



Review Article

Integrated Versus Cognitively-Enriched Physical Education: Differential Effects on Mathematics Performance in School-Aged Children

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Accepted for Publication: April 16, 2026

Published: May 30, 2026

DOI: 10.17309/tmfv.2026.3.05

Abstract

Background. Physical activity (PA) interventions are increasingly being studied due to their potential to improve academic performance, particularly in mathematics. However, it remains unclear whether specific approaches such as Mathematics Integrated Physical Education (Math-PE) are more effective than general approaches such as Cognitively Enriched PE.

Objectives. The purpose of this study is to demonstrate the effects of physical activity interventions on mathematics performance and compare the effectiveness of Mathematics Integrated Physical Education (Math-PE) and Cognitively Enriched PE.

Materials and Methods. This study employed a systematic review and meta-analysis. A literature search was conducted in the Scopus, PubMed, and Taylor & Francis Online databases in accordance with the PRISMA 2020 guidelines. The studies that met the criteria (N = 11 independent samples) consisted of randomized controlled trials and quasi-experiments. The analysis used a random-effects model to calculate the pooled standardized mean difference (SMD).

Results. The analysis revealed a significant and moderate overall effect of PA interventions on mathematics performance (SMD = 0.425; 95% CI [0.187; 0.663]; $p < 0.001$). Importantly, moderator analysis revealed no statistically significant difference between Integrated Math-PE ($k = 7$; SMD = 0.436) and Cognitively Enriched PE ($k = 4$; SMD = 0.427; $Q_b = 0.00$; $p = 0.974$).

Conclusions. While both methods produce statistically similar results, their implementation needs to be tailored to specific pedagogical circumstances. Integrated Physical Education and Mathematics is most effective for introducing specific mathematical concepts in early grades, while Cognitively Enriched Physical Education is more appropriate for improving general problem-solving skills and calculation speed in older children. Therefore, educators must carefully select methods that are truly relevant to the developmental stage of the students and the learning objectives they wish to achieve, emphasizing that Physical Education is a crucial factor in mathematics achievement when applied in the right context.

Keywords: physical education, mathematics performance, integrated learning, embodied cognition.

Introduction

Global education systems currently face a paradoxical dual pressure: the need to improve mathematical literacy

amidst stagnant academic achievement, often met by reducing PE time in favor of more classroom time (Donnelly & Lambourne, 2011; Resaland et al., 2016). This sedentary approach has been sharply criticized for ignoring neurophysiological evidence showing that physical activity is not simply a biological necessity but a crucial catalyst for the development of brain structure and cognitive plasticity during childhood and adolescence (Hillman et al., 2008;

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Tomporowski et al., 2015). Furthermore, reduced PA in schools is linearly correlated with declines in executive functions—such as working memory, inhibition, and cognitive flexibility—which are fundamental predictors of successful logical-mathematical reasoning (Diamond, 2015; F. Egger et al., 2019).

Theoretically, physical activity interventions in mathematics learning are based on two distinct but complementary frameworks. First, the Cognitive Stimulation perspective argues that complex physical exercise (e.g., Cognitively-Enriched PE) triggers physiological arousal and the secretion of neurotrophic factor (BDNF), which prepares the brain's neural networks for more efficient learning (Egger et al., 2019; Pesce et al., 2016; Schmidt et al., 2015). Second, the Embodied Cognition theory proposes that cognition is rooted in the body's sensorimotor interactions with the environment (Kiefer & Trumpp, 2012; Wilson, 2002). In this context, abstract mathematical concepts become more concrete when mapped through physical body movements (Integrated PE), such as jumping to understand a number line or manipulating objects for geometry (Mavilidi et al., 2018; Mullender-Wijnsma et al., 2016).

Although previous meta-analyses have confirmed a positive association between PA and academic achievement in general (Alvarez-Bueno et al., 2017; Singh et al., 2019), the existing literature often fails to distinguish specific effectiveness based on intervention type. Many systematic reviews conflate Integrated PE (learning through movement) with Enriched PE (moving to stimulate the brain), yet the two operate through distinct cognitive mechanisms (Schmidt et al., 2019; Vetter et al., 2020).

