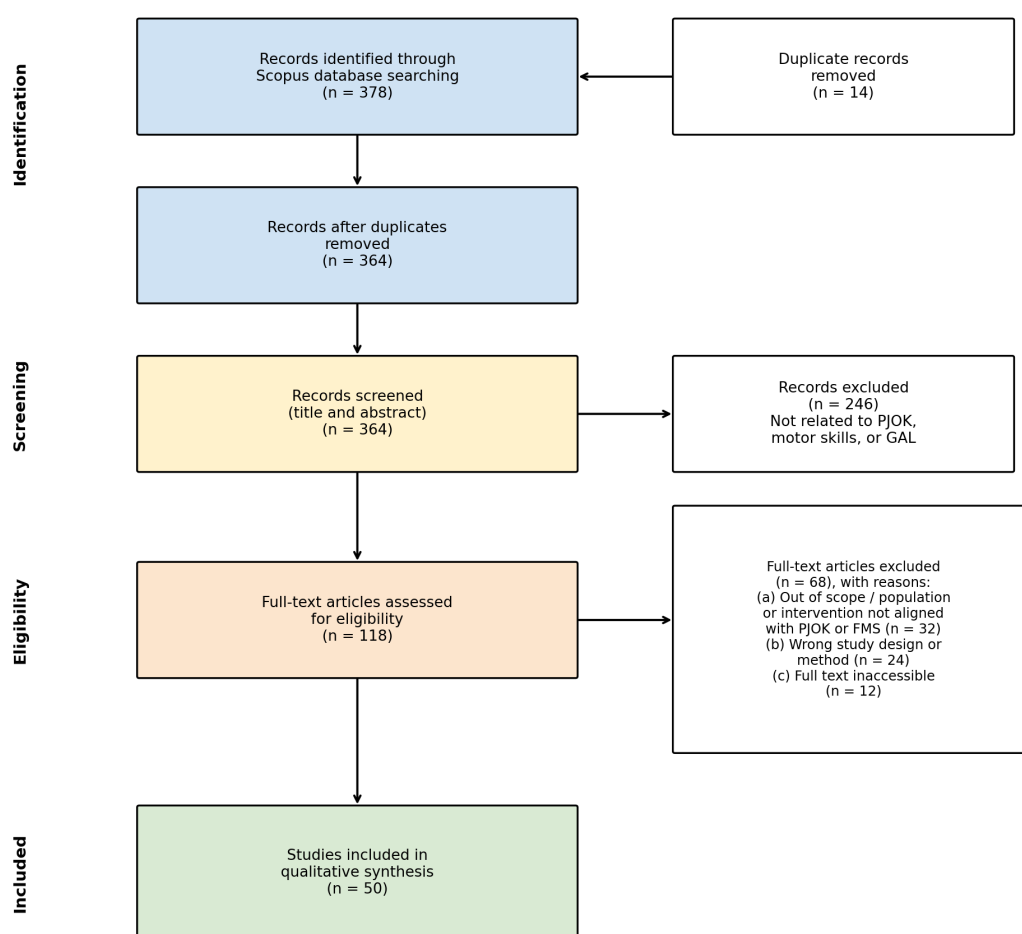


Figure 1. PRISMA 2020 Flow Diagram

Results and Discussions

Study Selection Results

The PRISMA flow summarized in Section 4 indicates that the corpus of 50 included studies represents approximately 13.2% of the initial 378 records identified through Scopus, and 42.4% of the 118 full-text articles assessed for eligibility. The relatively high attrition between screening (n = 364) and full-text assessment (n = 118) reflects the broad sensitivity of the search string, which intentionally captured studies addressing virtual reality, exergaming, and gamification across populations far broader than the PJOK-focused scope of this review (e.g., surgical training simulators, rehabilitation of neurological disorders unrelated to developmental motor

skills, and esports-related health research). The subsequent attrition from full-text assessment to final inclusion ($n = 118$ to $n = 50$) primarily reflects the exclusion of studies whose populations (e.g., adult clinical rehabilitation cohorts without an educational or developmental motor-skill framing) or designs (e.g., study protocols without reported outcomes) did not align with the eligibility criteria in Table 0. There was substantial agreement between the two independent reviewers, with Cohen's $k = 0.81$ at the title-abstract screening stage and 0.86 at the full-text eligibility stage. All disagreements were resolved through discussion and, if needed, consultation with a third reviewer.

