Effect of a gamified physical education programs on physical fitness and motor coordination: systematic review and meta-analysis

Efecto de los programas de educación física gamificados sobre la condición física y la coordinación motora: revisión sistemática y metaanálisis

Authors

Cristina Castro-Collado[1]
Rafael Cortés-Rojas[3]
Alejandro Pradas-Ponce[3]
Daniel Rangel-Rodríguez[3]
José Andrés Ruiz-Castaño[3]
Vanesa Cuevas-Cuevas[3]
Pablo Pradas-Villaécija[3]
Jose Manuel Jurado-Castro[1,2,3,*].

[1] University of Cordoba. (IMIBIC), Reina Sofia University Hospital., Córdoba, Spain.
[2] Institute of Health Carlos III (ISCIII), Madrid, Spain
[3] Escuela Universitaria de Osuna (Centro Adscrito a la Universidad de Sevilla), Osuna, Spain.

Corresponding author:
Jose Manuel Jurado-Castro
juradox@gmail.com

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Abstract

Introduction: Physical education (PE) has shifted toward active approaches that enhance engagement and promote healthy lifestyles. Gamification has emerged as a promising tool to boost student motivation and physical performance, positively impacting fitness, including cardiorespiratory fitness and body composition. However, comprehensive reviews on its effectiveness in PE are limited.
Methodology: This systematic review and meta-analysis examined the effects of gamified PE interventions on physical fitness and motor coordination compared with traditional or non-gamified approaches. The protocol was registered in PROSPERO (CRD42025642780). Searches were conducted in PubMed/MEDLINE, Web of Science, ScienceDirect, and Scopus up to September 2024. Randomized controlled trials assessing physical fitness outcomes were included. Risk of bias was assessed using the Cochrane RoB 2 tool.
Results: From 958 identified records, six studies met the inclusion criteria. Gamified PE interventions improved VO_2max (MD 4.05; 95% CI 2.54 to 5.57; $p < 0.001$; $I^2 = 38\%$) and agility (MD 1.04; 95% CI 0.17 to 1.92; $p = 0.02$; $I^2 = 99\%$). No beneficial effects were observed for horizontal jump performance (MD -0.01; 95% CI -0.06 to 0.04; $p = 0.67$; $I^2 = 95\%$), and CMJ performance favored the control group (MD -2.39; 95% CI -3.76 to -1.02; $p < 0.001$; $I^2 = 62\%$). Most studies showed low risk of bias in several domains, although some concerns were identified, mainly regarding randomization and deviations from intended interventions.
Conclusion: Gamified PE interventions may improve VO_2max and agility, but evidence for strength-related outcomes is inconsistent. These findings should be interpreted cautiously due to the limited number of studies, high heterogeneity for several outcomes, and some methodological concerns.

Keywords

Agility; children; exercise; strength; VO2max.

Resumen

Introducción: La educación física (EF) ha evolucionado hacia enfoques activos que favorecen la participación del alumnado y promueven estilos de vida saludables. La gamificación ha surgido como una estrategia prometedora para incrementar la motivación del alumnado y mejorar el rendimiento físico, con efectos positivos sobre la condición física, incluida la capacidad cardiorrespiratoria y la composición corporal. Sin embargo, las revisiones exhaustivas sobre su eficacia en el contexto de la EF son todavía limitadas.
Metodología: Esta revisión sistemática y metaanálisis examinó los efectos de las intervenciones basadas en gamificación en educación física sobre la condición física y la coordinación motriz, en comparación con enfoques tradicionales o no gamificados. El protocolo fue registrado en PROSPERO (CRD42025642780). Se realizaron búsquedas en PubMed/MEDLINE, Web of Science, ScienceDirect y Scopus hasta septiembre de 2024. Se incluyeron ensayos clínicos aleatorizados que evaluaban resultados relacionados con la condición física. El riesgo de sesgo se evaluó mediante la herramienta Cochrane RoB 2.
Resultados: De los 958 registros identificados, seis estudios cumplieron los criterios de inclusión. Las intervenciones gamificadas en educación física mejoraron el VO_2máx (DM = 4,05; IC del 95%: 2,54 a 5,57; $p < 0{,}001$; $I^2 = 38\%$) y la agilidad (DM = 1,04; IC del 95%: 0,17 a 1,92; $p = 0{,}02$; $I^2 = 99\%$). No se observaron efectos beneficiosos sobre el rendimiento en el salto horizontal (DM = −0,01; IC del 95%: −0,06 a 0,04; $p = 0{,}67$; $I^2 = 95\%$), mientras que el rendimiento en el salto con contramovimiento (CMJ) favoreció al grupo control (DM = −2,39; IC del 95%: −3,76 a −1,02; $p < 0{,}001$; $I^2 = 62\%$). La mayoría de los estudios presentaron un bajo riesgo de sesgo en varios dominios, aunque se identificaron algunas limitaciones, principalmente relacionadas con el proceso de aleatorización y las desviaciones de las intervenciones previstas.
Conclusiones: Las intervenciones gamificadas en educación física pueden mejorar el VO_2máx y la agilidad; sin embargo, la evidencia sobre los resultados relacionados con la fuerza es inconsistente. Estos hallazgos deben interpretarse con cautela debido al reducido número de estudios incluidos, la elevada heterogeneidad observada en varios desenlaces y algunas limitaciones metodológicas.

Palabras clave

Agilidad; niños; ejercicio; fuerza; VO2max.