This ambiguity creates a significant knowledge gap: whether improvements in math performance are driven more by integrating curriculum content into movement (domain-specific) or by the general cognitive stimulation of physical activity (domain-general). This study aims to fill this gap through a systematic review and meta-analysis of recent randomized controlled trials (RCTs) and quasi-experiments Desains (QEDs). Specifically, the study compares the efficacy of Integrated Math-PE and Cognitively-Enriched PE approaches on math learning outcomes. Understanding these nuances is crucial for policymakers designing time-efficient future curricula in which physical health and

academic excellence are no longer viewed as trade-offs but rather as mutually reinforcing elements.

Materials and Methods

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). All methodological procedures—including the search strategy, inclusion criteria, and analytical plan—were predetermined to minimize potential bias.

Eligibility Criteria (PICO)

Study eligibility was determined using the PICOS framework (Population, Intervention, Comparator, Outcome, Study design) (Richardson et al., 1995). We included controlled trials evaluating physical activity interventions specifically, those classified as either integrated math content or cognitively enriched PE on the mathematics achievement of school-aged children. Detailed inclusion and exclusion criteria are provided in Table 1.

Information Sources and Search Strategy

A systematic literature search was conducted in three electronic databases (Scopus, PubMed, and Taylor & Francis Online). The search strategy used a combination of predetermined keywords related to the topic, linked using structured Boolean operators (AND, OR). The complete search syntax and specific queries for each database are detailed in Supplementary Table 1.

Study Selection Process

The selection process followed the PRISMA 2020 flow diagram (Page et al., 2021). After removing duplicates, two independent reviewers screened titles and abstracts against the eligibility criteria, followed by a full-text assessment of potentially relevant records. Disagreements regarding inclusion were resolved through consensus or consultation with a third investigator. Complete workflow, including exception reasons at the full text stage

Table 1. PICOS criteria for inclusion and exclusion of studies

Criterion	Inclusion Criteria	Exclusion Criteria
Population	School-aged children (kindergarten to lower secondary level).	Children with specific learning disabilities (e.g., dyscalculia) or clinical conditions (e.g., ADHD), unless separable from typically developing peers.
Intervention	(1) Integrated Math: Physical tasks explicitly combined with academic content (e.g., math games). (2) Cognitively-Enriched PE: Motor tasks with high cognitive demands (e.g., executive function focus) without direct academic instruction.	Acute (single-bout) exercise sessions; pure aerobic/fitness training without cognitive engagement; after-school programs unrelated to the curriculum.
Comparator	Traditional physical education (active control) or sedentary classroom lessons (passive control).	Studies lacking a concurrent control group (e.g., pre-post single group designs).
Outcome	Quantitative mathematics performance (e.g., standardized tests, grades, procedural fluency).	Qualitative perceptions; self-reported grades without verification; math anxiety (without performance data).
Study Design	RCTs, Cluster-RCTs, and QEDs with a control group.	Cross-sectional studies, reviews, conference abstracts, or grey literature.

Data Extraction

Data extraction was conducted independently by two reviewers (AC and JT). The information collected included: (1) study characteristics (author, publication year, country); (2) participant characteristics (sample size, mean age, sex ratio); (3) intervention specifications (activity type, duration, frequency, and categorization as integrated vs. enriched); and (4) quantitative outcome data (mean, standard deviation, and sample size) for the experimental and control groups at post-intervention. Any discrepancies between reviewers were resolved through consensus discussions or adjudication by a third reviewer. For studies that did not report complete data, statistical conversions were performed using standard errors or confidence intervals, where possible.

Methodological quality assessment

We assessed risk of bias using the Cochrane RoB 2 tool for Cluster Randomized Trials (Sterne et al., 2019). Although some included studies were quasi-experimental, they used allocation at the classroom or school level; thus, treating them as cluster-randomized trials ensured a rigorous and comparable evaluation (Eldridge et al., 2016; Higgins et al., 2023). Two reviewers (JT and TAN) independently assessed five domains of bias (randomization, identification, bias, missing data, and measurement). Discrepancies were resolved through consensus or consultation with a third reviewer. Visualizations were generated using robvis (McGuinness & Higgins, 2021).