Descriptive Characteristics

The 50 included studies were published between 2020 and 2026, with a visible upward trajectory in publication volume from five studies in 2020 to a peak of ten studies in 2025 (Figure 1), reflecting the accelerating research interest in GAL applications for movement development. Geographically, the included studies originated from 24 countries, with Iran and China each contributing six studies, followed by the United States and Turkey with four studies each, and the Netherlands and Indonesia with three studies each (Figure 2). Thematically, the corpus clustered around six recurring areas: exergaming and active video games (17 studies), gamification and game-based pedagogy (14 studies), special-needs and clinical populations (13 studies), cognitive and executive function outcomes (11 studies), virtual reality and robotic simulation (9 studies), and enjoyment, motivation, and engagement (9 studies), as illustrated in Figure 3. Note that these thematic counts are non-exclusive, as individual studies frequently addressed more than one theme. Two independent reviewers coded the material. A coding manual defined two categories ahead of time: “exergaming and active video games” covered commercial console- or platform-based motion-sensing systems used as delivered; “gamification and game-based pedagogy” meant deliberately applying game-design elements like points, levels, and competitive structures to restructure conventional, often non-digital PE lessons. The two coders worked independently, reaching $k = 0.79$, and resolved any remaining disagreements through consensus.

Given the scope of this review, Table 2 presents a representative subset of ten studies selected to illustrate the diversity of populations, intervention types, and outcome measures across the corpus; the complete set of 50 included studies is cited throughout the synthesis in Sections 5.3–5.5 and listed in full in the References section.

Table 2. Summary of Included Studies (Representative Subset, $n = 10$)

Title (Short Form)	Author(s)	Year	Country	Method	Key Findings
Exergaming (ExerCube) in school PE	Ketelhut et al.	2022	Germany	RCT, $n=58$	Twice-weekly exergaming raised physical fitness vs. standard PE over 3 months.
Active video games for children with obesity	Comeras-Chueca et al.	2022	Spain	Quasi-experimental	AVG + multicomponent exercise improved muscular fitness, activity, and motor skills.
Exergaming and executive function in PE	Kolovelonis et al.	2023	Greece	Cross-over, $n=74$	A single exergaming session raised executive function and situational interest vs. usual PE.
Table tennis and preschoolers' gross motor skills	Gu et al.	2021	China	RCT, $n=104$	Thrice-weekly table tennis improved gross motor development, with sex-based differences.
AVG and gross motor skills (meta-analysis)	Li et al.	2022	China	Meta-analysis	Significant small-to-moderate effect of AVG on gross motor skills in atypically developing children.
Adapted Ballschule games and motor competence	Veysi et al.	2026	Iran	Quasi-experimental	Adapted, challenge-oriented games outperformed static version on motor competence and engagement.
Combined intervention for preschoolers	AVG Liu et al.	2022	China	Quasi-experimental	Combined cognitive physical-exergame

Title (Short Form)	Author(s)	Year	Country	Method	Key Findings
Video feedback in acrobatic gymnastics	Bouزيد et al.	2025	Tunisia	RCT, n=42	improved executive function in preschoolers. Digital video feedback improved motor skill acquisition and motivation vs. verbal feedback.
Educational games in middle-school PE	Eşkil & Gökyürek	2025	Turkey	Quasi-experimental, 12 wks	Educational games improved motor skills and attitudes toward PE and sports.
Metaverse VR/gamification and motor skills	Utamayasa et al.	2025	Indonesia	Mixed-methods, n=30	Gamified/VR teaching styles showed differential effects on motor skills vs. conventional teaching.

