Effectiveness of Gamification Interventions to Improve Physical Activity and Sedentary Behavior in Children and Adolescents: A Systematic Review and Meta-Analysis

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Abstract

Background: Physical activity (PA) is closely related to the health of children and adolescents. Gamification interventions are highly potential measures to promote PA. However, the effects of gamification interventions on PA and sedentary behavior (SB) in children and adolescents remain a controversial topic. This review aims to resolve this controversy.

Objective: This systematic review aims to evaluate the effectiveness of gamification interventions in improving PA and reducing SB in children and adolescents and to summarize potential moderators of gamification interventions to promote PA participation.

Methods: RCTs of the effects of gamification interventions on PA participation in children and adolescents were retrieved from PubMed, Web of Science, Embase, EBSCO, and the Cochrane Library electronic databases. Meta-analyses were performed using RevMan 5.4 and Stata 18 software. Studies of the effects of gamification interventions on PA and SB in children and adolescents were included in the analysis, and due to high heterogeneity, meta-analysis was performed using a random-effects model, and the risk of bias was assessed using the Cochrane Risk of Bias Assessment Tool (Cochrane RBAT). Egger tests and sensitivity analyses were used to ensure the robustness of the results, and subgroup analyses were used to explore the possible effects of different factors on the results.

Results: We included 16 RCTs with a total of 7,472 children and adolescents were ultimately included. A meta-analysis of the results showed that the gamification intervention had a positive effect on MVPA?SMD=0.15,95% CI:0.01 to 0.29; P=.04) and BMI (SMD 0.11,95% CI 0.05 to 0.18; P=.0004). However, there was no significant improvement in SB (SMD 0.07, 95% CI -0.07 to 0.22; P=.33), VPA (SMD 0.12, 95% CI -0.03 to 0.55; P=.56), MPA (SMD 0.16, 95% CI -0.2 to 0.53; P=.38), LPASMD (SMD -0.00, 95% CI -0.49 to 0.48; P=.99), and Daily Step (SMD 0.22, 95% CI -0.51 to 0.94; P=.55). Results of subgroup analyses indicated that theoretical paradigm, game elements, intervention duration, and study setting had a significant moderating effect on MVPA in children and adolescents.

Conclusions: Meta-analyses indicated that gamification interventions effectively increased MVPA in children and adolescents, and this effect persisted beyond the follow-up period. Theoretical paradigms, game elements, and intervention duration may be associated with the efficacy of gamification interventions, and further exploration of the optimal implementation of game elements and theoretical features is needed to maximize PA engagement. Clinical Trial: CRD42023426532

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Keywordsgamification; physical activity; behavior change; eHealth; health behavior; intervention; meta-analysis; mobile phone; systematic review

Introduction

Background

Regular physical activity participation is associated with numerous health benefits. However, most children and adolescents do not meet global physical activity guidelines[1-3]. It is estimated that nearly one in five (324 million; 18%) adolescents worldwide are overweight or obese. In addition, poor health outcomes and chronic diseases are increasing due to insufficient physical activity (PA)[4-7]. Conversely, regular PA can avert the risk of chronic diseases[8, 9] and reduce the development of non-communicable risk factors[10, 11]. Furthermore, epidemiological studies have shown a "dose-response" relationship between SB and mortality[12]. Increasing high levels of PA has been shown to attenuate or even eliminate the deleterious effects of SB on early adolescent mortality[12]. Consequently, there is a need to identify effective interventions to increase PA levels and reduce sedentary time in adolescents.

Gamification, using electronic devices and immersive technologies, appears to be a promising approach to influencing health behaviors[13, 14]. Gamification has been defined as the use of game design elements in non-game environments[14], driven by the incorporation of gamification elements (e.g., rewards, feedback, social interactions, etc.) to transform non-game situations into a game-like experience that encourages physical activity (PA) engagement in adolescents[14].

However, most of the current research on gamification interventions has focused on the effects on adults or individuals with specific chronic diseases, including rheumatic diseases, cancer survivors, and cardiovascular disease[15-19]. The results of these studies have been significant. In contrast, the impact of gamification interventions on children and adolescents remains understudied. While the existing literature has begun to elucidate the impact of gamification interventions on physical activity and sedentary behaviors in healthy adolescents, the results of these interventions have been inconsistent [20-22]. Direito[23] found that underlying factors may influence gamification interventions for PA. Despite the limited impact of studies measuring TPA or MVPA levels in children and adolescents on outcomes, it is still possible that the included studies and general physical activity (PA) interventions were ineffective[24-26]. However, these reviews highlight the lack of high-quality studies and emphasize the need for more rigorous trials to isolate the effects of gamification, particularly randomized controlled trials (RCTs)[20, 21, 27].

Nevertheless, when rigorous experiments are employed, the effects of gamification may be less pronounced[21]. In conclusion, the evidence on the effectiveness of gamification interventions in promoting PA and reducing SB is inconclusive. Meta-analyses based on high-quality randomized controlled trials are of particular interest.

In addition, gamification interventions based on theoretical paradigms may be more conducive to increasing physical activity (PA) in children and adolescents[28]. Several theoretical paradigms have been used for gamification interventions[29], including self-determination theory (SDT), transtheoretical models (TTM), behavior change techniques (BCTs), and social cognitive theory (SCT). Different factors, such as game elements and theoretical paradigms, are crucial in determining the effectiveness of gamification interventions. Therefore, systematic evaluation is essential.

This Study

This systematic review aims to assess the effectiveness of gamification interventions in promoting PA and reducing SB in children and adolescents. Specifically, 1）The aim is to evaluate the efficacy of a gamification intervention in improving moderate-to-vigorous physical activity MVPA, vigorous physical activity VPA, moderate physical activity MPA, LPA, daily step count, and reducing SB in children and adolescents. 2）The aim is to examine the effectiveness of gamification interventions across diverse subgroups, considering the moderating effects of variables such as theoretical framework, game elements, and intervention cycle. In addition, unlike existing reviews, this review will assess the effectiveness of gamification interventions in promoting PA and reducing SB in children and adolescents based on rigorous research components derived from randomized controlled trials (RCTs). Subgroup analyses will examine the influence of crucial moderating variables, including theoretical framework, game elements, and intervention duration, on the effectiveness of gamification interventions. This approach will improve our understanding of the factors that influence the effectiveness of these interventions and facilitate the accurate quantification of intervention programs.

Methods

Registration and Approval

The article was conducted in accordance with the PRISMA 2020 Statement and the Cochrane Guidelines for Systematic Reviews[30, 31]. The systematic reviews were registered on the PROSPERO (CRD42023426532).

Search Strategy and Information Sources

MW and XCL conducted independent literature searches according to the PRISMA 2020 statement. A comprehensive search of multiple databases was performed, including PubMed, Web of Science, EBSCO, Embase, and the Cochrane Library. The search period was limited to January 1, 2010, and

August 1, 2024. A literature search strategy was developed by two investigators using Boolean operators ("AND" and "OR") to combine subject terms with open-access terms. The following search terms were used: The search terms were "child" or "adolescent," "gamification," "exergaming," "exer-gaming," "gamified," "gameful," and "physical activity," "PA," "MVPA," and "sedentary behavior." The search terms "exergaming," "exergaming," "gamified," and "gameful" were combined with the search terms "physical activity," "PA," "MVPA," "sedentary behavior," "SB," and "sedentary behavior." In addition, the search terms "sedentary lifestyle," "sedentary behavior," and "sedentary behavior" were included. A detailed description of the PubMed search strategy can be found in Multimedia Appendix 1. In addition, we supplemented our search results with references cited in previous reviews.

