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Original article

Performance of gamification strategies in obesity management: A network meta-analysis

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Abstract. *Background and Aims:* Obesity remains a global public health challenge, with conventional interventions focusing on diet and physical activity often showing limited long-term success. Gamification (applying game elements in non-game contexts) has emerged as a novel strategy to promote healthier behaviors. This study assessed the comparative effectiveness of gamification strategies in improving nutritional knowledge, physical activity, and nutritional status among individuals with overweight or obesity through a network meta-analysis. *Methods:* A systematic search of PubMed, ScienceDirect, Wiley, and Cochrane databases was conducted in August 2024 to identify randomized controlled trials assessing gamification interventions. Outcomes included nutritional knowledge, physical activity, and nutritional status. Risk of bias was evaluated using RoB 2.0 and certainty of evidence using GRADE. Standardized mean differences (SMD) were pooled using fixed-effects models, and a network meta-analysis compared different gamification strategies. *Results:* Gamification interventions showed positive trends in improving nutritional knowledge (SMD = 2.71). Significant reductions were found in BMI (SMD = -0.23). The most effective strategy was “Programme + Active Game.” *Conclusions:* Gamification strategies, particularly those incorporating active physical components, are associated with significant reductions in BMI. While improvements in nutritional knowledge and physical activity showed positive trends, these effects did not reach statistical significance, highlighting the need for further research to validate these outcomes. (www.actabiomedica.it)

Key words: obesity, gamification, physical activity, nutritional knowledge, health promotion

Introduction

Obesity is characterized by the accumulation of excessive body fat, leading to a state of increased body weight, and is specifically diagnosed when an individual’s body mass index (BMI) reaches a certain percentile based on age and sex in children and adolescents. Currently, obesity in children is defined when the BMI is greater than or equal to the 95th percentile based on age and sex, mainly for children more than 2 years old. For children younger than 2 years old, overweight and obesity are defined based on the weight-for-length chart for age and sex. This issue has become a significant global challenge, impacting a substantial number of individuals. From mid-1980 until 2016, the prevalence of overweight and obesity in children has doubled and reached 18% in 2019 (1-3). This causes significant problems as obesity and overweight could cause future health consequences, such as hypertension, hypercholesterolemia, and obstructive sleep apnea. In the modern world, the transformation of the human environment from an adverse to an affluent environment, where the necessity for physical activity is reduced and the diet trend changes to refined sugars and fats, has contributed to the rise of obesity and overweight conditions (4). The healthcare sector is actively seeking solutions to address the significant global public health issue of obesity. Several important factors are related to the reduction in obesity risk, including knowledge about proper diet and nutrition, as well as adequate physical activity. Studies have shown that better nutritional knowledge leads to better diet quality, which in turn results in better body measurements; thus, promoting this knowledge is recommended for reducing obesity risk (5,6). Physical activity also plays a crucial role in safeguarding against obesity and related health conditions. The World Health Organization (WHO) encourages adolescents to partake in a minimum of 60 minutes or more of moderate-to-vigorous physical activity daily, while adults should aim for at least 150 minutes each week (7). However, encouraging and maintaining consistent physical activity are difficult tasks for individuals. Despite extensive public health education and encouragement regarding obesity risk reduction, these interventions have been proven to be ineffective over time (8). A relatively new potential solution that shows promise is the use of gamification, which employs elements of game design to inspire behavioral changes (9). This approach has been applied in workplace wellness programs, often in combination with wearable devices, to encourage physical activity (10). Promoting physical activity and adopting a healthy way of life have long been recognized as effective methods for enhancing health across various age groups (11). Additionally, gamification can serve as a valuable educational tool, helping young children learn about nutrition and dietary habits in a fun and engaging manner (12). However, the involvement with sedentary media forms, such as video games, creates a challenge that balances entertainment with public health priorities (13). Gamification involves integrating game design components, such as points and levels, into non-game scenarios and is increasingly used to encourage positive actions (14). Unfortunately, many workplace wellness programs and digital health applications do not appropriately leverage principles from health behavior theories. This oversight may explain why recent evaluations suggest that these practices have minimal effect on health behaviors (15,16). Sebastian et al. conducted a school-based gamification strategy that was successful at preventing childhood obesity, as it resulted in lower BMI Z-scores and reduced systolic blood pressure (17). Similarly, a WeChat-based intervention integrating gamification and social incentives increased physical activity and related social cognition among Chinese undergraduate students (18). Additionally, a study of primary school children demonstrated improvements in children's nutritional knowledge after receiving card-based and role-playing food games (19). The effectiveness of gamification strategies can vary. A study revealed that social interaction was significant for the gamification effect (20). Overall, the combination of gamification with social incentives has shown promise in increasing physical activity among individuals with obesity (21). To the best of our knowledge, there is a lack of meta-analyses that explicitly compare different types of gamifications to conventional strategies, encompassing a variety of outcome variations. We conducted a comprehensive systematic review and meta-analysis in response to the escalating demand for innovative interventions designed to strengthen preventive strategies and policies. This study harnesses the potential of gamification as an instructional tool. The primary objective of our network meta-analysis was to assess the impact of gamification on improving nutritional knowledge, promoting physical activity, and enhancing nutritional status among a specific population facing the challenges of obesity.