Data Synthesis and Statistical Analysis

The meta-analysis was conducted using JASP software (Version 0.16.3). Effect sizes were calculated as SMDs using Hedges' g to correct for bias in small samples (Hedges, 1981). A random-effects model with the Restricted Maximum Likelihood (REML) method was applied to accommodate inter-study variability (Borenstein et al., 2010). Heterogeneity was assessed using the I^2 statistic and the Cochrane's Q test, with I^2 values $>50\%$ indicating substantial heterogeneity (Higgins & Thompson, 2002). To address the primary research objective, subgroup moderator analyses were conducted by intervention type (Integrated Math vs. Enriched PE) to compare the effectiveness of the two approaches. Potential publication bias was evaluated visually through a symmetric funnel plot and quantified using Egger's regression test (Egger et al., 1997) and Begg & Mazumdar's rank correlation test (Begg & Mazumdar, 1994).

Results

Study Selection

An initial literature search retrieved 46,700 records from three electronic databases. After removing duplicates and screening titles and abstracts, 16 full-text articles were assessed in detail for eligibility.

Five studies were excluded at this stage for not meeting eligibility criteria, primarily because they used non-equivalent comparators (e.g., artificial control activities or active video games) or lacked a control group. Ultimately,

11 studies met all inclusion criteria and were included in the systematic review and meta-analysis. The complete selection process is illustrated in Figure 1.

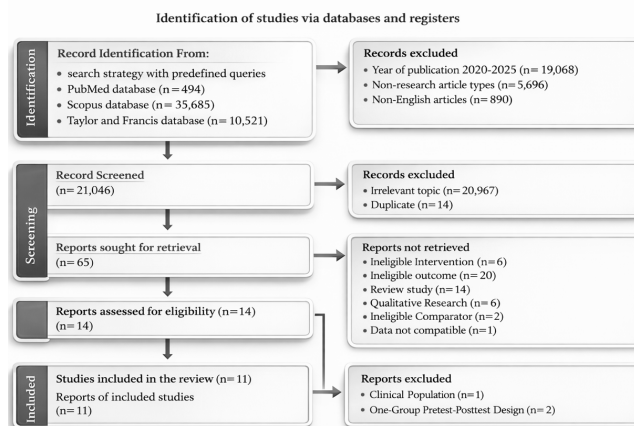


Fig. 1. PRISMA flow diagram showing the study identification and selection process.

Study Characteristics

Table 2 outlines the characteristics of the 11 included studies. The studies were conducted across diverse geographic settings, predominantly in Europe (n=8), followed by North America (n=1), South America (n=1), and North Africa (n=1). The sample comprised school-aged children aged approximately 6 to 14, with a primary focus on elementary education grades. Methodologically, the review incorporated a mix of RCTs, cluster-RCTs, and quasi-experimental designs.

Effect size, SMD (Hedges' g); random-effects model (REML); CI, confidence interval; PI, prediction interval; Qe, heterogeneity test; I^2 , heterogeneity (%); τ^2 , between-study variance. Main subgroup differences: $Qm(1)=0.00$, $p=.974$; Sensitivity subgroup differences: $Qm(1)=0.00$, $p=.979$; statistical significance was set at $p < 0.05$. The sensitivity analysis excluded studies with passive (sedentary) control.

Interventions were stratified into two distinct modalities: (1) Integrated Math-PE (n=7), where academic concepts were explicitly embedded within physical tasks (e.g., 'Eduball', geometry treasure games, or fraction courts); and (2) Cognitively-Enriched PE (n=4), which targeted executive functions through complex motor circuits without direct mathematical instruction. Intervention duration exhibited significant heterogeneity, ranging from short-term exposures (2–3 weeks) to longitudinal programs spanning a full school year. Regarding comparators, most studies used an active control group (traditional physical education), while others used sedentary classroom instruction.