Inclusion and Exclusion Criteria

Inclusion Criteria

The PICOS principles developed the screening criteria, and the inclusion criteria for this study were as follows:

Participants

The study included children and adolescents between the ages of 1 and 18, regardless of gender or health status. This included individuals with chronic medical conditions, overweight or obesity status, and other health conditions that would not preclude participation in the study. Subjects with physical dysfunction, including those with contraindications to PA or other medical conditions that preclude participation in PA, and those with intellectual and cognitive disabilities were excluded.

Intervention

Gamification interventions aim to increase physical activity (PA) or sedentary behavior (SB) in children and adolescents, distinguishing between serious and mature games[32]. Serious games are video games designed for non-entertainment purposes such as education, training, or advocacy (e.g., the augmented reality sports game Pokémon Go) to provide a highly purposeful gaming experience. In contrast, gamification is often used to incentivize and facilitate user participation, enhance the experience, and increase user motivation and engagement, for example, by using gaming elements such as points, leaderboards, or badges (e.g., wearables combined with mobile apps combined with user feedback, points, and leaderboards to increase PA) to influence user behavior and motivation. However, the three concepts have considerable subjectivity and definitional ambiguity[33]. Therefore, three researchers (MW, JSX, and XCL) discussed and defined this study.

Comparators

This review included randomized controlled trials (RCTs) that compared a gamification intervention with a control group that did not include gamification elements. The control groups consisted of two different categories: an inactive group, which was represented by a waiting list and served as a non-exposed control group, and an active group, which consisted of a control group with other non-gamified interventions.

Outcome

The primary outcome measures included the following: moderate-to-vigorous physical activity (MVPA), vigorous-intensity physical activity (VPA), moderate-intensity physical activity (MPA), low-intensity physical activity (LPA), daily steps, and sedentary behavior (SB). These outcomes were measured objectively as continuous data using accelerometers, pedometers, and a smartphone application (APP). Due to the increased risk of data bias associated with subjective measures obtained via self-report questionnaires, objective data are consistently preferred over self-report questionnaires in analyses[34]. Consequently, outcome measures derived from self-report questionnaires were excluded from this study.

Study design.

The studies included in the analysis were randomized controlled or cluster randomized controlled trials.

Exclusion Criteria

The exclusion criteria were as follows: (1) unavailability of original articles, review studies, conference abstracts, repetitive publications, animal experiments, and non-randomized controls; (2) incomplete data and fruitless attempts to contact the authors of the articles; (3) non-English-language literature; and (4) literature in which the outcome metrics were not related to physical activity and sedentary behavior.

Study Selection

The article screening process uses the PRISMA 2020 Statement flowchart paradigm to document the studies selected or excluded at each step[30]. The search results were summarized and imported into EndNote 21 literature management software (Clarivate Analytics, Inc., USA), where MW performed the initial screening by sorting and removing duplicates. To ensure the inclusion of original studies that met the established criteria, authors XCL and JSX independently assessed the title and abstract of the article using EndNote 21 software. Two researchers subjected all articles potentially meeting the criteria to a full-text review. Any discrepancies arising during the review process will be discussed and resolved with MW.

Data Extraction

Two authors (XLZ and XCL) used a standardized data abstraction form to extract the data. Any discrepancies were discussed and resolved with the second author (MW). The extracted content included the following elements:

1. Basic information (e.g., authors, year, country, and type of study)
2. Subject characteristics (sample size, age, and sex ratio)
3. Intervention (gamification elements, intervention period, and intervention mode)
4. Control group intervention
5. Mean and standard deviation of outcome measures
6. Type of study, theoretical basis, and measurement instruments

Risk of Bias Assessment

For each eligible trial, two reviewers (MW and XLZ) used the specially constructed Cochrane Risk of Bias tool (outlined in Table 8.5 of the Cochrane Handbook for Evaluation of Intervention Systems[35]) to assess the risk of bias. The risk of bias was assessed in seven domains: sequence generation, allocation concealment, blinding of subjects and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other risks of bias. In this meta-analysis, we comprehensively assessed the potential risk of bias based on the content of the included literature. We categorized the studies as high risk, low risk, or unclear (if relevant information was unavailable). The results of these risk-of-bias assessments were documented in the review and included in the final analysis. To assess inter-rater agreement, we calculated the κ statistic. After a comprehensive assessment, we determined that the included studies were strikingly similar in design and that blinding was not feasible for this intervention. Consequently, we rated the risk of blinding bias for these studies as high. Given these considerations, the increased risk of bias associated with blinded programs is particularly evident in the risk of bias assessment plot.

Statistical Analysis

A meta-analysis was performed using RevMan 5.4 software (Cochrane, UK) and Stata17 software (StataCorp LLC, USA). This included calculating effect size combinations, performing heterogeneity tests, generating forest plots, performing subgroup analyses, assessing publication bias (using funnel plots and Egger's test [36]), and performing sensitivity analyses. The original study data set included continuous variables. Therefore, the standardized mean difference (SMD) and its 95% confidence interval (CI) were selected as the effect measures for the pooled analysis. In addition, PA and SB data, including means and standard deviations, were extracted independently from each study. For some of the studies that did not provide these data directly, we supplemented them using the estimation method of Hozo [36] et al. The heterogeneity test of this study was performed using I^2 and P values. When I^2 was less than 50%, and P was equal to or greater than 0.10, the data were analyzed using a fixed-effects model. Conversely, a meta-analysis used a random-effects model when I^2 exceeded 50%, and P was less than 0.10[37]. Subgroup analyses will be performed to gain a deeper understanding of the impact of other potential factors on the outcome indicators. The potential for publication bias in the literature was assessed using funnel plots and Egger's test. Publication bias was inferred if the funnel plots showed asymmetry or the $P < 0.05$ in Egger's test. Otherwise, the possibility of publication bias was considered low. The effect size interpretation criteria were SMD < 0.2 for negligible effect sizes, 0.2 ≤ SMD < 0.5 for small effect sizes, 0.5 ≤ SMD < 0.8 for moderate effect sizes, and SMD ≥ 0.8 for large effect sizes. A z-statistic of $P < 0.05$ was used to assess the significance of the overall effect.

Results

Study Selection

A total of 2021 relevant articles were retrieved from PubMed (n=249), Web of Science (n=1276), EBSCO (n=174), Cochrane Library (n=297), and EBBASE (n=25). Figure 1 summarizes the screening process for the included studies. The five databases were initially searched using a search strategy that yielded 2021 articles. Following the list of relevant references, five articles were identified. After removing 843 duplicates using EndNote 21 software, 1183 irrelevant articles were excluded by reviewing titles and abstracts. Finally, 54 articles were evaluated by reading the full text. Thirty-eight articles were excluded, and 16 documents were finally included [38-53].