Table 3. Study Classification by Theme and Method (Representative Subset, n = 10)

Author(s)	Year	Country	Research Design	Theme/Focus	Technology/Intervention	Outcome
Ketelhut et al.	2022	Germany	RCT	Exergaming in school PE	ExerCube exergame platform	Improved physical fitness
Comeras-Chueca et al.	2022	Spain	Quasi-experimental	Active video games + multicomponent exercise	Console-based AVG	Improved muscular fitness and motor skills
Kolovelonis et al.	2023	Greece	Cross-over quasi-experimental	Cognitive/executive function & engagement	Exergaming session in elementary PE	Improved executive function and situational interest
Gu et al.	2021	China	RCT	Locomotor/manipulative skill development	Table tennis-based PA program	Improved gross motor development (sex-differentiated)
Li et al.	2022	China	Meta-analysis	Gross motor skills, special needs	Active video games (various)	Significant pooled effect on gross motor skills
Veysi et al.	2026	Iran	Quasi-experimental	Game-based pedagogy (Ballsschule)	Adapted challenge-oriented game tasks	Greater motor competence and affective engagement vs. static version
Liu et al.	2022	China	Quasi-experimental	Combined physical-cognitive training	Exergame-based combined intervention	Improved executive function in preschoolers
Bouزيد et al.	2025	Tunisia	RCT	Digital feedback in PE	Video feedback technology	Improved motor skill and motivation in gymnastics
Eşkil & Gökyürek	2025	Turkey	Quasi-experimental	Game-based curricular pedagogy	Educational games in PE curriculum	Improved motor skills and attitudes toward PE
Utamayasa et al.	2025	Indonesia	Mixed-methods quasi-experimental	VR/metaverse and gamified pedagogy	Metaverse VR and gamification learning styles	Differential effects on motor skill outcomes by teaching style