Risk of Bias Assessment

The risk of bias assessment using the RoB 2 Cluster instrument showed a varied quality profile (see Figure 2). Overall, two studies (18%) were classified as having a low risk of bias, five studies (45%) as having some concerns, and four studies (36%) as having a high risk. The main sources of bias were structural and centered in Domain 1 (Randomization),

Table 2. Characteristics of included studies (N = 11)

Study ID (Country)	Study Design	Sample Characteristics	Intervention Group (Description)	Control Group	Duration & Dosage	Math Domain
(Bustamante et al., 2022) (USA)	Cluster-RCT	N analyzed=158 Age: 4th-6th Grade Female: 52%	Fraction Ball Basketball games with court markings modified to represent fractions/decimals to teach rational numbers.	Active Control: Regular PE classes (Business-as-usual)	3 weeks 2x / week 50 min / session (Total 6 sessions)	Rational Numbers (Overall Composite: Fractions & Decimals)
(Wawrzyniak et al., 2022) (Poland)	Cluster-RCT	N=70 Age: 6-7 yrs (First Grade) Female: 44% (Pooled)	Eduball Integrated PE using balls with letters/numbers. Conducted by varying teachers (Classroom/PE teachers).	Active Control: Standard PE program (no educational balls).	10 months (1 School Year) 2x / week 45 min / session	Early Numeracy (TUNSS: Numbers, space, shape, relationships)
(Chikha et al., 2024) (Tunisia)	Randomized Crossover Trial	N=24 Age: 6.1 ± 0.7 yrs (Grade 1) Female: 41.7% (14 Boys, 10 Girls)	Treasure Game (TG) Integrated PE where students run/walk on a 12x12m grid to form geometric shapes based on topological coordinates.	Passive Control: Sedentary conventional geometry lessons.	2 weeks (Experimental Phase) During PE Sessions (Frequency not specified, typical PE)	Geometry (Van Hiele Level I: Visualization & Shape Identification)
(Romero-Martínez et al., 2025) (Spain)	Cluster-RCT	N=332 Age: 10-11 yrs (Grade 5) Female: 51.8%	ALPHYL Intervention Combination of classroom-based Physically Active Learning (PAL) and Quality PE. Teachers integrated movement into academic lessons (e.g., math) using SAAFE principles.	Active Control: Standard PE lessons + Regular sedentary curriculum.	9-10 weeks Daily PAL (≥ 30 min/day)	Arithmetic Fluency (Woodcock-Johnson III: Addition, subtraction, multiplication speed)
(Cecchini & Carriedo, 2020) (Spain)	QEDs	N=46 Age: 6.4 yrs (77 mos) Female: 58.7%	ITU Group (Integrated Teaching Unit) Interdisciplinary approach combining PE and Math content (subtraction) in unified sessions.	Active Control: Traditional curriculum (separate PE and Math lessons).	3 weeks 5 hours / week (Total 15 hours)	Arithmetic (Single-digit Subtraction Fluency)
(Ruiz-Hermosa et al., 2025) (Spain)	QEDs	N=77 Age: 12-14 yrs (Secondary School) Female: 57.1%	ACTIVE CLASS Integrated PAL (Physically Active Learning) lessons where math content is taught through movement (e.g., running, jumping) in outdoor areas.	Passive Control: Sedentary mathematics lessons in the classroom.	4 weeks 1x / week 60 min / session	Arithmetic Fluency (Woodcock-Muñoz III: Math Fluency Test)
(Cichy et al., 2020) (Poland)	QEDs	N=47 Age: 7 yrs (First Grade) Female: 45% (12 IG, 9 CG)	Eduball Integrated PE classes using educational balls with letters/numbers/signs. (Replaced 2 of 3 weekly PE lessons)	Active Control: Regular PE classes (no educational balls).	1 school year (10 months) 2x / week 45 min / session	General Math Knowledge (Comprehensive Test: Sets, Arithmetic, Geometry, Measurement)
(García-Hermoso et al., 2020) (Chile)	Cluster-RCT	N analyzed=158 Age: 10 yrs (Range 8-10) Female: 43%	Active-Start Before-school PA program involving moderate-to-vigorous games and cognitive engagement (no math content).	Passive Control: Sedentary routine (no before-school activity).	8 weeks 5x / week 30 min / session (Daily)	General Mathematics (School Grades / GPA, Scale 1-7)

Table 2 (continued)