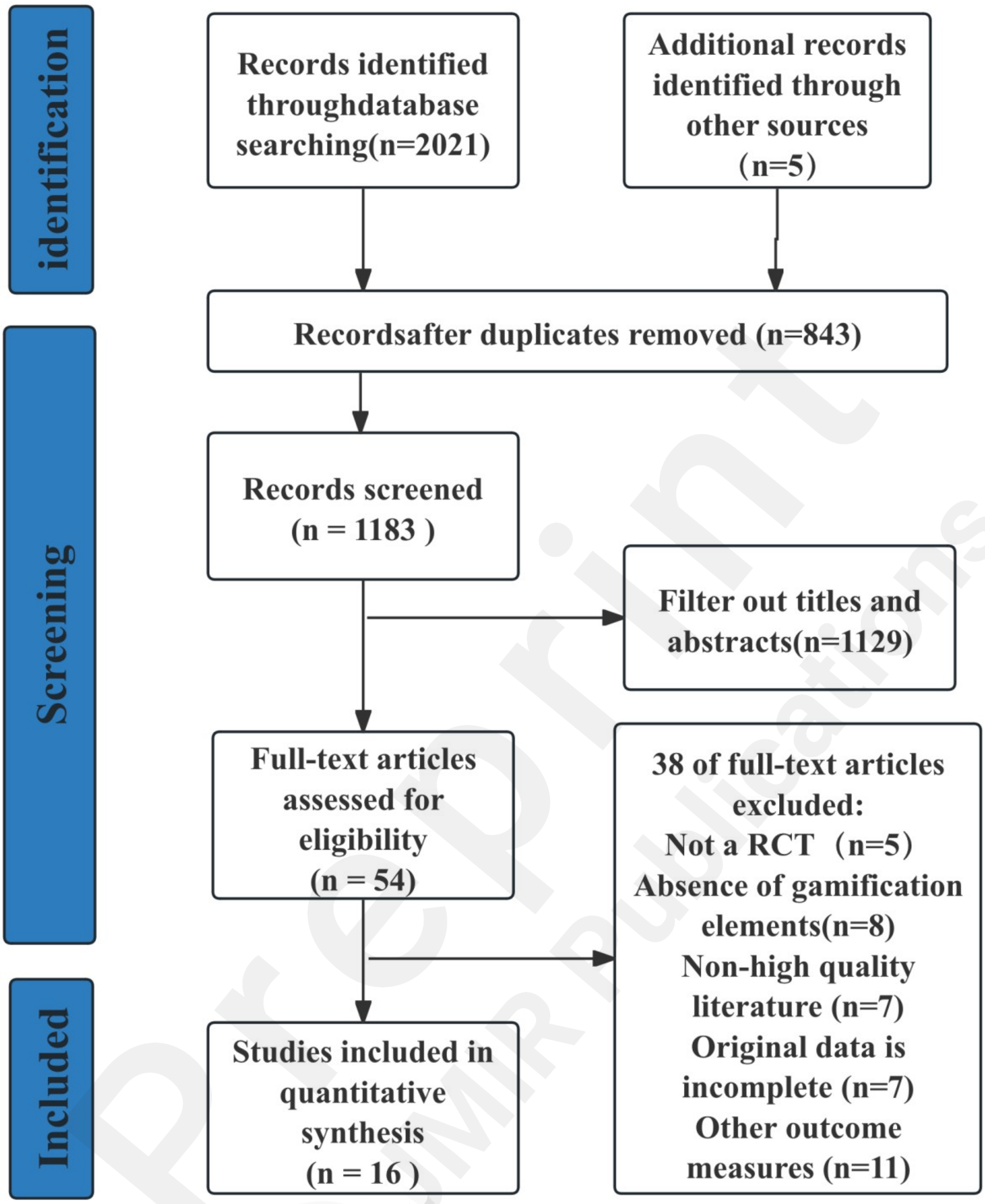


Figure 1. Flowchart of the study selection.

Characteristics of the Included Studies

The 16 English-language papers included in this study were published from 2012 to 2024[38-53] and contained 7,472 subjects, ranging from 13 to 1,544 subjects per study. As shown in Table 1, the included studies had the following essential characteristics. Subjects ranged in age from 1 to 18 years. Study countries included the United States (6/16) [38, 42-44, 53]Canada (4/16)[39-41, 50]New Zealand2/16[49, 52]Finland (1/16)[47]Chile (1/16)[45]Northern Ireland1/16[46]Singapore1/16[51]UK1/16[48]. 8 were tested in school settings [40-46, 48, 52]5 in home settings [38, 43, 50, 51, 53]， and 3 in settings where families and communities worked together [39, 47, 49].12 studies were randomized controlled trials [38-44, 47, 49-51, 53]，4 trials were cluster randomized controlled trials [45, 46, 48, 52]，7 studies used belt worn accelerometers [38, 42-44, 49, 52, 53]，5 studies used wristband activity trackers [45-48, 50]，3 studies used foot sensors as activity trackers [39-41]，1 study used the MapMyFitness app on a smartphone, eliminating the need for an additional wearable activity tracker [51]. The intervention period was 1-48 weeks, and the follow-up was 24-96 weeks. Outcome measures included MVPA, VPA, MPA, LPA, SB, and Daily Steps. 14 studies used behavior change research theories, including the social cognitive theory （SCT）[43, 53]，Self Determination Theory (SDT) [39-42, 44, 46, 48, 51]，Behaviour Change Wheel (BCW)[45]，Behaviour Change Techniques (BCTs)[49]，The Transtheoretical Model (TTM) [47, 50]. trials have been registered in the Clinical Trials Registry [38-50, 52, 53], and 1 trial is not registered[51]. 14 studies have been funded[38-41, 43-50, 52, 53]，And 2 studies did not receive any funding[42, 51]. 1 completed follow-up 48 to 96 weeks (mean 12 weeks) after completing the intervention[52], and 3 studies completed follow-up assessments 12-28 weeks after the intervention ended [45, 46, 53]. In terms of how gamification interventions were implemented, 14 studies used mobile applications (e.g., smartphone apps, iPod touch, Facebook groups, Fitbit mobile apps) in addition to wearable physical activity trackers[38-44, 46-51, 53]， and 2 studies focused on building school gamification environments [45,52]. The number of game elements used in gamification interventions ranged from 1 to 8, with most including four or more game elements. The most used game elements were socialization, interaction, rewards, points, feedback, challenges, and achievements. Additionally, intervention durations ranged from 1 week to 96 weeks, with 5 (31.3%) studies having a follow-up period. This suggests that further evaluation of PA gamification is needed to determine the effectiveness and sustainability of game element interventions.

Table 1. Summary of the intervention characteristics of the included studies.

Study	Participans	Total sample size (n)/ male	Age (years)	Interventions	control	Theoretical paradigm	Duration	Main Outcomes M(SD)
Maloney et al（2012）	Adolescents with obesity or overweigh	64/53	9-17	pedometer plus DDR（‘ Dance Dance Revolution’’ Konami of America)	pedometer only	1	12week	LPA, MPA, VPA, Daily Steps
Garde et al（2015）	Adolescents	47/16	8-13	'“MobileKids Monster Manor” was a mobile exergame synchronized with an external activity monitor	feedback through Tractivity	SDT	2week	Daily step
Garde et al（2016）	adolescents	56/35	11.3 ± 1.2	"MobileKids Monster Manor (MKMM) combines a game with activity monitors."	Participants do not engage with the game;	SDT	1weeks	Daily step
Garde et al（2018）	adolescents	37/16	10.6 – 0.51	"MobileKids Monster Manor (MKMM) combines a game with activity monitors."	Participants do not engage with the game;	SDT	1weeks	Daily step
Fu et al（2018）	preschool children	65/34	4.9 ± 0.7	‘‘GoNoodle’’ is an online active videogame program that provides children with a variety of PA and exercise choices	five 30-minute active free-play sessions	SDT	12week	Daily step
Staiano（2018）	children with obesity or overweigh	46/23	10-12	Exergaming group (kinect and Xbox 360 gaming console, exergames, telehealth coaching)	keep normal level of physical activity	SCT	24week	BMI z-score
Staiano(2016)	adolescent girls	42/0	14-18	dance-based motion game intervention, featuring a structured gaming environment	without specific interventions.	SDT	12weeks	SB,LPA,MPA, VPA
pena et al（2021	Fifth and sixth grade	2320/1398	11.08 ± 0.7	Nutrition and physical activity interventions using	Standard Education	BCW	16-28 weeks	BMI z-score

[a] MVPA: moderate to vigorous physical activity.
[b]VPA: vigorous physical activity.
[c]MPA: moderate physical activity.
[d]LPA: light physical activity.
[e] SB: Sedentary

time/behavior

[f] SCT: sociocognitive theory.