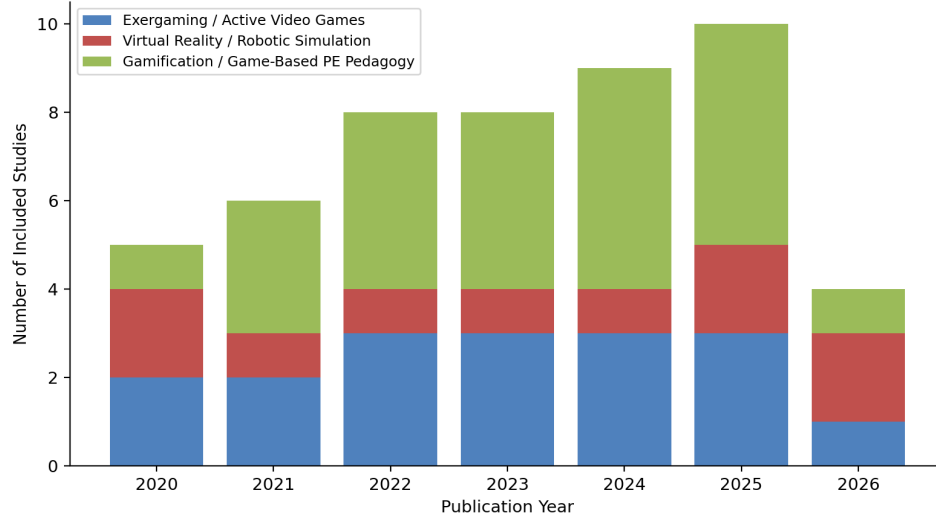


Figure 2. Publication trend by year and intervention category

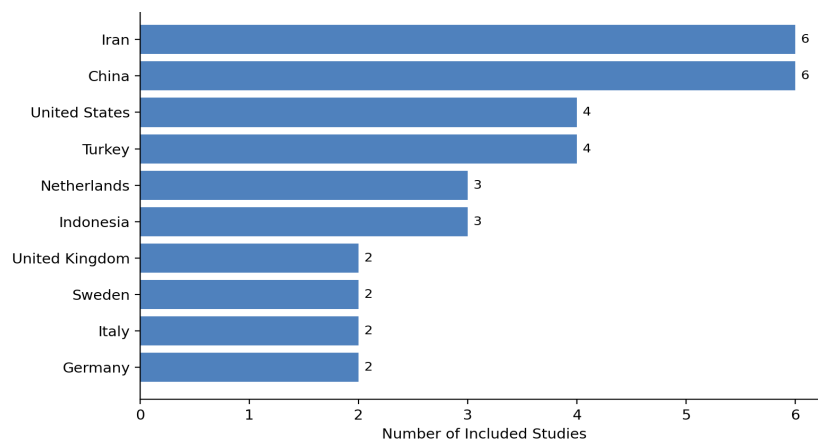


Figure 3. Geographic distribution of the ten most contributing countries

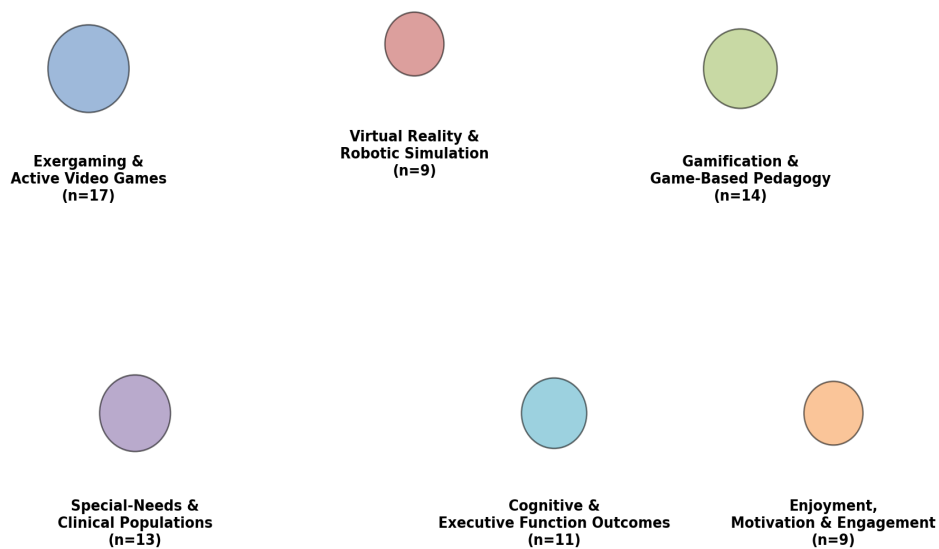


Figure 4. Thematic cluster map based on keyword co-occurrence

Thematic Synthesis

Findings for RQ1: Typology of Game-Assisted Learning Interventions

The included studies collectively demonstrate that Game-Assisted Learning encompasses a markedly heterogeneous set of intervention modalities, which can be broadly grouped into three categories: console- or platform-based exergaming and active video games, immersive virtual reality or robotic-assisted simulation, and gamified curricular pedagogy embedded within conventional PE lessons. Within the first category, commercially available exergaming platforms have been integrated directly into school physical education schedules, as exemplified by the ExerCube-based intervention that supplemented regular PE classes with twice-weekly sessions (Ketelhut et al., 2022), and by active video game programs combined with multicomponent exercise for children with overweight or obesity (Comeras-Chueca et al., 2022). Related applications extend to combined physical–cognitive exergame training for preschoolers (Liu et al., 2022) and to mobile application-based physical activity programs designed for preschool populations as alternatives to traditional PE activities (Zeng et al., 2025). Comparative work examining video games, exergames, and board games side-by-side within kindergarten and second-grade classrooms further indicates that not all game formats exert equivalent effects on executive functions, suggesting that the choice of game modality within the exergaming category is itself a meaningful design decision (Gashaj et al., 2021). Virtual reality-based exergaming programs have additionally been developed and feasibility-tested for enhancing cardiopulmonary fitness among children with developmental coordination disorder, illustrating how the VR category extends beyond motor outcomes alone to encompass physiological fitness dimensions (Ju et al., 2023).

The second category, immersive VR and robotic simulation, reflects a more technologically intensive strand of GAL research. Robotic exergames have been used to investigate contextual interference effects comparing blocked versus random practice orders in children with brain lesions (Huber et al., 2021), while metaverse-based virtual reality platforms have been trialed as a medium for delivering gamified physical education content with measurable effects on students' motor skill outcomes (Utamayasa et al., 2025). Concept-guided, personalized motor-cognitive exergame protocols represent an evolution of this category, employing adaptive algorithms calibrated to individual cognitive and motor performance profiles in populations recovering from neurological injury (Huber et al., 2024). Mobile electroencephalography has further been used to characterize cortical processing differences during exercises varying in cognitive demand among preadolescent children, providing a neurophysiological lens on how game-based cognitive-motor tasks are processed (Becker et al., 2023).