Study ID (Country)	Study Design	Sample Characteristics	Intervention Group (Description)	Control Group	Duration & Dosage	Math Domain
(Latino et al., 2025) (Italy)	Cluster-RCT	N=200 Age: 11.5 ± 0.5 yrs (Early Adolescence) Female: 49%	DCC Program Cognitively-Enriched PE involving motor circuits combined with executive function tasks (e.g., 1-back motor chain, stroop-like agility) without explicit math instruction.	Active Control: Standard PE curriculum (sports techniques/free play).	12 weeks 2x / week 60 min / session	Problem Solving (AC-MT 11-14 Standardized Test) Also reported: Math Grades
(De Bruijn et al., 2020) (Netherlands)	Cluster-RCT	N=891 Age: 9.17 yrs (Grade 3-4) Female: 50.6%	Cognitively-Engaging PE Exercises with complex coordination and changing rules (e.g., tag games with cognitive tasks) to challenge executive functions, without explicit math content.	Active Control: Standard PE curriculum.	14 weeks 4x / week 30 min / session	General Mathematics (CITO Mathematics Test)
(Kliziene et al., 2020) (Lithuania)	Cluster-RCT	N=178 Age: 6-7 yrs (Grade 1) Female: 49.4%(88/178)	Innovative PE Program Combined physical exercises with cognitive tasks (spatial perception, logical tasks) using a specialized textbook during PE lessons.	Active Control: Standard PE lessons (unmodified) without the innovative program/textbook.	8 months 2x / month (Program intensity) 45 min / session	General Mathematics (Diagnostic Progress Tests: 5 Curriculum Areas)

N, number of participants; RCT, randomized controlled trial; QEDs, quasi-experimental design; PE, physical education; PA, physical activity; PAL, physically active learning; IG, intervention group; CG, control group; SAAFE, Supportive, Active, Autonomous, Fair, and Enjoyable principles; ITU, Integrated Teaching Unit; TG, Treasure Game; DCC, Dual-Challenge Circuit; GPA, grade point average; CITO, Centraal Instituut voor Toetsontwikkeling (Central Institute for Test Development); AC-MT, Test of Calculation Ability and Problem Solving (Abilità di Calcolo e Soluzione di Problemi); TUNSS, Test of Understanding of Number Systems and Structures.

where the high risk classification was due to the use of a quasi-experimental design or a limited number of clusters (e.g., k=2), which hindered effective allocation concealment.

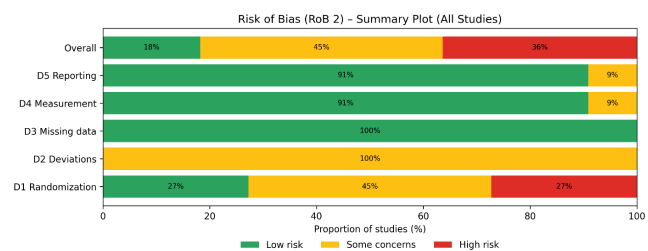


Fig. 2. Summary plot of Risk of Bias (RoB 2) across studies (D1–D5)

Although the lack of blinding for physical interventions raises consistent concerns in Domain 2, the internal validity of the studies remains intact. This is supported by strong data integrity, with 100% of studies having a low risk of missing data (Domain 3), and the majority of studies minimizing detection bias through the use of objective, standardized math tests (Domain 4).

Primary Outcomes and Moderator Analysis

Random-effects (REML) meta-analysis using SMD (Hedges' g) showed a significant overall improvement in mathematics performance (SMD = 0.425, 95% CI [0.187, 0.663], p < .001). Heterogeneity was substantial (Qe(10) = 59.15, p < .001; I² = 82.28; τ² = 0.121), and the prediction interval crossed zero (95% PI [-0.297, 1.147]), indicating significant between-study variability in the magnitude of effects.

Both subgroups showed significant positive effects: Integrated Math Content (SMD = 0.436, 95% CI [0.089, 0.782], p = .014) and Cognitively-Enriched PE (SMD = 0.427, 95% CI [0.074, 0.780], p = .018), with high residual heterogeneity in each subgroup (I² = 78.61% and 86.64%). The subgroup difference test was not significant (Qm(1) = 0.00, p = .974), providing no evidence that one approach outperformed the other (see Table 3).