[g] SDT: self-determination theory.

[h] TTM: The Transtheoretical Model

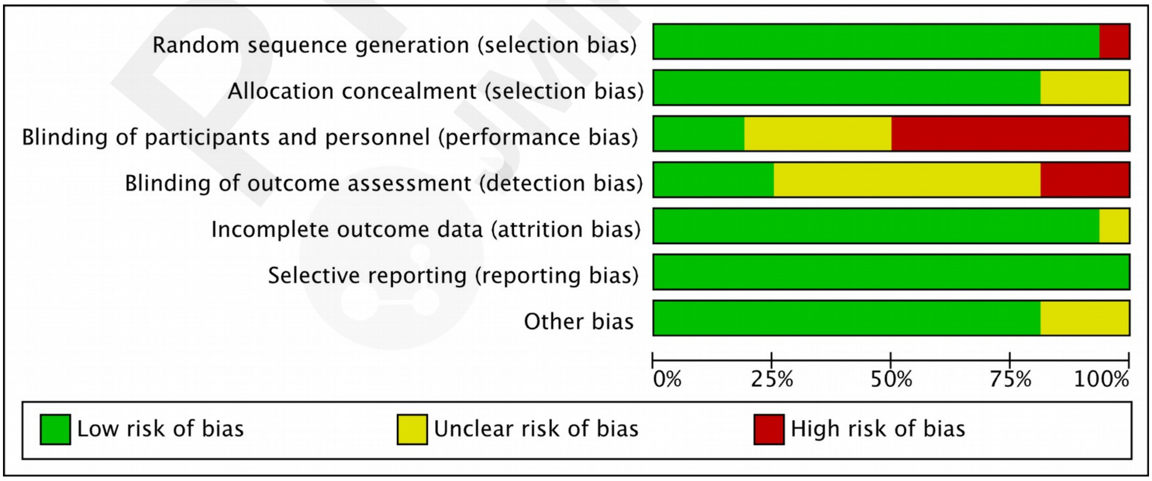
[J]The Behavioral Change Wheel

[1]No theory mentioned.

Risk of Bias Assessment

The κ coefficient of the risk of bias data extracted by both authors was 0.73, which is in excellent agreement. The authors' ratings for each risk of bias item are presented as percentages in the meta-analysis, and the different biases for each study are summarized. Overall, 15 trials adequately reported randomized sequence generation and one trial with randomized sequence generation was considered high risk because the trials were assigned sequentially in the order of recruitment[39]□13 trials (72%) described programs designed to conceal [38-43,45,47-51,53]. The blinding of the subjects and the personnel in a total of 5 trials is not known [41,44,47,48,51]□8 trials had unclear blinding of the outcome assessments [38,40,41,44,47,49,51,52]□17 trials provided data on subjects lost to follow-up, In contrast, 1 trial had unclear information [44], and 2 trials were at high risk of other bias [46,51]. 1 trial crossover trial was conducted without a blinding condition [40], and 1 trial has not yet been registered for publication, so there is uncertainty [50].

A



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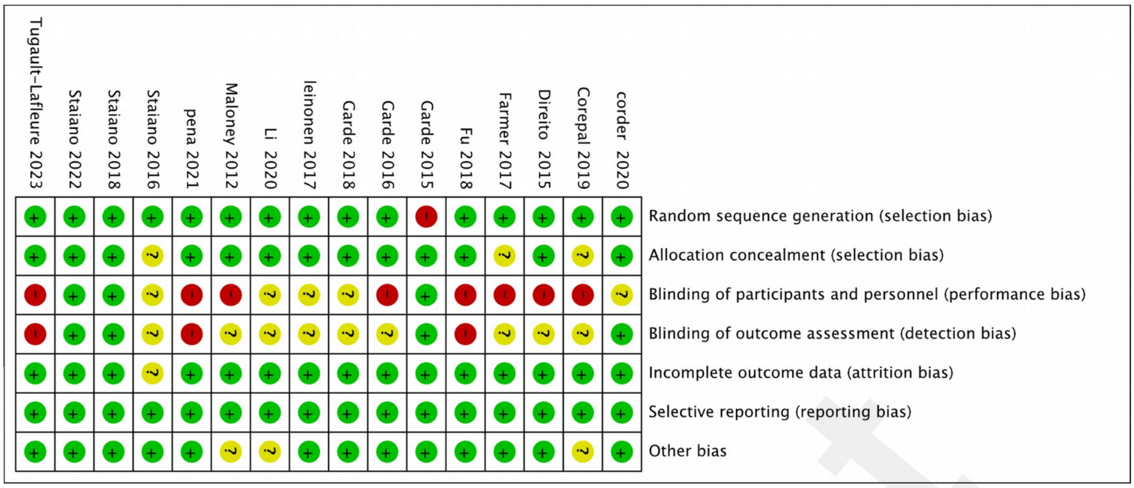

Figure 2. Risk bias assessment of the included studies. (A) Risk of bias graph and (B) risk of bias summary.

Results of the Meta-Analysis

Of the 16 studies, 11 (69%) were examined to assess the impact of gamification interventions on MVPA. The heterogeneity test showed a significant heterogeneity among the studies (I^2 =68% *P*< 0.1) so a random effects model was used for the analysis. The combined effect sizes showed that the gamification intervention significantly improved MVPA in children and adolescents compared to the control group (SMD=0.15,95% CI:0.01 to 0.29; *P*=.04); Figure 3([43, 46-49, 52, 53]).

Of the 16 studies, 6 (38%) were examined to assess the impact of gamification interventions on VPA. The heterogeneity test revealed heterogeneity between studies (I^2=78%; *P*<.001), which required analysis using a random effects model. The combined effect size indicated that gamification interventions were ineffective in improving VPA in children and adolescents compared to controls (SMD 0.12, 95% CI -0.03 to 0.55; *P*=.56), Figure 4 ([38, 44, 46, 49]).

Of the 16 studies, 6 (38%) were examined to assess the impact of gamification interventions on MPA. Tests for heterogeneity showed more significant heterogeneity between studies (I^2=70%; *P*<.001), requiring analysis using random effects models. The meta-analysis found no significant differences in the effects of gamification interventions on moderate physical activity in children and adolescents compared with controls. SMD 0.16,95% CI -0.2 to 0.53; *P*=.38; Figure 5([38, 44, 46, 49]).

Of the 16 studies, 6 (38%) were examined to assess the impact of gamification interventions on LPA. The heterogeneity test revealed heterogeneity between studies (I^2=88%; *P*<.001), which required analysis using a random effects model. The combined effect sizes showed that the difference in LPA between the gamification intervention and the control group was insignificantSMD -0.00,95% CI -

0.49 to 0.48; *P*=.99; Figure 6([38, 44, 46, 49, 53]).