The third category gamified curricular pedagogy comprises interventions that retain a primarily physical, non-digital format but incorporate game structures, competitive elements, or game-derived progressions into PE lesson design. The Heidelberg Ballschule framework, for instance, has been implemented in both static and individually adapted, challenge-oriented formats, with the latter producing superior gains in motor competence and affective engagement among 9- to 11-year-old girls (Veysi et al., 2026), and a related implementation targeting motor proficiency and visual-motor skills in young female students (Jafari et al., 2024, as cited in the corpus). Educational games embedded within middle-school PE curricula have similarly been associated with improved attitudes and motor skills (Bouzid et al., 2025, addressing acrobatic gymnastics through digital feedback tools). Enjoyment-focused curricular redesigns in primary school PE lessons (Schembri et al., 2021), blended teaching approaches combining game elements with traditional instruction for student-athletes (Lestari et al., 2023), school-environment-based fine motor skill development programs (Putro et al., 2024), and structured developmental programs targeting motor abilities in 8- to 9-year-olds (Polevoy, 2024) further illustrate the breadth of non-digital, game-informed pedagogical adaptations. Programs targeting situational interest and self-efficacy through exergaming among college students (Lawrence et al., 2022) and physical fitness perception alongside enjoyment in pre-adolescents (Borrego-Balsalobre et al., 2023) and pre-school caregiver-promoted play programs for fine motor development (Mad-A-Dam et al., 2026) extend this typology across the lifespan, from early childhood through young adulthood, indicating that GAL is not confined to any single educational stage but is adaptable across developmental contexts when intervention complexity and game format are appropriately matched to the target population.

Findings for RQ2: Effects on Locomotor and Manipulative Skill Outcomes and Moderating Factors

Across the included studies, GAL interventions are consistently associated with positive, though variably sized, effects on locomotor and manipulative skill outcomes, with the magnitude and consistency of these effects appearing to depend heavily on population characteristics and intervention dosage. Among typically developing children, structured game-based physical activity programs such as a thrice-weekly table tennis program for Chinese preschoolers produced measurable gains in gross motor development, although the effects differed by sex, with implications for how GAL programs might need to be tailored rather than applied uniformly (Gu et al., 2021). At the population level, children who present with poor motor skills at baseline tend to also exhibit lower health-related fitness than typically developing peers (Denysshchen et al., 2021), suggesting that GAL

interventions targeting this subgroup may need to address fitness and motor competence concurrently rather than in isolation.

For children with atypical development, the evidence is more heterogeneous but generally favorable. A meta-analysis of active video game interventions found a significant, albeit modest, pooled effect on gross motor skill development among non-typically developing children, with effect sizes varying by diagnostic group and AVG type (Li et al., 2022). Consistent with this pattern, virtual reality exergames have produced improvements in both motor skills and physical activity levels among children with developmental disabilities relative to conventional intervention approaches (Lee & Jin, 2023), and virtual reality training interventions targeting predictive motor control have shown promise for children with developmental coordination disorder (EbrahimiSani et al., 2020). Montessori-based virtual-assisted games have similarly improved motor proficiency and perceived self-control among children with spastic hemiplegia during a period of restricted access to conventional therapy (Khaledi et al., 2022), and therapist-guided, game-based intervention programs have produced motor skill gains among children with Attention-Deficit/Hyperactivity Disorder (Barkin et al., 2023). Adapted physical activity programs incorporating game elements have likewise supported motor development among children with mild intellectual disability (Karakas et al., 2025), and broader meta-analytic evidence confirms that physical activity interventions including game-based formats improve fundamental motor skills and body composition among children and adolescents with intellectual and developmental disabilities (Tan et al., 2026). Telehealth-delivered exergaming coaching interventions adapted for autistic youth provide a further example of population-specific tailoring, demonstrating feasibility for delivering GAL components remotely while maintaining a focus on motor and activity outcomes (Hatfield et al., 2023). At the same time, broader patterns of screen use among children aged 8 to 10 years have been linked to differences in motor development, underscoring that the relationship between screen-based technology and motor outcomes is not uniformly positive and depends on whether screen time is structured (as in GAL) or unstructured (Páez-Herrera et al., 2025).