Introduction

Physical education (PE) has undergone a notable shift in recent decades, moving away from traditional, instruction-based approaches towards student-centered methodologies that promote engagement and active participation (Arufe-Giráldez et al., 2023; Arjomandi et al., 2018). Within this context, active methodologies such as cooperative learning, problem-based learning, and gamification have gained increasing attention due to their potential to enhance both learning outcomes and healthy behaviors (Fanaroff et al., 2024; Konopka et al., 2015).

Among these approaches, gamification has emerged as a promising pedagogical strategy. In the educational context, gamification can be operationally defined as the intentional use of game elements (e.g., points, challenges, feedback systems, and narratives) in non-game settings to enhance motivation, engagement, and behavior (Deterding et al., 2011; Liu & Lipowski, 2021). Importantly, in PE, gamification encompasses structured interventions that integrate these elements into motor tasks and physical activities, including hybrid approaches that may incorporate digital tools (e.g., apps or active video games) insofar as they are embedded within a pedagogical design aimed at increasing physical engagement.

From a theoretical perspective, gamification may influence physical condition through several mechanisms. By increasing motivation and enjoyment, it can promote higher levels of participation and adherence to physical activity (Yang & Koenigstorfer, 2021). Additionally, structured challenges and feedback may encourage greater effort and intensity during practice, which are key factors in improving fitness components such as cardiorespiratory fitness, strength, and agility. These mechanisms are particularly relevant in school settings, where student engagement is a critical determinant of physical activity levels (Jurado-Castro et al., 2023).

Empirical evidence suggests positive effects of gamified interventions in PE and related contexts. Previous studies have reported improvements in body composition, physical activity levels, and cardiorespiratory fitness following interventions that incorporate game-based elements or active digital tools (Camacho-Sánchez et al., 2023; Comeras-Chueca et al., 2022). However, the available literature is heterogeneous in terms of intervention types, populations, and outcome measures. Moreover, existing reviews have primarily focused on motivational or educational outcomes, or have examined gamification broadly without specifically addressing its impact on physical condition variables.

Therefore, there is a need for a systematic synthesis of the evidence that specifically examines the effects of gamification-based interventions on physical condition and cardiorespiratory fitness in PE settings. In particular, it remains unclear to what extent these interventions contribute to improvements in key fitness components and whether their effects are consistent across studies. Therefore, the objective of this study is to conduct a systematic review and meta-analysis of the existing literature to understand how gamification in PE might contribute to improving physical condition and cardiorespiratory fitness.

Method

Inclusion criteria of selected studies

It was conducted a systematic review and meta-analysis of studies, following the "Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA)" criteria (Page et al., 2021). The PRISMA criteria were assessed by a check-list (Supplementary material 1). The review protocol was registered at the PROSPERO (International Prospective Register of Systematic Reviews) with the registration number (CRD42025642780).

Criteria for considering studies for inclusion in the review

In this systematic review, the search criteria used were to review all clinical trials up to September 2024 that were found in the above-mentioned databases written in English and published in any country.

Inclusion criteria were defined based on the PICO(S) system as follows: P (population): primary school students, secondary school students, and university students; I (intervention): experimental group (EG) that received PE gamification interventions; (C) (comparison): control group (CG) not involved in PE gamification; (O) (outcomes): assessment of physical fitness and cardiorespiratory fitness (maximum oxygen volume (VO2max)), strength (Horizontal Jump and Countermovement Jump (CMJ)), Agility; (S) (study type): randomized controlled trial.

Exclusion criteria were applied to articles that were not available through university services or memberships, lacked measurable and objective data on academic performance, or were written in languages other than English.

Protocol for searching

The bibliographic search was carried out in different databases of articles published as MEDLINE (Pubmed), WOS (Web of Science), Science direct y SCOPUS; 119 articles were retrieved from PubMed, 403 from Scopus, and 436 from Web of Science. The keywords used to perform the search were related to "physical education" and "gamification". The search was performed using the equation "physical education"[All Fields] AND "gamification"[All Fields] for PubMed and Scopus, and ("physical education" AND "gamification" AND ("children" OR "adolescents")) for Web of Science. More details about the electronic search are shown in the Supplementary Material (Supplementary material 2).

Study selection and data collection

Two independent reviewers conducted the searches and analyzed the studies (C.C-C., J.M.J-C). Disagreements between reviewers were resolved by a third author (R. R-C.). In cases of missing or incomplete data, the original study authors were contacted. Articles found were coded using the reference manager RefWorks (Lorenzetti & Ghali, 2013). The data from each article were carefully analysed to ensure that the interpretation of the data was completely correct. The articles were then screened according to the established inclusion criteria.

The literature search was conducted in two steps. During the first step, articles were screened by their titles and abstracts, and those that did not meet the inclusion criteria were excluded. In the second phase, a thorough analysis of all articles was conducted, extracting information such as the countries where the studies were conducted, participant age, sex, the method used (participants, educational level, assessment of physical fitness and cardiorespiratory fitness), the type of intervention, and the general results and conclusions.

In two cases, there were two studies with the same author, so to differentiate them, the letters "a" and "b" were added (Melero-Canas et al., 2021; Melero-Cañas et al., 2021; Mora-Gonzalez, Pérez-López, & Delgado-Fernández, 2020; Mora-Gonzalez, Pérez-López, Esteban-Cornejo, et al., 2020). Additionally, there was one case where a study was divided into two parts (boys and girls), and these terms were used to distinguish the data (Cenizo-Benjumea et al., 2022).