Of the 16 studies, 7 (44%) were examined to assess the impact of gamification interventions on SB. Heterogeneity tests showed heterogeneity between studiesI^2=19%; *P*>001, so fixed effects models were used for analyses. A meta-analysis found that gamification interventions did not significantly reduce sedentary behavior in children and adolescents (SMD 0.07,95% CI -0.07 to 0.22; *P*=.33); Figure 7([46, 49, 50, 53]).

Of the 16 studies, 12 (75%) were examined to assess the impact of gamification interventions on Daily Step. Tests for heterogeneity showed more significant heterogeneity between studies (I^2=95%; *P*<.001), requiring analysis using random effects models. A meta-analysis found that gamification interventions did not increase daily steps among children and adolescentsSMD 0.22,95% CI -0.51 to 0.94; *P*=0.55; Figure 8([38-42, 44, 46, 50, 51]).

Of the 16 studies, 4 (25%) were examined to assess the impact of gamification interventions on BMI. Heterogeneity tests showed little heterogeneity between studiesI^2=0%; *P*=0.72, which required analysis using a fixed-effects model. A meta-analysis found that gamification interventions improved BMI in children and adolescentsSMD 0.11,95% CI 0.05-0.18; *P*=0.0004; Figure 9([43, 45, 50]).

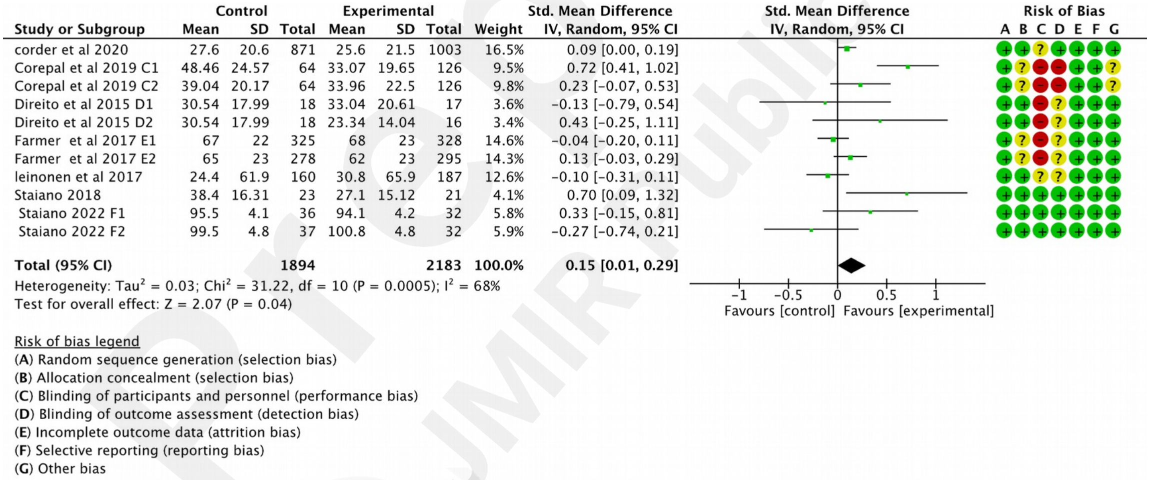

Figure 3. Forest plot of the effect of gamification interventions on increasing moderate to vigorous physical activity.

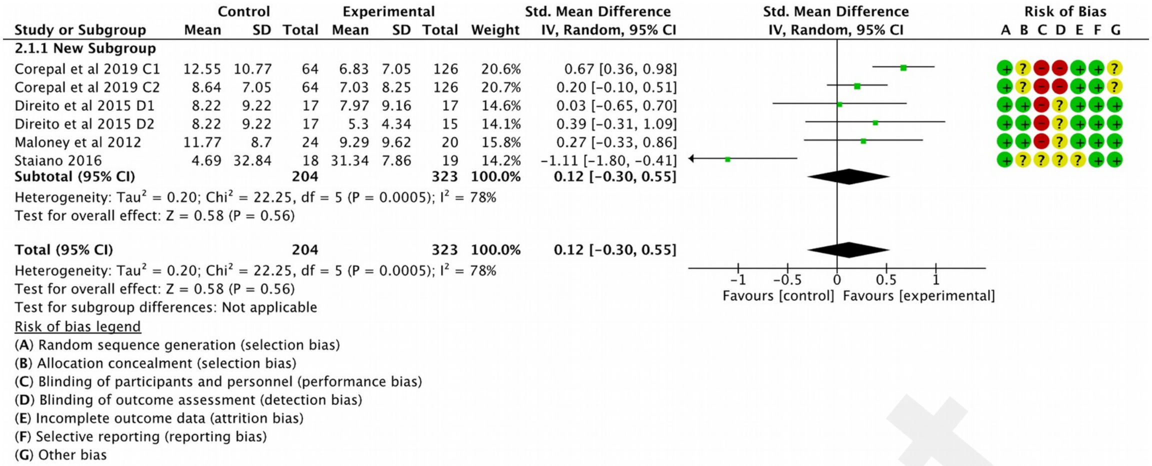

Figure 4. Forest plot of the effect of gamification interventions on increasing vigorous physical activity.

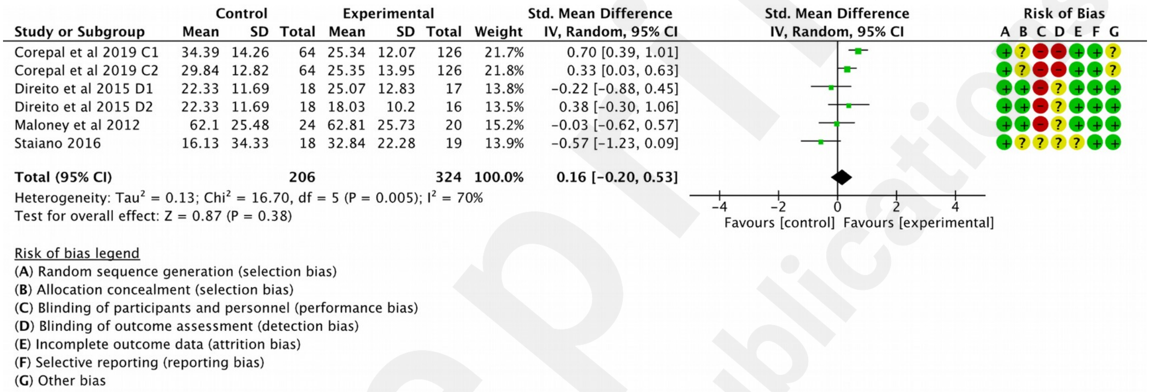

Figure 5. Forest plot of the effect of gamification interventions on increasing moderate physical activity.

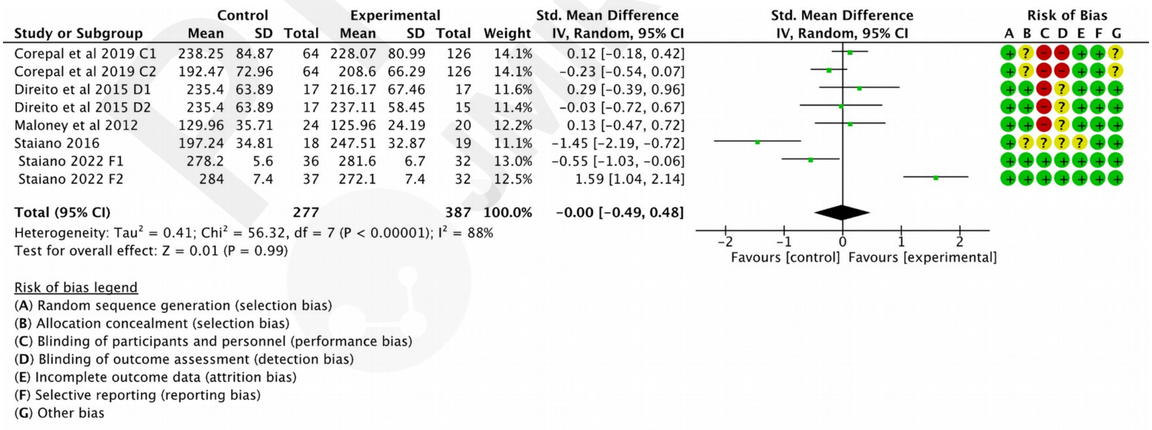

Figure 6. Forest plot of the effect of gamification interventions on increasing light physical activity.