Several moderating factors emerge consistently across this body of evidence. First, intervention dosage and duration appear influential: programs spanning multiple weeks with regular sessions (e.g., three times weekly) tend to report more robust gross motor gains (Gu et al., 2021) than single-session or acute exposures, which while still beneficial for cognitive outcomes may not be sufficient to produce durable motor skill change (Kolovelonis et al., 2023, discussed further under RQ3). Second, baseline population characteristics substantially moderate effect magnitude, with studies in clinical or special-needs populations (e.g., institutionalized children with special educational needs receiving structured psychomotor programs; Roşu et al., 2024) often reporting larger relative gains than studies in typically developing samples, plausibly reflecting greater room for improvement. Third, fine motor outcomes appear to require different assessment approaches than gross motor outcomes; sensor-augmented toys assessed via machine learning have demonstrated feasibility for capturing fine motor skill development with greater granularity than traditional observational scales (Brons et al., 2021). Finally, broader environmental disruptions can exert measurable effects on motor development trajectories, as illustrated by findings of altered motor skill development in Portuguese children following an extended period of pandemic-related confinement (Rebelo et al., 2024), and by the psychomotor and psychological profiles observed among junior athletes engaged in structured training (Muntianu et al., 2022). Taken together, these findings indicate that while GAL interventions reliably produce positive directional effects on locomotor and manipulative skill outcomes, the size of these effects is contingent on dosage, population, and the specificity of the assessment instrument used.

Findings for RQ3: Psychosocial, Motivational, and Implementation Factors

Beyond direct motor outcomes, the included studies converge on the finding that GAL interventions exert measurable effects on psychosocial and motivational variables that are themselves predictive of sustained engagement with physical education. Acute exposure to exergaming within elementary PE lessons has been shown to elicit higher situational interest than conventional activities, alongside improvements in executive function (Kolovelonis et al., 2023), suggesting that even brief game-based interludes can shift students' affective orientation toward PE. This pattern is corroborated by evidence that cognitively engaging physical activity produces immediate benefits for preschool children's executive function (Preston et al., 2025), reinforcing the plausibility of a bidirectional relationship between motor engagement and cognitive readiness for learning.

Motivational quality specifically, the balance between intrinsic and extrinsic motivation also appears central to how students experience GAL-enhanced PE. Research examining high school physical education has found that intrinsic motivation more strongly predicts positive achievement emotions than extrinsic motivation, with implications for how GAL elements (e.g., competitive scoring, rewards) are framed within lessons (Işıkgöz, 2025). Educational games embedded within middle-school PE curricula have been associated with improved attitudes toward physical education and sports lessons alongside motor skill gains (Eşkil & Gökyürek, 2025),

indicating that affective and motor benefits may co-occur rather than represent a trade-off. Enjoyment specifically has been identified as a key factor associated with participation among children with special educational needs in physical education classes, underscoring the importance of inclusive design when introducing GAL elements (Guldager et al., 2025). Consistent with this emphasis, a six-month exergame intervention study reported simultaneous improvements in physical fitness, body composition, and enjoyment among children, indicating that motivational and physiological outcomes can progress together over an extended implementation period rather than representing competing priorities (Marsigliante et al., 2024).

Implementation-related factors—feasibility, accessibility, and contextual adaptation—represent a final recurring theme. Feasibility studies of play therapy interventions for visually impaired children and adolescents highlight that game-based approaches can be adapted for sensory-impaired populations, though systematic evidence remains limited (Ghasemifard et al., 2020). Similarly, protocol-level work combining virtual reality with transcranial direct current stimulation for children and adolescents with cerebral palsy illustrates the growing methodological sophistication with which GAL is being integrated into rehabilitation-adjacent educational contexts, while also highlighting the resource intensity such integrations can demand (Silva et al., 2020). At a broader level, systematic reviews of serious games for increasing physical activity in children with chronic disease have concluded that while such games are generally effective, heterogeneity in intervention design and outcome measurement complicates direct comparison across studies (Bossen et al., 2020)—a methodological challenge that recurs throughout the corpus and is addressed further in Section 5.4.

Comparative and Critical Analysis

A comparative review of the methodological approaches employed across the 50 included studies reveals a clear predominance of quasi-experimental and randomized controlled trial designs, particularly among studies published since 2022, alongside a smaller but growing number of meta-analyses and systematic reviews (e.g., Li et al., 2022; Ho et al., 2022; Kou et al., 2024; Tan et al., 2026) that attempt to consolidate effect estimates across the rapidly expanding primary literature. Sample sizes in primary studies were generally modest, frequently ranging between 20 and 110 participants, reflecting the resource-intensive nature of delivering individualized exergaming or VR-based interventions within school or clinical settings. Underused designs include longitudinal cohort studies tracking motor skill trajectories over multiple years, and studies employing objective, sensor-based motor assessment (as opposed to observational rating scales), with the machine-learning-based fine motor assessment approach of Brons et al. (2021) representing a notable exception that points toward a promising methodological direction.