Risk of bias in individual studies

To assess the risk of bias the Cochrane Risk of Bias 2 (RoB 2) (Sterne et al., 2019) tool was used. This instrument assesses bias across five areas: bias from the randomization process, bias from deviations in intended interventions, bias due to missing outcome data, bias in outcome measurement, and bias in the selection of reported results. It also provides an overall risk of bias rating. These categories encompass all recognized biases that can affect randomized controlled trials (RCTs) and are classified as low risk, some concerns, or high risk of bias.

Data analysis

Data were extracted considering sample size, mean, and standard deviation from each study. For continuous outcomes, mean change scores were calculated as the difference between post- and pre-intervention values. The standard deviation of the change scores (SDchange) was calculated using the following formula: "$SDchange = \sqrt{(SDbaseline^2 + SDfinal^2 - 2 \times r \times SDbaseline \times SDfinal)}$" where r represents the correlation coefficient between baseline and post-intervention measurements. When this value was not reported, a correlation coefficient of $r = 0.5$ was assumed, in line with previous meta-analyses, as a conservative estimate.

A random-effects model was applied to account for between-study variability, using the inverse variance method with the DerSimonian and Laird estimator. The effect of gamification-based educational interventions on physical fitness and cardiorespiratory fitness was examined by comparing experimental groups (EG) and control groups (CG). Subgroup analyses were conducted for VO2max, strength (horizontal jump and CMJ), and agility.

The results were presented using forest plots, showing mean differences (MD) with 95% confidence intervals (CI). The MD was selected to maintain the original measurement scales and provide a direct interpretation of the differences between groups. Statistical heterogeneity was assessed using the I^2 statistic, interpreted as low (0–40%), moderate (30–60%), substantial (50–75%), and considerable (>75%). Sensitivity analyses were performed to explore the sources of heterogeneity; however, high heterogeneity persisted. Publication bias was assessed using Egger's test (Egger et al., 1997) and visually inspected through funnel plots (Supplementary Material 3).

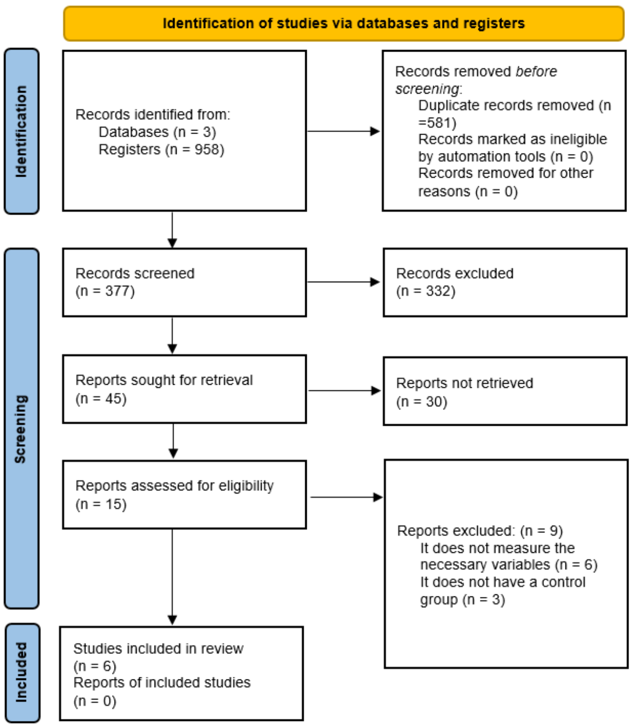
The meta-analysis was conducted using Review Manager software (RevMan, version 5.4.1) as described by Higgins et al. (2011). A p-value below 0.05 in the overall Z-test was considered statistically significant. Results are presented as mean values with the standard deviation indicated by the '±' symbol.

Results

Studies selected

Figure 1 presents a flow chart outlining the study selection process for the meta-analysis. Initially, 958 articles were identified through database searches conducted up to September 2024. After removing 581 duplicates, 377 unique records remained. Of these, 362 were excluded for the following reasons: (1) titles and abstracts were not relevant to the research aims; (2) the participants did not meet the inclusion criteria; or (3) the studies did not involve gamification. This left 15 articles for full-text review. Among these, six were excluded for not assessing the required variables, and three for lacking a control group (see Supplementary Material 4). In the end, six studies met all inclusion criteria and were selected for the meta-analysis.

Figure 1. PRISMA flowchart for the selection of relevant studies from databases for this meta-analysis.



Description and characteristics of different studies

The characteristics of the included studies are provided in Table 1. All 5 selected studies were conducted in Spain (Cenizo-Benjumea et al., 2022; Comeras-Chueca et al., 2022; Melero-Canas et al., 2021; Melero-Cañas et al., 2021; Mora-Gonzalez, Pérez-López, & Delgado-Fernández, 2020; Mora-Gonzalez, Pérez-López, Esteban-Cornejo, et al., 2020). A total of 962 students (14.08 ± 4.5 years old) were included in the meta-analysis, with 602 participating in the EG and 360 in the CG.