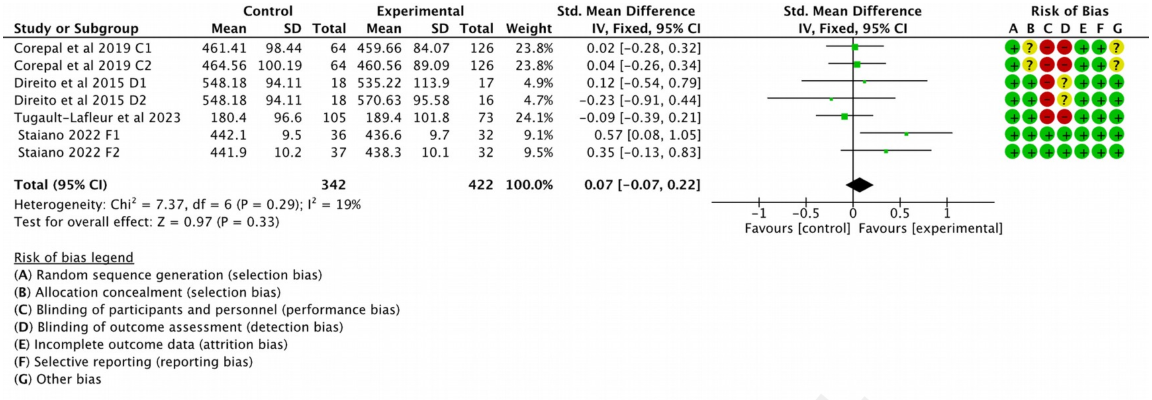

Figure 7. Forest plot of the effect of gamification interventions on decreasing sedentary behavior

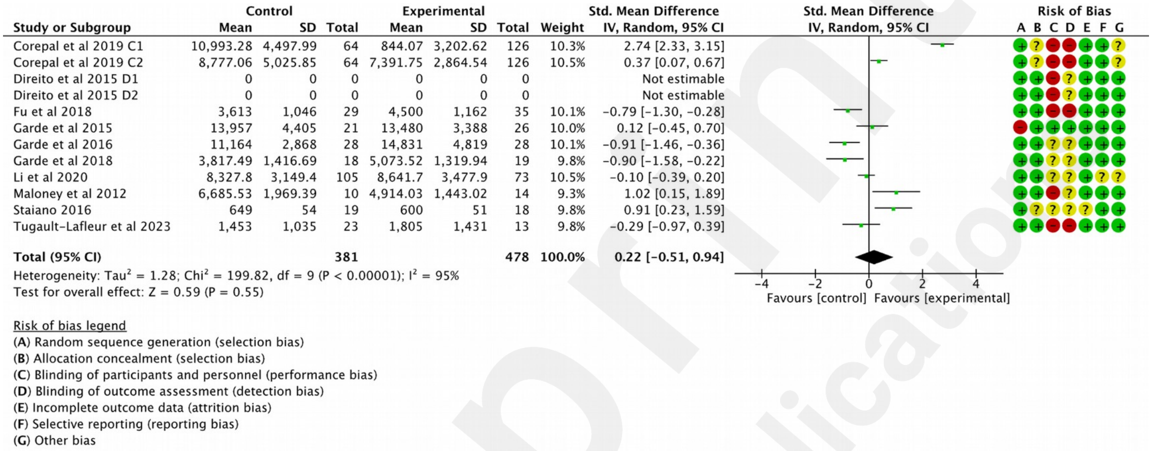

Figure 8. Forest plot of the effect of gamification interventions on the daily steps

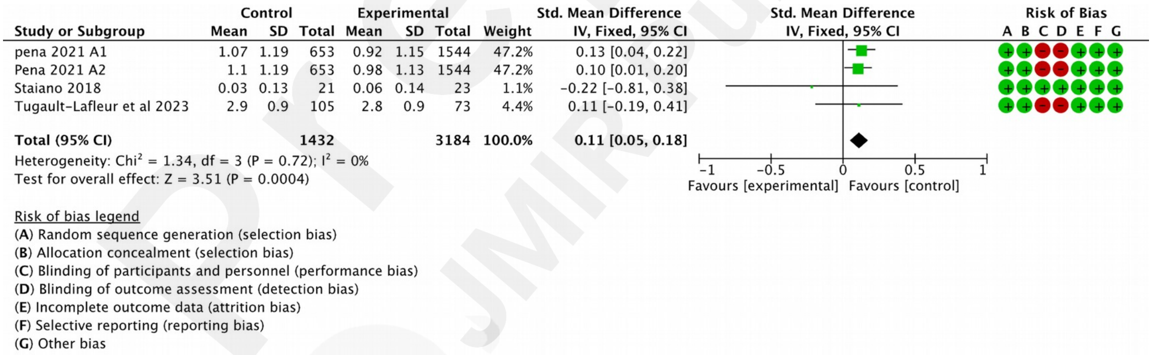

Figure 9. Forest plot of the effect of gamification interventions on BMI

Sensitivity Analysis

In this study, sensitivity analyses of MVPA, LPA, and SB were conducted using Stata 18.0 to assess the robustness and reliability of the results. The sensitivity analyses showed that excluding any of the studies did not affect the magnitude of the effect of the gamification intervention on the outcomes of LPA and SB in Multimedia Appendix 2-4, suggesting the robustness and reliability of the findings[10]. However, for MVPA, the sensitivity analysis identified four studies as outliers[43, 46, 48, 53]. Excluding one of these studies changed the overall effect size, suggesting that the results were not robust enough and should be interpreted cautiously.

Subgroup Analyses

To further explore the effects of other components on outcome indicators, this study focused on subgroup analyses of MVPA, including age, theoretical paradigm, game elements, intervention duration, study setting, position of the physical activity monitor, and sample size. Only four articles assessed BMI as an outcome. Subgroup analyses were not performed for this outcome due to the small sample size. In addition, the results of all subgroup analyses for SB and other PA indicators were not significant and were, therefore, not analyzed in detail.