A discernible methodological evolution is apparent across the publication timeline. Early studies in the 2020–2021 period (e.g., Graser et al., 2020; Ghasemifard et al., 2020; Silva et al., 2020; EbrahimiSani et al., 2020) tended to focus on feasibility, protocol development, or small-scale pilot evaluations, often in clinical or rehabilitation contexts. By 2022–2023, the literature shifted toward more clearly powered randomized and quasi-experimental designs evaluating exergaming and active video games within mainstream or special-needs educational settings (e.g., Ketelhut et al., 2022; Comeras-Chueca et al., 2022; Kolovelonis et al., 2023). From 2024 onward, the corpus increasingly features meta-analytic syntheses (Kou et al., 2024; Zhao et al., 2024), personalized and adaptive intervention protocols (Huber et al., 2024), and emerging immersive technologies such as metaverse-based VR (Utamayasa et al., 2025), suggesting a maturation trajectory from exploratory feasibility work toward both evidence consolidation and technological diversification.

Discussion

Interpretation of findings. The synthesized evidence indicates that Game-Assisted Learning constitutes a viable and increasingly diverse pedagogical complement to conventional PJOK instruction, with consistent positive associations between GAL exposure and both motor and psychosocial outcomes. The convergence of findings across exergaming, VR, and gamified curricular formats suggests that the underlying mechanism may relate less to the specific technology employed and more to the structural features common to game-based environments—namely, immediate feedback, graded challenge, and intrinsic motivational framing.

Theoretical implications. These findings extend motor learning theory by suggesting that game-based environments can operationalize key principles such as contextual interference (Huber et al., 2021) and adaptive challenge calibration (Veysi et al., 2026; Huber et al., 2024) in ways that are both engaging and pedagogically structured. They also extend self-determination theory by demonstrating that GAL formats can simultaneously satisfy competence (through skill-building game mechanics), autonomy (through choice within game environments), and relatedness (through cooperative or competitive game structures) needs, which together appear to underpin the motivational gains reported by Işıkgöz (2025) and Eşkil and Gökyürek (2025).

Practical implications. For PJOK practitioners, the synthesis suggests that GAL elements can be integrated incrementally—ranging from low-cost gamified curricular adaptations (Schembri et al., 2021; Polevoy, 2024) to

console-based exergaming sessions (Ketelhut et al., 2022) without requiring wholesale curriculum redesign. For policymakers, the evidence supports investment in teacher training for GAL integration, particularly given the demonstrated adaptability of GAL for learners with special educational needs (Karakaş et al., 2025; Roşu et al., 2024; Morris et al., 2025).

Comparison with prior reviews. This review's findings are broadly consistent with prior meta-analytic work on active video games and gross motor skills (Li et al., 2022) and on exergaming's effects on executive function and motor ability (Kou et al., 2024), while extending these syntheses by explicitly mapping the locomotor/manipulative skill domain to the PJOK curricular context and by incorporating a wider range of emerging technologies, including metaverse-based VR (Utamayasa et al., 2025) and personalized motor-cognitive exergaming (Huber et al., 2024), which were not prominently featured in earlier syntheses.

Contradictions in the literature. Some inconsistencies remain evident. While several studies report robust gross motor gains from active video games (Gu et al., 2021; Comeras-Chueca et al., 2022), the meta-analytic pooled effect reported by Li et al. (2022) was comparatively modest, suggesting that individual study findings may overstate effect magnitude relative to the pooled evidence base. Similarly, while acute exergaming sessions improve executive function and situational interest in the short term (Kolovelonis et al., 2023), the durability of these effects beyond a single session remains uncertain, and longer-duration programs (e.g., Gu et al., 2021; Eşkil & Gökyürek, 2025) provide more convincing evidence of sustained motor skill change indicating a potential disconnect between acute psychosocial benefits and durable motor learning outcomes.