In three studies, the gradual walking protocol with respiratory gas exchange was used to also assess cardiorespiratory capacity (Comeras-Chueca et al., 2022; Mora-Gonzalez, Pérez-López, & Delgado-Fernández, 2020; Mora-Gonzalez, Pérez-López, Esteban-Cornejo, et al., 2020) Three studies used the 4 × 10 m speed-agility test to assess agility (Cenizo-Benjumea et al., 2022; Melero-Canas et al., 2021; Melero-Cañas et al., 2021), and one study used the CMJ test to evaluate lower body strength (Cenizo-Benjumea et al., 2022). Lastly, three studies measured strength through the horizontal jump (Cenizo-Benjumea et al., 2022; Melero-Canas et al., 2021; Melero-Cañas et al., 2021)

Regarding the type of gamification used, one study utilized a program called "Matrix rEFvolution" (Mora-Gonzalez, Pérez-López, Esteban-Cornejo, et al., 2020), another study used an AVG exercise program combined with multicomponent exercise (Comeras-Chueca et al., 2022), two studies employed a hybrid gamification program (Melero-Cañas et al., 2021; Melero-Canas et al., 2021), one study used a gamification program based on a mobile app (Mora-Gonzalez, Pérez-López, & Delgado-Fernández, 2020), and one study utilized a gamification program called GPS (Cenizo-Benjumea et al., 2022).

Table 1. Characteristics of the selected studies using interactive competitive intervention in the classroom in real-time.

Autor (Year)	Country	N	Age	Educational context / intervention and assignment criterion	Duration, frequency and intensity	Variables	Main Results	Type Of Gamification
Mora-González et al. (2020) (A)	Spain	112	20.93 ± 1.32	University PE-related subject; "Matrix rEFvolution" gamification program to promote PA and CRF. Quasi-experimental non-randomized trial; convenience sample; class groups based on schedule.	15 weeks; 42 lectures. PA promoted through running/cycling 3–5 days/week; intensity not objectively prescribed.	(VO2max, ml/kg/min)	Of the students who attended 100% of the classes, 87.8% met the physical activity recommendations for 100% of the weeks, while among those who attended less than 100%, only 26.7% met them for 100% of the weeks.	"Matrix rEFvolution": The initiative aimed to motivate university students to adhere weekly to internationally recognized physical activity guidelines. This was achieved by providing a role-playing experience inspired by movie heroes and villains over a 15-week period, involving activities such as running or cycling to evade "The Sentinels."
Comeras-Chueca et al. (2022)	Spain	28	10 ± 0.8	Supervised AVG + multicomponent exercise; children 9–11 y with overweight/obesity. RCT; 2:1 allocation; SPSS-generated random sequence; EG vs daily-activity CG.	5 months; 3/week; ~60 min/session. Progressive intensity; HR/RPE not prescribed.	(VO2max, ml/kg/min)	The AVG group significantly reduced heart rate and oxygen use during submaximal efforts, while the control group showed no notable changes. There were no differences in peak VO_2max.	The AVG group participated in a 5-month program consisting of three 60-minute sessions per week. Each session started with a 10-minute warm-up that included joint mobility, dynamic stretching, muscle activation, core exercises, balance, and coordination.

								This was followed by 45 minutes of combined AVG and multicomponent training in a dynamic circuit format. The session concluded with a 5-minute cool-down featuring static stretching routines.
Melero Cañas et al. (2021) (A)	Spain	58	13.89 ± 1.14	Secondary school PE; adolescents 13–15 y; hybrid TPSR + gamification. Quasi-experimental group-randomized trial; schools selected by convenience; EG/CG by school.	9 months; 2 PE lessons/week; 110 min/week. Intensity not reported.	Speed agility, strength, agility and cardiorrespiratory fitness		
Melero-Cañas et al. (2021) (B)	Spain	150	14.33 ± 1.8	Secondary school PE; adolescents 13–15 y; hybrid TPSR + gamification focused on PF, PA and sedentary time. Group-randomized controlled trial; two schools assigned to EG/CG.	9 months; 2 PE lessons/week; 55 min/session. Intensity not reported.	Speed-agility, strength, agility-coordination, cardiorrespiratory fitness and flexibility.	The combination of TPSR and gamification strategies led to improvements in speed-agility and increased physical activity levels on weekends, while also helping to reduce sedentary time. However, it did not lead to changes in motivation.	The Enigma of Seneb guided students in exploring overall health. They completed two activities outside school with varying difficulty levels, working individually and in groups. The focus was on completing tasks, supporting teammates, and earning points and badges. Clear instructions, points, and progress updates were provided via a social platform. Students earned "healthy years" to unlock badges, and their final status—squires, "Egyptian melli," or bearers of Seneb—depended on the mythologies completed.
Mora-González et al. (2020) (B)	Spain	117	20,1 ± 2,9)	University PE-related subject; "$in TIME" mobile-app gamification program to promote PA and CRF. Quasi-experimental design; convenience sample; class section by schedule; lecturers randomly allocated.	16 weeks; 44 lectures. PA encouraged 3–5 days/week; ≥150 min/week moderate or ≥75 min/week vigorous PA; intensity monitored by Runtastic pace.	Cardiorespiratory Fitness (mL/(kgxmin)	After the intervention, there were significant differences between the groups in the 20m shuttle run test and estimated maximum oxygen uptake, with an average difference of 1.2 stages and 3.69 mL/(kg·min). Only the intervention group showed a significant improvement, increasing by 1.4 stages.	The use of a game-based mobile app on the Cardiorespiratory Fitness levels of college students.
Cenizo-Benjumea et al. (2022)	Spain	271	8 -11 years	School PE; children 8–11 y; "Salticity/GPS" gamified jumping program. Quasi-	5 weeks; 10 sessions; 2/week. Intensity not reported; self-	Coordination, strength, and agility.	An enhancement in lower limb strength was observed,	The program took place over 10 sessions across 5 weeks