A Subgroup Analysis of the Effects of a Gamification Intervention on MVPA

The results of the subgroup analyses of the gamification intervention on MVPA are presented in Multimedia Appendix 5, and there were no significant differences in age, wearer position, or sample size regarding improvements in MVPA in children and adolescents. Subgroup analyses based on theoretical paradigms showed a more pronounced effect of SDT-based interventions on MVPA promotion（SMD=0.39，95%CI0.01 To 0.77， I^2=91%）. However, the effect of other theoretical paradigms based on SCT (SMD=-0.19, 95% CI-0.76 to 0.39, I^2=72.6%) and BCTs (SMD=0.01, 95% CI-0.11 to 0.13, I^2=25%) was negligible. Subgroup analyses based on game elements showed significantly larger effect sizes for interventions based on elements such as rewards and feedback (SMD=0.19, 95% CI 0.01 to 0.37, I^2=86%) compared to interventions based primarily on social interaction (SMD=-0.07, 95% CI -0.46 to 0.33, I^2=58%), with more significant heterogeneity between the two groups, but effect sizes 95% CI overlapped. Subgroup analyses based on intervention duration showed a more significant MVPA promotion effect for interventions >12 weeks compared to interventions ≦12 weeks (SMD=0.02, 95% CI -0.16 to 0.19, I^2=76.9%) SMD=0.14, 95% CI 0.02 to 0.26, I^2=1.1%), less heterogeneity. There was no overlap in the 95% CIs of effect sizes. Subgroup analyses based on trial setting showed that school-based interventions (SMD = 0.18, 95% CI 0.01 to 0.36, I^2 = 79%) had larger effect sizes than home-based or combined home- and community-based interventions (SMD = -0.08, 95% CI -0.35 to 0.20, I^2 = 50.1%). Heterogeneity was also more significant, and there was no overlap in the 95% CIs for effect sizes.

Reporting Biases

Qualitative and quantitative methods were used to assess publication bias. Funnel plots were used to assess publication bias for the effects of gamification interventions on MVPA, LPA, and SB in children and adolescents. Funnel plots showed a mostly symmetrical pattern across the three studies. (Multimedia Appendices 6-8). Egger's test was used to assess the size of publication bias of the included studies for all three studies. Egger test was performed for MVPA (t_{11}=0.05; *P*=.97), LPA（t_{10}=0.01; *P*=.99), and SB (t_7=–0.83; *P*=.44). Therefore, all the literature included was judged to be free of publication bias in a comprehensive manner.

Discussion

Principal Findings

This article systematically reviews the effects of gamification interventions on MVPA, VPA, MPA, LPA, SB, daily steps, and BMI in children and adolescents through a meta-analysis of 16 randomized controlled trials. It also responds to the call for future research needs by Mazeas et al. [13]. The absence of significant publication bias for all outcomes in the included articles enhances the reliability of the evidence. The results showed that the gamification intervention group had a positive effect on improving MVPA but a more minor effect on reducing SB than the control group. Age, theoretical paradigm, game elements, and intervention duration were identified as essential moderators associated with the increased effectiveness of gamification interventions on MVPA. However, the effects on effect sizes were not entirely consistent.

PA impact of gamification interventions

The study found that the gamification intervention significantly increased MVPA in children and adolescents but did not show positive effects on VPA, MPA, LPA, Daily Step, and reduction in SB, with an overall small, combined effect size. Although our findings are an extension of the most recently published systematic review, they are inconsistent with previous findings[13]. Previous research has demonstrated that gamification interventions can increase levels of physical activity (PA) and have shown efficacy in promoting PA in non-healthy individuals as well as those with chronic disease, particularly in adults and older adults, as evidenced by significant increases in steps per day and low-intensity physical activity[54, 55]. This increase was particularly evident in studies of overweight and obese adults, cancer survivors, and patients with chronic cardiometabolic disease[55-57]. In addition, people who are overweight or obese may have increased their physical activity levels because of weight loss goals or specific weight loss programs. However, compared with these studies, the results showed more minor and nonsignificant effects with lower quality of evidence. This may be because increasing physical activity in children and adolescents has proven challenging, whether through home-based gamification interventions or interventions targeting the school environment or curriculum[25, 58, 59]. This reduces individual adherence to some extent[56]. Five studies in the included literature showed poor adolescent adherence during the intervention, which affected the final study results[39-41, 46, 50, 53]. Alternatively, the lack of benefit we observed for the intervention may be because part of the target population was already sufficiently active (mean MVPA of 67 minutes at baseline), which leaves little room for an increase in MVPA[52]. Five of these studies had baseline activity levels greater than 150 min/d[39, 42, 46, 49, 53]. The article also found daily step goal orientation essential for promoting increased daily step counts[60]. Research has shown that setting higher physical activity goals typically motivates individuals to achieve higher physical activity[61, 62]. This effect is powerful when combined with goal setting, self-monitoring, and rewarding feedback [63]. Interventions targeting step goal setting were more limited in the included literature. This further explains the limited role of gamification interventions in promoting daily steps and low-intensity physical activity in healthy adolescents. At the same time, given the limited amount of relevant literature on both, the validity of this finding requires further validation.

Subgroup analyses of MVPA indicated that interventions based on game elements, such as rewards and feedback, maybe the most effective strategy. Rewards (8/16, 50%) were vital to the gamified intervention. Using game elements such as rewards and feedback may significantly increase PA participation compared to interventions with social interaction elements. In the literature included in this study, interventions based on reward and feedback elements were more limited, further explaining the limited use of game elements to reduce SB in children and adolescents. In addition, subgroup analyses of MVPA revealed that intervention duration, theoretical paradigm, and experimental setting were the key factors influencing the intervention effect. First, the long-term intervention (including the follow-up period) (>12 weeks) was significantly more effective than the short-term intervention (≦12 weeks), indicating a long-term effect of the gamification intervention, which is consistent with previous research[13].

Regarding theoretical underpinnings, most studies in the included literature (14/16,88%) used theoretical paradigms to design gamified PA interventions. SDT was the most used theory, followed by SCT, consistent with previous systematic reviews[64]. SDT is a well-established theory of motivation that has become a critical framework for health behavior interventions. An individual's motivation, considered the primary driver of behavior change, is often viewed as an extrinsic driver of PA activity. While elements such as rewards and feedback, primarily goal-directed, are considered intrinsic drivers, it is difficult to distinguish whether the effect is due to the sum of the internal and external drivers or an independent driver intervention. Subgroup analyses in this study indicated that game elements such as rewards and feedback can promote MVPA and that interventions from the SDT theoretical paradigm are effective in promoting MVPA. However, due to the limited amount of literature included, it was not possible to explore the importance of combining both on PA further. Therefore, further coordinated interventions are recommended for the future, such as increasing the weight of elements such as rewards and feedback in gamification while synergizing the SDT theoretical paradigm.

SB impact of gamification interventions

The meta-analysis showed that although the gamification intervention reduced SB in children and adolescents compared to the control group, the effect was insignificant, and the quality of the evidence was low, consistent with the findings of several previous reviews[65, 66]. Meta-analyses underscore the enormous challenge of significantly increasing PA among children and adolescents, whether through community, school, or home-based approaches [25, 59, 64]. Previous research suggests that parents are vital in supporting health behavior change through the home environment[67, 68]. Of the four articles included, three (75%) were implemented in the home environment[49, 50, 53]. In an eHealth intervention study among Canadian adolescents, family environment (precisely parenting style, parenting style, and family income), she predicted much of the variance in adolescents' adherence to the intervention[69], Tugault-Lafleur's data also confirmed a strong relationship between parental adherence and youth participation[70]. Only one trial[46] in the included literature assessed sedentary behavior in a school setting, and due to the small sample size, subgroup analyses of this outcome were not conducted. In addition, the study found that the position in which the physical activity device is worn can significantly impact the results. When accelerometers were used to measure physical activity, subjects were less compliant[70]， and the time the activity monitor was worn affected the estimation of sedentary time[71]. Of the included studies, 2 reported a decrease in subjects' adherence to wearing accelerometers during the intervention period[49, 52], with no significant difference between the intervention and control groups affecting the final study results. In addition, interventions targeting SB are more effective than interventions promoting physical activity [72]. Most articles in the included studies did not present specific goals and individualized interventions for SB reduction[43, 45, 47, 49]. Although two studies included interventions to reduce sedentary behavior[46, 51]， these were primarily suggestive, for example, through Facebook groups or VFB ecosystems. These methods may not be effective in motivating adolescents to actively participate and respond to the feedback and reminders provided by the device. In addition, adolescents' self-management skills and intrinsic motivation are key factors influencing behavior change. Effective behavior change requires external technical support and, more importantly, the stimulation of an individual's intrinsic motivation and increased self-efficacy. Therefore, future research must develop and evaluate more targeted interventions to encourage adolescents to reduce sedentary behavior and increase their physical activity levels.