Sensitivity Analysis

To test the robustness of our findings, we conducted a sensitivity analysis excluding studies with a passive (sedentary) control group. Even under these more stringent conditions, the combined effect of the cognitively engaged physical education intervention remained statistically significant (SMD = 0.42, 95% CI [0.06, 0.78], p = 0.029). This suggests that the academic benefits are not solely due to increased levels of physical activity relative to sedentary behavior, but rather stem from the additional cognitive component of the intervention.

Interestingly, moderator analysis in this sensitivity subset revealed no significant difference between Math-Integrated Physical Education and Cognitively Enriched Physical Education (Qb = 0.00, p = 0.98). Both approaches yielded nearly identical medium effect sizes (SMD = 0.42 and SMD = 0.43, respectively). This suggests that cognitive engagement—regardless of content integration—is the primary driver of academic improvement compared to standard aerobic physical education.

Table 3. Summary of meta-analytic results for primary outcomes, moderator analysis by intervention type, and sensitivity analysis

Analysis	Group	k	g (SMD)	95% CI	p	95% PI	Qe(df)	p(Q)	I ² (%)	τ ²
Primary Outcomes and Moderator Analysis	Overall	11	0.425	[0.187, 0.663]	<.001	[-0.297, 1.147]	59.15(10)	<.001	82.28	0.121
	Integrated Math Content	7	0.436	[0.089, 0.782]	0.014	[-0.423, 1.294]	31.15(6)	<.001	78.61	0.16
	Cognitively-Enriched PE	4	0.427	[0.074, 0.780]	0.018	[-0.314, 1.169]	27.15(3)	<.001	86.64	0.111
Sensitivity Analysis	Overall	8	0.42	[0.056, 0.784]	0.029	[-0.576, 1.417]	52.55(7)	<.001	87.11	0.154
	Integrated Math Content	5	0.424	[-0.193, 1.041]	0.129	[-0.956, 1.804]	25.37(4)	<.001	83.3	0.198
	Cognitively-Enriched PE	3	0.433	[-0.632, 1.498]	0.223	[-1.632, 2.497]	26.08(2)	<.001	91.58	0.169

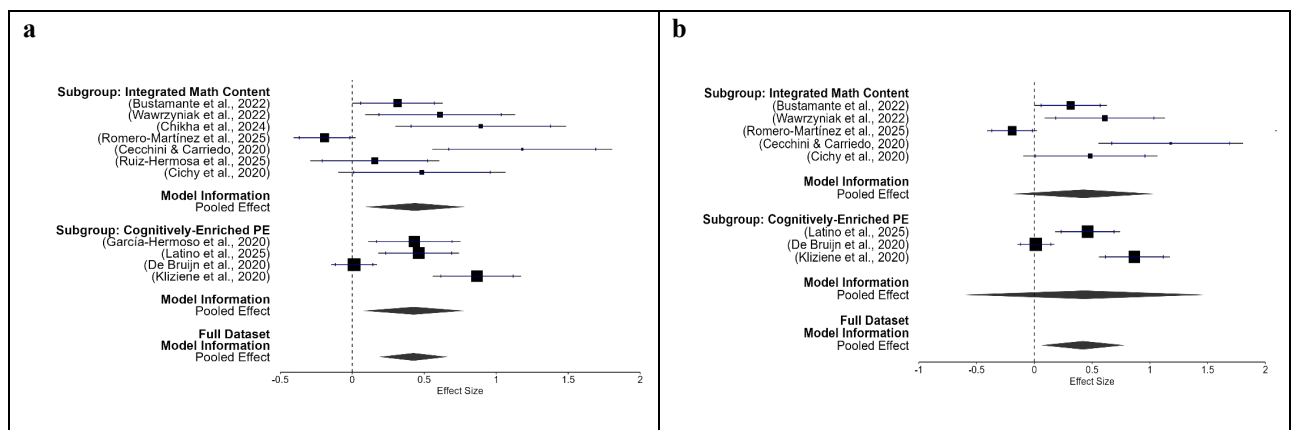


Fig. 3. Forest plot a) comparing the effects of Integrated vs. Enriched PE on math achievement, b) sensitivity analysis forest plot comparing cognitively-engaging PE interventions versus active control groups only