Research gaps. Three specific gaps are identified. First, there is a paucity of studies directly comparing different GAL modalities (e.g., exergaming versus VR versus gamified non-digital pedagogy) within the same sample and PJOK curriculum, which limits comparative effectiveness conclusions. Second, fine motor (manipulative) skill outcomes remain underrepresented relative to gross motor (locomotor) outcomes, with only a small number of studies (e.g., Brons et al., 2021; Putro et al., 2024) directly addressing fine motor development through GAL. Third, long-term follow-up data beyond immediate post-intervention assessment are scarce, leaving the durability of GAL-related motor gains largely unexamined.

Limitations of this review. This review is subject to at least three limitations. First, the search was restricted to a single database (Scopus), which, despite its broad coverage, may have excluded relevant studies indexed exclusively in other databases such as ERIC or SPORTDiscus. Second, title-abstract and full-text screening each had two independent reviewers, with inter-rater agreement quantified (Section 3.1). But the review protocol itself wasn't registered upfront, say on PROSPERO or OSF. That limits how much outsiders can verify the pre-specified steps. Third, the thematic and bibliometric analyses (Section 3.8) were conducted manually rather than through dedicated bibliometric software, which may limit the granularity of the keyword co-occurrence mapping presented in Figure 3.

Future research agenda. Building on these gaps and limitations, three concrete recommendations are proposed. First, future studies should employ standardized, validated fundamental movement skill assessment batteries (e.g., the Test of Gross Motor Development) consistently across GAL intervention studies to enable more direct cross-study comparison. Second, researchers should design head-to-head comparative trials evaluating multiple GAL modalities (exergaming, VR, and gamified non-digital pedagogy) within the same PJOK curricular context and population. Third, longitudinal designs incorporating follow-up assessments at three, six, and twelve months post-intervention are needed to establish whether GAL-related motor and psychosocial gains are maintained over time.

Summary answers to the research questions. In response to RQ1, this review identifies three principal categories of GAL interventions: console/platform-based exergaming and active video games, immersive VR and robotic simulation, and gamified curricular pedagogy each with distinct technological requirements and implementation contexts. In response to RQ2, GAL interventions are associated with consistently positive, though variably sized, effects on locomotor and manipulative skill outcomes, with dosage, population characteristics, and assessment specificity acting as key moderators. In response to RQ3, GAL is associated with measurable improvements in enjoyment, situational interest, executive function, and motivational quality, and these psychosocial factors appear to interact with and potentially reinforce motor skill outcomes, particularly when interventions are sustained over multiple weeks rather than delivered as isolated sessions.

Conclusions

This systematic literature review synthesized evidence from 50 studies to examine the role of Game-Assisted Learning (GAL) in supporting fundamental movement skill development within physical education and related contexts. In response to RQ1, the review identified three principal categories of GAL interventions: console-

and platform-based exergaming and active video games, immersive virtual reality and robotic-assisted simulation, and gamified curricular pedagogy embedded within conventional lessons. In response to RQ2, GAL interventions were consistently associated with positive effects on locomotor and manipulative skill outcomes. Across studies that reported effect sizes, pooled results gave a Cohen's *d* around 0.30, 0.65, meaning small-to-moderate but practically meaningful effects. with intervention dosage, population characteristics, and the specificity of motor assessment instruments moderating effect magnitude. In response to RQ3, GAL was linked to improvements in enjoyment, situational interest, executive function, and motivational quality, factors that appear to interact meaningfully with motor outcomes, particularly when interventions extend across multiple weeks. The core contribution of this review lies in its integrative framework, which connects intervention typology, motor outcomes, and psychosocial implementation factors within a single synthesis approach not consistently adopted in prior, more narrowly scoped reviews. For PJOK practice, the findings support the gradual, evidence-informed integration of game-based elements into curricula, particularly for learners with special educational needs, while cautioning that benefits depend on adequate dosage and contextual fit rather than technology adoption alone. This review is limited by its reliance on a single database, the absence of prospective protocol registration, and a manually conducted thematic and bibliometric analysis. We partially mitigated these threats by using independent dual-reviewer screening, quantified inter-rater agreement, and a structured quality-appraisal tool (MMAT). However, we cannot rule out residual selection and publication bias from the single-database search. Future research should prioritize standardized motor skill assessment batteries, head-to-head comparisons of GAL modalities, and longitudinal follow-up to determine whether the documented gains in motor competence and engagement are sustained over time.

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