Moderating Variables on the Effects of Gamification Interventions for PA

Theoretical Paradigm

Several types of BCTs are currently commonly used in gamification interventions, and they have also been shown to be effective in influencing intervention outcomes[46]. Only 2 of 16 studies (11.1%) did not use a theoretical paradigm in their gamification interventions [38, 52]. The majority was SDT (8/16). Self-determination theory (SDT) is the most used theoretical paradigm in gamification intervention trials. SDT-based interventions are effective in improving MVPA in youth[20]. SDT is a well-established theory of motivation that has become a critical framework for health behavior interventions because of the belief that an individual's motivation is the primary driver of behavior change[73]. However, intrinsic or extrinsic motivation has different effects on behavior change. Existing research suggests that intrinsic motivation promotes more stable behavior change and psychological and social well-being[20]. Therefore, future research could use gamification to promote intrinsic motivation and increase PA engagement. Second, social cognitive theory (SCT) is another theoretical framework widely adopted in physical activity (PA) promotion interventions. CT proposes that a combination of personal factors, the social environment, and the physical environment influences an individual's level of physical activity. Among these factors, self-efficacy, self-regulation, and efficacy expectations are vital personal factors that promote physical activity and reduce sedentary behavior (SB)[74]. In conclusion, SCT or SDT-based interventions may produce more effective outcomes than gamification interventions. However, due to the limited number of included studies, further validation through many high-quality studies is needed to support these conclusions.

Intervention Duration

Subgroup analysis of intervention duration showed an association between the effect of gamification on MVPA and intervention duration. Compared to intervention ≦ 12 weeks, intervention cycles of more than 12 weeks (including the follow-up period) were more likely to promote MVPA (SMD=0.14, 95% CI 0.02 to 0.26, I^2=71.4%), with a mean duration of 32.67 weeks, suggesting that the effects of gamification persisted beyond the end of the intervention. Smartphone apps have been claimed to have a significant positive effect on PA only when used for a short period of <3 Months[41], which is inconsistent with the current meta-analysis results. This may be due to the playful nature of gamification, where the effectiveness of the intervention is not only influenced by the intervention period but also by age, theoretical paradigm, game elements, and type of measurement tool. It is worth noting that gamification interventions are not just a novelty effect and should have some long-term effects. However, given the limited amount of literature included, it is still worth exploring whether this long-term effect diminishes after the intervention has ended.

Game Elements

Achievement-based and goal-oriented game elements, such as rewards and feedback, were the most frequently used game elements in the systematic evaluation, consistent with the results of the previous evaluation[33, 75]. Analyses of the PA subgroup showed that a gamification intervention with rewards and feedback at its core significantly increased MVPA, effectively combining techniques to promote behavior change and motivate participants to be active. However, it has also been argued that extrinsic motivation (rewards, etc.) may be detrimental to the long-term maintenance of intervention effects compared to intrinsic motivation (SDT or SCT)[76]. The effectiveness of socialization and interactivity, the second most commonly used game element, is significantly influenced by the type of social incentive and the application method[77]. Gamification strategies significantly increased physical activity (PA) levels when used collaboratively between families. In contrast, they were less effective when used with individuals who did not know each other as intervention targets[77]. Therefore, future studies must explore the effectiveness of gamification interventions that integrate different social incentives to increase PA engagement and assess the applicability and impact of these interventions in different social relationship contexts. This will help to develop more precise and personalized gamified health promotion programs.

Limitations

This study has several limitations. First, the included literature was in English, which may have led to selection bias, and some studies had small sample sizes and poor compliance, which increased the risk of publication bias. Second, due to the nature of the intervention, the included literature did not implement blinding in data processing and analysis, as well as differences in recruitment settings, which may affect the results of the meta-analysis. Third, the outcome indicators used in the included literature studies had inconsistent units, and using SMD as an effect indicator requires caution in interpreting the results. Results suggest heterogeneity in some studies, and the source of this heterogeneity is unclear. The effectiveness of gamification interventions may vary among children and adolescents depending on demographics (e.g., ethnic background, region, gender, and BMI), economic level, type of intervention (parent-centered versus child-centered), and degree of application personalization. These factors may have contributed to the observed heterogeneity. However, these factors were not analyzed in this study due to limitations imposed by the number and characteristics of the included studies. In conclusion, the results of this systematic review and meta-analysis should be interpreted with caution.

Conclusions

Gamification interventions effectively increase MVPA in children and adolescents, and this effect persists beyond the follow-up period. This suggests that the effects of gamification interventions are not solely due to their novelty but have long-term effects. However, the effects of gamification interventions on improving VPA, MPA, LPA, Daily Step, and SB are not yet apparent. The number and quality of studies limit them and should be interpreted cautiously. In addition, theoretical paradigms, game elements, and intervention duration may be associated with the effectiveness of gamification interventions, and further research is needed on the optimal implementation of game elements and theoretical features to maximize PA engagement. In conclusion, due to the limited number and quality of included studies, the above findings need to be validated by additional high-quality studies.

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Authors' Contributions

MW designed the research protocol and drafted the report; XLZ and XCL searched the literature, analyzed the data, and interpreted the results; JSX participated in the research protocol and reviewed the manuscript; and YZ reviewed and revised the manuscript.

Conflicts of Interest

None declared.

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Supplementary Files

Multimedia Appendixes

Literature search strategy.
URL: http://asset.jmir.pub/assets/ae55d334dc76219182280b8eec2c4587.doc

Sensitivity analyses results on moderate to vigorous physical activity.
URL: http://asset.jmir.pub/assets/20b9958df7dd2ec4bfadd982f787cba0.png

Sensitivity analyses results on light physical activity.
URL: http://asset.jmir.pub/assets/8117fc7402e89d22908d8bc466cadeda.png

Sensitivity analyses results on sedentary behavior.
URL: http://asset.jmir.pub/assets/9ebad2ef14bed773720fa606b6e32bc9.png

Summary of subgroup analysis results of mobile health app–based interventions on moderate to vigorous physical activity.
URL: http://asset.jmir.pub/assets/971519dfcc28da3c730814531b37cdf9.doc

Funnel plot of moderate to vigorous physical activity.
URL: http://asset.jmir.pub/assets/c96a93e7b309d24f159560823c296331.png

Funnel plot of light physical activity.
URL: http://asset.jmir.pub/assets/4fd9d1886ad6798c866b77bb1759e41c.png

Funnel plot of sedentary behavior.
URL: http://asset.jmir.pub/assets/26a1a850f1dc32c26c738eea5f058730.png

Egger test results moderate to vigorous physical activity.
URL: http://asset.jmir.pub/assets/f2b56c74a2ba4613bdc3871cf9729cfb.png

Egger test results light physical activity.
URL: http://asset.jmir.pub/assets/0488e3e912b6ea677d297009ddae3abd.png

Egger test results sedentary behavior.
URL: http://asset.jmir.pub/assets/1acc8e66d281404066a9de2642de36a5.png

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