(BOYS)				experimental design; intentional non-probabilistic sampling; non-randomized EG/CG.	regulated 3-level jumping challenges.		assessed through tests of jumping capacity, agility, and motor coordination. The improvement across all age ranges supports the importance of implementing gamified environments that can be tailored to the individual needs of each student. The findings revealed a notable increase of 12 centimeters in horizontal jump performance, with no significant differences between boys and girls.	during Physical Education classes. Students worked to rescue the fictional town of "Salticity" from an evil character's spell by earning points through various challenges to restore their lost games. Each challenge was monitored by a peer who had been trained to recognize correct and incorrect performances.
Cenizo-Benjumea et al. (2022) (GIRLS)	Spain	226						

AVG, active video games; CG, control group; CMJ, countermovement jump; CRF, cardiorespiratory fitness; EG, experimental group; HJ, horizontal jump; HR, heart rate; IG, intervention group; PA, physical activity; PE, physical education; PF, physical fitness; RCT, randomized controlled trial; RPE, rating of perceived exertion; SRT, shuttle run test; TPSR, Teaching Personal and Social Responsibility; VO_2, oxygen uptake; VO_2max, maximum oxygen uptake; y, years.

Risk of bias in included studies

Taking into account the five domains established to analyse the risk of bias, five of them are noteworthy (Supplementary material 5). After reading all the selected articles in depth, it was observed that all included studies met nearly all the established domains with a low risk of bias, except for two studies where it is unclear whether randomization of participant groups occurred (Cenizo-Benjumea et al., 2022; Mora-Gonzalez, Pérez-López, & Delgado-Fernández, 2020), and one study where randomization was not performed (Mora-Gonzalez, Pérez-López, Esteban-Cornejo, et al., 2020) (Figure 2).

Figure 2. Risk of Bias Assessment of Included Studies (Intention-to-Treat Analysis)

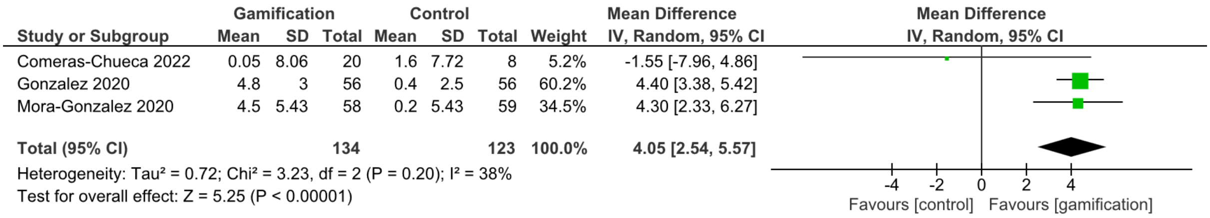
Effects of the intervention

To measure the effect of the studies, improvement in variables such as VO2max, strength (horizontal jump and CMJ), and agility was analysed. Six studies were included in the meta-analysis.

VO2max (Respiratory Gas Exchange for Cardirrespiratory Capacity Assessment)

The VO2max was measured in 3 studies included in the meta-analysis (Comeras-Chueca et al., 2022; Mora-Gonzalez, Pérez-López, & Delgado-Fernández, 2020; Mora-Gonzalez, Pérez-López, Esteban-Cornejo, et al., 2020), comparing EG vs. CG (MD 4.05; CI 2.54 to 5.57; P<0.001; I2 = 38%) (Figure 3) and observed an increase of VO2max in favor of gamification. The study that had the most weight (60.2%) (Mora-Gonzalez, Pérez-López, Esteban-Cornejo, et al., 2020)

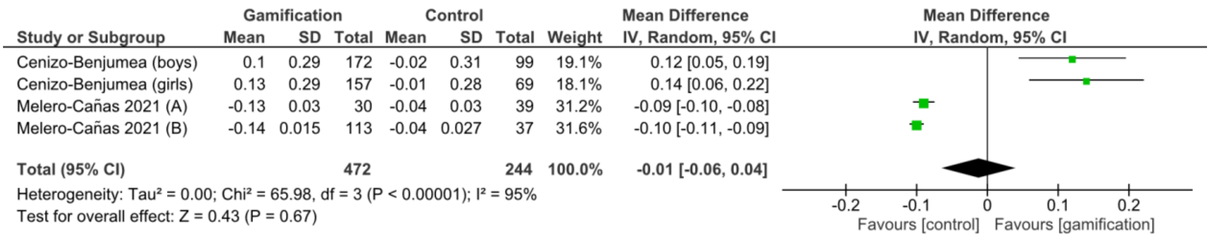
Figure 3. Effect interventions of VO_2max changes in gamification and control group.