Publication Bias

Based on weighted regression (Egger-type), there is an indication of asymmetry/small-study effects in the funnel plot (supplementary figure S2) ($t(9) = 3.029, p = .014; \mu = -0.317, 95\% \text{ CI } [-0.773, 0.139]$). However, in supplementary table S2, the rank correlation (Begg-type) is not significant (Kendall's $\tau = 0.382, p = .121$), indicating inconsistent evidence of asymmetry across trials.

Discussion

This study aimed to analyze the effectiveness of physical activity interventions on students' mathematics performance through a systematic review and meta-analysis, specifically comparing the impact between Integrated Math and Cognitively-Enriched PE approaches. This meta-analysis confirmed a moderate positive impact of physical activity interventions on mathematics performance, refuting concerns that time allocation for physical activity is detrimental to academic achievement (Alvarez-Bueno et al., 2017; Donnelly et al., 2016). However, the most crucial and distinctive finding of this study is the statistical equivalence between Integrated Math and Cognitively-Enriched PE. This absence of significant disparity indicates that embodiment (content integration) and cognitive priming (neural stimulation) pathways have equal potential to amplify learning outcomes, providing significant pedagogical flexibility for school curricula.

The effectiveness of Integrated Math is validated by Embodied Cognition Theory, where physical movement facilitates the processing of abstract concepts by reducing intrinsic cognitive load (Mavilidi et al., 2018; Wilson, 2002). Sensorimotor manipulation of numerical content (e.g., jumping on a number line) creates multimodal memory traces that strengthen long-term retention (Beck et al., 2016; Liang et al., 2023). Conversely, the efficacy of Cognitively-Enriched PE is supported by the Cognitive Stimulation Hypothesis. Complex coordinative activities stimulate the prefrontal cortex and executive function, triggering BDNF secretion that prepares the neural architecture for academic learning without the need for explicit math instruction (Best, 2010; Diamond & Lee, 2011; Schmidt et al., 2015).

The novelty of this study lies in a methodological disaggregation often overlooked in previous meta-analyses that tend to generalize across physical activity modalities (Singh et al., 2019). By separating and comparing them head-to-head, this study fills a gap in the literature by demonstrating that improvements in math achievement can be achieved through both domain-specific (Integrated) and domain-general (Enriched) mechanisms. These findings have significant practical implications. Rather than using one approach for all, educators need to wisely select intervention methods that best suit students' developmental stages, specific mathematical objectives, and timing, ensuring the difficulty of the physical tasks aligns with the learning targets.

Importantly, the significant statistical variation observed in this meta-analysis should not be viewed solely as a flaw in the method, but rather as an important indicator of differing conditions of effectiveness. These differences reflect the various ways in which these interventions are driven by different implementation contexts, intervention dosages, and participant ages. For example, the effectiveness of these interventions depends largely on the precise match between the program duration, which varied from 2 weeks to 10 months across the included studies and the specific academic outcomes of interest. Therefore, this variation suggests that physical interventions need to be precisely tailored to instruction to achieve the best academic benefits. Furthermore, the preponderance of short-term studies limits conclusions about the durability of effects on academic performance over the long term. The relatively small sample sizes of some of the studies used also require caution in extending the findings due to potential bias in assessment.

Conclusions

Overall, this systematic review and meta-analysis indicates that Integrated Mathematics Physical Education and Cognitive Enhanced Physical Education both improve mathematics performance with statistically similar results. Rather than finding one strategy that is better for all, our results suggest that the choice of the best method depends largely on the specific circumstances in which it is implemented, including the students' developmental stage and the type of mathematics task being addressed. For younger students (such as 6–8 years old) or if the goal is to help them understand new and abstract concepts such as geometry or fractions, Integrated Mathematics Physical Education is preferable because it uses a concrete learning experience to reduce the burden of complex thinking. On the other hand, for older children (such as 10–14 years old) or if the goal is to improve their abilities in general arithmetic and solve more complex problems, Cognitive Enhanced Physical Education is very effective in stimulating their thinking skills. Furthermore, the appropriateness of implementing these methods depends on the context in which they are implemented; Schools with tight schedules may benefit from using Integrated Physical Education to combine academic and physical education time, while schools focused on long-term neurocognitive development may want to implement enhanced motor tasks within regular physical education classes. Future curricula need to go beyond simple choices and instead provide educators with the tools to make dynamic decisions about implementing active learning approaches in line with evolving educational goals.