Strength (Horizontal Jump)

The strength by horizontal jump was measured in 3 studies included in the meta-analysis (Cenizo-Benjumea et al., 2022; Melero-Canas et al., 2021; Melero-Cañas et al., 2021), comparing EG vs. CG (MD -0.01; CI -0.06 to -0.04; P=0.67; I2 = 95%) (Figure 4) and observed an increase of strength in favor of CG. The study that had the most weight (31.6%) (Melero-Cañas et al., 2021)

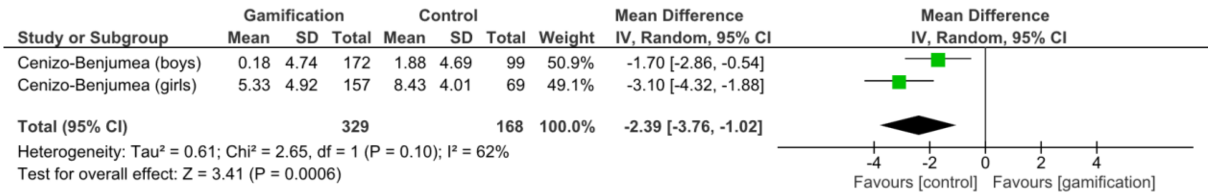
Figure 4. Effect interventions of strength changes in gamification and control group.



Strength (CMJ)

The strength by CMJ was measured in 1 study that is subdivided into boys and girls included in the meta-analysis (Cenizo-Benjumea et al., 2022), comparing EG *vs.* CG (MD -2.39; CI -3.76 to -1.02; P<0.001; I^2 = 62%) (Figure 5) and observed an increase of CMJ in favor of CG.

Figure 5. Effect interventions of CMJ changes in gamification and control group.



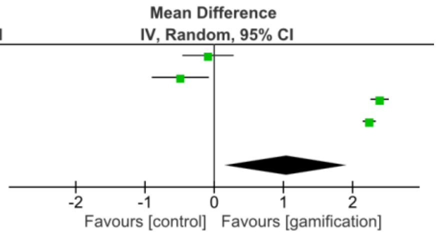
Agility (4 × 10 m Speed-Agility)

The agility was measured in 3 studies included in the meta-analysis (Cenizo-Benjumea et al., 2022; Melero-Canas et al., 2021; Melero-Cañas et al., 2021), comparing EG vs. CG (MD 1.04; CI 0.17 to 1.92; P=0.02; I2 = 99%) (Figure 6) and observed an increase of agility in favor of gamification. The study that had the most weight (25.6%) (Melero-Cañas et al., 2021)

Figure 6. Effect interventions of agility changes in gamification and control group.

Study or Subgroup	Gamification Mean	Gamification SD	Gamification Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Cenizo-Benjumea (boys)	-0.02	1.7	172	0.07	1.3	99	24.6%	-0.09 [-0.45, 0.27]
Cenizo-Benjumea (girls)	-1.25	1.59	157	-0.76	1.34	69	24.3%	-0.49 [-0.89, -0.09]
Melero-Cañas 2021 (A)	2.74	0.27	30	0.35	0.24	39	25.5%	2.39 [2.27, 2.51]
Melero-Cañas 2021 (B)	2.63	0.142	113	0.39	0.252	37	25.6%	2.24 [2.15, 2.33]
Total (95% CI)			**472**			**244**	**100.0%**	**1.04 [0.17, 1.92]**

Heterogeneity: Tau² = 0.78; Chi² = 332.12, df = 3 (P < 0.00001); I² = 99%
Test for overall effect: Z = 2.34 (P = 0.02)



Discussion

This meta-analysis suggests that gamified PE could improve VO2max and agility compared to CGs, while no positive effects were observed on strength (measured through horizontal jump) or CMJ performance. Nevertheless, these results should be interpreted with caution due to the high heterogeneity.

For VO2max, a significant and moderate effect was found (MD = 4.05; 95% CI: 2.54 to 5.57; $p < 0.001$) with low heterogeneity ($I^2 = 38\%$), suggesting a relatively consistent positive effect of gamified physical education interventions on cardiorespiratory fitness.

In contrast, the results related to muscular strength showed no significant improvements. The horizontal jump presented a trivial and non-significant effect (MD = -0.01; 95% CI: -0.06 to 0.04; p = 0.67) with extremely high heterogeneity ($I^2 = 95\%$), indicating substantial variability between studies. Similarly, CMJ results showed a negative effect in favor of control groups (MD = -2.39; 95% CI: -3.76 to -1.02; $p < 0.001$), though based on a single study, which limits the generalizability of the findings.

Regarding agility, a small but significant improvement was observed (MD = 1.04; 95% CI: 0.17 to 1.92; p = 0.02); however, the heterogeneity was extremely high ($I^2 = 99\%$), which reduces the confidence in this result and suggests that differences in study design, intervention characteristics, or sample populations may have influenced the outcomes.

The interpretation of the results should also consider the heterogeneity of the interventions included under the term "gamification". Although all studies incorporate game-based elements, they differ in design (e.g., active video games, mobile applications, or narrative-based approaches), which may influence the type and intensity of physical activity performed. This variability could explain the differences observed between outcomes, particularly the positive effects on VO2max and agility compared to the lack of improvement in explosive strength.

Motivation plays a pivotal role in gamification studies, significantly influencing outcomes. However, a decline in student motivation over time has been documented, often attributed to the diminishing novelty effect as the intervention progresses (Ning et al., 2022). Various studies have highlighted that a hybrid approach combining multiple pedagogical models is more effective than relying on a single model, as it enhances physical/motor, cognitive, affective, and social domains. Moreover, gamification fosters physical activity both within and beyond the school environment, reinforcing its positive impact on student learning and well-being (Melero-Canas et al., 2021). Although gamification analyses typically focus on social and psychological factors, its impact on promoting healthy lifestyle habits, such as increased physical activity, is less commonly addressed. This aspect is particularly relevant given the findings of one study included in the meta-analysis, which observed an increase in body mass index among participants who did not engage in gamification (Melero-Cañas et al., 2021). These findings suggest that gamified dynamics not only have a positive impact on educational and social outcomes but also play a critical role in preventing issues associated with sedentary behaviour and promoting more active lifestyles (Melero-Cañas et al., 2021)

The study results revealed that participants in the intervention group, who engaged in gamification, showed a significant improvement in VO2 max values compared to the CG. This difference suggests that gamification in PE can positively impact cardiorespiratory performance. These findings align with previous research indicating that gamification enhances participation and motivation in physical activity, potentially leading to increased intensity and duration of exercise—key factors for improving aerobic capacity (Xu et al., 2022). The interpretation of the results should also consider the characteristics of the interventions. Many gamified programs include dynamic and intermittent activities that may increase overall physical activity levels and cardiovascular demand, which could explain the improvements observed in VO2max and agility. However, these interventions may lack the specific intensity and structured load required to enhance explosive strength, which could account for the absence of significant effects in this variable.

It can be observed that the studies examining this variable focused on improving the physical condition of the intervention group. One of the studies involved an intensive physical activity program for university students (Mora-Gonzalez, Pérez-López, & Delgado-Fernández, 2020). In another study, the intervention group engaged in CORE exercises, balance training, and agility and strength circuits, targeting children with overweight or obesity (Comeras-Chueca et al., 2022). In another study, the participants were university students who followed a physical activity promotion program through various gamified exercises. These students, being from the field of physical activity, performed the exercises with high effectiveness (Mora-Gonzalez, Pérez-López, Esteban-Cornejo, et al., 2020).

The success of gamification in improving VO2 max can be explained by several mechanisms. Firstly, the playful and competitive nature of gamification may enhance participants' intrinsic motivation (Pimentel-Ponce et al., 2024). Elements such as points, challenges, and rewards create an environment where participants feel they are achieving goals, which promotes greater adherence to exercise sessions. This increased adherence and enjoyment of physical activity may lead participants to exert more effort, thereby increasing the intensity and frequency of exercise. Consequently, this results in physiological improvements, such as enhanced aerobic capacity (Yang & Koenigstorfer, 2021).

Moreover, gamified games and activities often include a greater variety of stimuli and dynamics, which help maintain interest and minimize monotony—factors that typically reduce motivation in traditional exercise programs (Mazeas et al., 2022). The variety of movements and activities within gamification may also engage different muscle groups and physical abilities, potentially contributing to a more comprehensive improvement in overall physical condition, including cardiorespiratory capacity (Cheng et al., 2020). In one of the studies analysed in this section, university students were encouraged to engage in physical activity through a mobile application, allowing them to exercise outside of class hours (Mora-Gonzalez, Pérez-López, & Delgado-Fernández, 2020). In another study included, the intervention focused on CORE exercises, balance training, and agility circuits, leading to improvements in physical fitness (Comeras-Chueca et al., 2022). In another study included, a gamification approach was used to encourage participants to engage in physical activity during their free time, through running or cycling exercises 3 to 5 days per week (Mora-Gonzalez, Pérez-López, Esteban-Cornejo, et al., 2020), The elements considered for the gamification included the dynamics and mechanics of the exercises through games, whereas the CG focused more on strengthening physical fitness with traditional exercises.

Gamified games and activities often include challenges that require quick and precise movements, which may have contributed to the improvement in participants' agility. By incorporating competitive elements, immediate rewards, and a playful environment, participants may be more motivated to perform movements with greater speed and accuracy, resulting in enhanced agility skills (Kim et al., 2022)

Furthermore, it is likely that the activities in the CG did not provide the same level of immediate feedback or reward components as those in the gamified intervention, which may have reduced the intensity with which participants performed the physical movements (Liu & Lipowski, 2021). Without the additional motivation provided by game elements, participants in the CG may not have exerted as much effort or maintained the same consistency in repeating movements that enhance agility (Ferriz-Valero et al., 2020).

Gamification, while an effective tool for enhancing motivation and engagement, often emphasizes the playful and competitive aspects of activities rather than the development of specific physical skills (Fanaroff et al., 2024). It is possible that the gamified activities were more focused on improving other physical qualities, such as agility, endurance, or coordination, rather than directly targeting the explosive strength required for the horizontal jump (Arora & Razavian, 2021). In this regard, participants in the intervention group may have been less exposed to specific exercises targeting leg strength, which could explain their inferior performance in the horizontal jump test compared to the CG

The horizontal jump requires intense use of the leg muscles and lower body, particularly in terms of explosive strength. In this context, one of the studies included in the analysis showed that the intervention group engaged in activities focused on free play, considering the dynamics, mechanics, and components of the exercises. Meanwhile, the CG focused on strengthening physical conditioning, which may explain the observed difference in performance (Cenizo-Benjumea et al., 2022). In another study, it was observed that the CG performed specific exercises targeting particular muscles. Additionally, a potential bias in the evaluation is evident, as the same individuals were not assessed across both groups (Melero-Cañas et al., 2021). If the gamified activities did not include specific training for this skill or similar movements, it is possible that the participants in the intervention group did not have the opportunity to develop the strength required to excel in this test. In contrast, the CG may have performed more traditional exercises, such as squats, jumps, or plyometric exercises, which are more directly related to the development of explosive strength (Monroe et al., 2023).