Data Availability Statement

The datasets generated and analyzed during this research are available from the corresponding author upon reasonable request.

Conflict of Interest Statement

The authors declare no conflicts of interest regarding the publication of this article.

Funding Statement

This study received special funding grants from the research and community service units of Padang State University, Indonesia University of Education, and Surabaya State University through the Indonesian Collaborative Research Program.

AI Transparency Statement

The artificial intelligence (AI) tool, in this case Grammarly, was used solely to assist with language correction and improve the readability of the manuscript. The authors are solely responsible for the content, data analysis, and integrity of the final article.

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Інтегроване та когнітивно збагачене фізичне виховання: диференційований вплив на математичну успішність дітей шкільного віку

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 3 табл., 3 рис., 43 джерела.

Передумови. Втручання, засновані на фізичній активності (ПА), дедалі частіше досліджуються через їхній потенціал покращувати академічну успішність, зокрема з математики. Однак залишається незрозумілим, чи є специфічні підходи, такі як інтегроване фізичне виховання та математика (Math-PE), більш ефективними, ніж загальні підходи, такі як когнітивно збагачене фізичне виховання.

Мета. Метою цього дослідження є демонстрація впливу втручань, заснованих на фізичній активності, на математичну успішність та порівняння ефективності інтегрованого фізичного виховання та математики (Math-PE) і когнітивно збагаченого фізичного виховання.

Матеріали та методи. У дослідженні використано систематичний огляд та метааналіз. Пошук літератури проводився в базах даних Scopus, PubMed і Taylor & Francis Online відповідно до рекомендацій PRISMA 2020. До аналізу були включені дослідження, що відповідали критеріям відбору (N = 11 незалежних вибірок) і мали дизайн рандомізованих контрольованих досліджень та квазіекспериментів. Для розрахунку об'єднаного стандартизованого середнього ефекту (SMD) застосовано модель випадкових ефектів.

Результати. Аналіз виявив статистично значущий помірний загальний ефект втручання, заснованих на фізичній активності, на математичну успішність (SMD = 0.425; 95% CI [0.187; 0.663]; $p < 0.001$). Важливо, що модераторний аналіз не виявив статистично значущої різниці між інтегрованим Math-PE ($k = 7$; SMD = 0.436) та когнітивно збагаченим фізичним вихованням ($k = 4$; SMD = 0.427; $Q_b = 0.00$; $p = 0.974$).

Висновки. Хоча обидва методи демонструють статистично подібні результати, їх впровадження має бути адаптоване до конкретних педагогічних умов. Інтегроване фізичне виховання та математика є найбільш ефективними для введення конкретних математичних понять у молодших класах, тоді як когнітивно збагачене фізичне виховання є більш доцільним для покращення загальних навичок розв'язування проблем і швидкості обчислень у старших дітей. Отже, педагоги повинні ретельно обирати методи, які дійсно відповідають віковим особливостям учнів і навчальним цілям, яких вони прагнуть досягти, підкреслюючи, що фізичне виховання є важливим чинником математичної успішності за умови його застосування у відповідному контексті.

Ключові слова: фізичне виховання, математична успішність, інтегроване навчання, втілене пізнання.

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Cite this article as: Chaeroni, A., Lisna, Y. P., Igoresky, A., Nur, L., Al Ardha, M. A., & Nurhasan, N. (26). Integrated Versus Cognitively-Enriched Physical Education: Differential Effects On Mathematics Performance In School-Aged Children. *Physical Education Theory and Methodology*, 26(3), 448-457. <https://doi.org/10.17309/tmfv.2026.3.05>

Received: 20.03.2026. Accepted: 09.04.2026. Published: 30.05.2026

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