The CMJ is a test that specifically assesses the ability to generate explosive power in the legs through a rapid flexion and extension movement (Jakicic & Rogers, 2020). If the gamified activities did not include specific exercises to develop explosive strength, such as plyometric jumps, deep squats, or resistance training targeting the leg muscles, participants in the intervention group may have been at a disadvantage in this test (Agarwal et al., 2021). In contrast, the CG, which likely engaged in more structured or specific training, may have targeted the strength and power of the muscles involved in the CMJ more directly, which could explain their superior performance (Saucedo-Araujo et al., 2020). In this case, one of the included studies shows that the intervention group focused on the dynamics of the game, while the CG concentrated on strengthening specific muscles (Cenizo-Benjumea et al., 2022).

Another possible explanation is that the gamified dynamics may have caused increased fatigue or overload in the participants of the intervention group, which could have negatively impacted their performance in the CMJ test (Veiga et al., 2022). If the gamification involved low-intensity but prolonged or repetitive physical activities, participants in the intervention group may have accumulated fatigue, which could have impaired their ability to perform jumps with maximum power in the CMJ test. In contrast, the CG, which likely followed a more balanced program with specific recovery times and physical demands, may have performed better (Ito et al., 2024).

Limitations

These findings have significant implications for the implementation of gamified strategies in PE programs. Gamification not only makes exercise more engaging and enjoyable for students, but it can also offer tangible benefits in terms of improving physical performance. The improvement in VO2 max observed in the gamified group suggests that this methodology could be particularly useful in promoting healthier lifestyle habits and enhancing athletic performance, which in turn may have long-term benefits for cardiovascular health. However, it is important to consider some limitations of the study. The duration of the intervention could have influenced the magnitude of the observed improvements. Additionally, participant heterogeneity (age, initial fitness level, gender) may have affected the results, so future studies with larger and more diverse samples would be valuable for generalizing the findings. Furthermore, the variety of gamified activities may have influenced the results, as imbalanced game dynamics targeting different physical capacities could have favoured certain outcomes over others. External factors, such as participant motivation driven by the playful environment, may have also impacted the results, complicating the generalization of the findings to non-gamified contexts. The meta-analysis showed a high level of heterogeneity, which is expected since various physical fitness tests were compared. To evaluate the stability of the results and the influence of individual studies, a sensitivity analysis was attempted by removing studies one by one and reassessing the outcomes when heterogeneity was moderate to high. Despite these attempts, heterogeneity remained high, preventing a full sensitivity analysis. The interpretation of the results should also consider the methodological quality of the included studies, as assessed by the RoB-2 tool. Although several studies showed a low risk of bias in most domains, some presented “some concerns”, particularly in aspects related to deviations from intended interventions and measurement of outcomes. These methodological limitations may have influenced the observed effect sizes and contributed to the variability of the results. Therefore, the findings of this meta-analysis should be interpreted carefully.

Future Research

From a practical perspective, gamified physical education programs may be a useful strategy to improve cardiorespiratory fitness and agility. However, future research should consider longer interventions to analyse long-term effects and promote more homogeneous designs. Additionally, exploring a greater diversity of gamified activities and comparing different gamification approaches would help determine which specific elements are most effective. Incorporating more structured training components may also improve outcomes such as explosive strength.

Conclusions

Gamification in PE significantly enhances VO_2max and agility, proving its effectiveness in boosting cardiorespiratory performance and specific motor skills. However, strength showed no improvement, likely due to the absence of targeted exercises. Although motivation plays a crucial role in these outcomes, it may decline over time, highlighting the importance of maintaining novelty in interventions.

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Author Affiliations

Cristina Castro-Collado[1], Rafael Cortés-Rojas[3], Alejandro Pradas-Ponce[3], Daniel Rangel-Rodríguez[3], José Andrés Ruiz-Castaño[3], Vanesa Cuevas-Cuevas[3], Pablo Pradas-Villaécija[3], Jose Manuel Jurado-Castro[123]*

[1] University of Córdoba, Maimonides Biomedical Research Institute of Córdoba (IMIBIC), Metabolism and Investigation Unit, Reina Sofía University Hospital, Avda. Menéndez Pidal s/n, 14004 Córdoba, Spain.

[2] CIBEROBN (Physiopathology of Obesity and Nutrition), Instituto de Salud Carlos III (ISCIII), 28029 Madrid, Spain.

[3] Ciencias de la Actividad Física y del Deporte, Escuela Universitaria de Osuna (Affiliated Center of the University of Seville), 41640 Osuna, Spain.

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Authors and translators' details:

Cristina Castro Collado	colladocac@gmail.com	Cristina Castro-Collado
Rafael Cortés Rojas	rafacortesrojas@gmail.com	Rafael Cortés-Rojas
Alejandro Pradas Ponce	alprpo9@gmail.com	Alejandro Pradas-Ponce
Daniel Rangel Rodríguez	Danielrangelrodriguez11@gmail.com	Daniel Rangel-Rodríguez
José Andrés Ruiz Castaño	a.ruiztuco@gmail.com	José Andrés Ruiz-Castaño
Vanesa Cuevas Cuevas	vcceso5@gmail.com	Vanesa Cuevas-Cuevas
Pablo Pradas Villaécija	pablopradasecija97@gmail.com	Pablo Pradas-Villaécija
Jose Manuel Jurado Castro	juradox@gmail.com	Jose Manuel Jurado-Castro