Methods

Study design and search strategy

This network meta-analysis was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines. The study protocol was previously registered in the International Prospective Register of Systematic Reviews (PROSPERO) with registration number CRD420251062150. A literature search was carried out on August 2024 on four databases, namely, PubMed, ScienceDirect, Wiley, and Cochrane. There was no restriction by year of publication. The literature search was carried out with keywords using Boolean operators. The inclusion criteria of this meta-analysis refer to the PICO framework in Table S1 and S2. The literature search terms are included in Table S3.

Study eligibility criteria

The inclusion and exclusion criteria were established prior to conducting the literature search, ensuring specificity and homogeneity in the outcomes. The inclusion and exclusion criteria are mentioned in Table S2. Using these inclusion and exclusion criteria, five authors independently assessed the eligibility of the papers, and any disagreements were resolved through discussion. The search results were downloaded, and duplicate removal was also carried out using the Zotero application. Four independent reviewers selected the titles and abstracts of the papers based on criteria regarding their accessibility (DDCHR, JNJ, DED, SEW). Any disputes were discussed by the fifth author to reach a consensus (JAJMN). It is important to note that we excluded low-quality studies from our review.

Quality appraisal

The Revised Tool for Risk of Bias in Randomized Trials (RoB 2.0) was used to assess the potential for bias in the selected final studies (22). Five authors evaluated the likelihood of bias using this tool and resolved disagreements through discussion. The results were subsequently recorded in the "bias" domain within the spreadsheet. Furthermore, we performed a critical appraisal using the GRADE methodology. The GRADE methodology, an outcome of thorough analysis of contemporary recommendation systems, offers a systematic and lucid approach to constructing and presenting summaries of evidence and their associated levels of confidence (23). This approach proves particularly instrumental in generating summary of findings tables for systematic reviews and shaping recommendations in the field of medical care. The initial robustness of evidence within a study's framework is subject to fluctuations due to various influencing factors or domains, either diminishing or augmenting the overall certainty of the evidence. Conventionally, evidence originating from clinical trials assumes a position of high initial certainty, whereas findings from observational studies embark with a relatively lower degree of certainty, although anomalies can occur (24). Domains that erode certainty encompass risk of bias, inconsistency, indirectness, imprecision, and publication bias, each rated at (-1) or (-2) based on the level of severity observed. Conversely, factors heightening the certainty of evidence include discernible dose-response patterns, significant effect magnitudes, and indications of plausible residual confounding, with each allocating a value of (+1) or (+2) depending on their impact on refining overall certainty (25).

Data extraction

We extracted the baseline characteristics of each selected study into a table. Two authors independently performed the data extraction. Disagreements were discussed and resolved by consensus, and where necessary, a third reviewer was consulted. The baseline characteristics obtained from the articles included (1) author(s) and year of publication, (2) country of study, (3) study design, (4) number of participants, (5) intervention and control group, (6) duration of study, (7) duration of intervention session and (8) main findings of the study. We also conducted a qualitative synthesis to assess each program and exercise in the study. The quantitative data of each study were also retrieved for statistical analysis.

Assessed outcome

The outcomes analyzed in this study were nutritional knowledge, physical activity levels, and nutritional status in both the intervention and control groups. The physical activity level was measured as steps and counts of activities per minute. Finally, nutritional status was measured using BMI, the BMI Z score and body fat percentage.

Statistical analysis

All analyses were conducted in R version 4.4.1 using the meta and netmeta packages. Continuous outcomes were synthesized as standardized mean differences with 95% CI using inverse variance weighting. When studies reported both change scores and post intervention values, change scores were preferred; otherwise, post intervention means, and standard deviations were used. Where necessary, standard errors, confidence intervals, or other dispersion metrics were converted to standard deviations using established formulas. Effect sizes were calculated as Hedges g with small sample correction. For outcomes expressed on a common scale, mean differences with 95% CI were used. Pairwise meta analyses were fitted with random effects models to account for between study variances. Heterogeneity was summarized with I^2 and τ^2, and we report pooled effects with 95% CI. We examined small study effects visually with funnel plots and, when at least ten studies were available for an outcome, with Egger regression. Influence diagnostics and leave one out analyses were undertaken as sensitivity checks when k was sufficient. The network meta analysis used a frequentist framework implemented in netmeta under a random effects consistency model. Multi arm trials were handled by appropriately splitting shared comparators and preserving the study level correlation structure as implemented by netmeta. Network geometry was described with node sizes proportional to sample size and edge widths proportional to the number of direct comparisons. We assessed the transitivity assumption qualitatively by comparing distributions of key effect modifiers across comparisons. Global and design specific heterogeneity were summarized with Q statistics and τ^2. Local inconsistency was examined with node splitting, comparing direct and indirect evidence for each contrast, and we report inconsistency tests for those splits. Treatments were ranked using surface under the cumulative ranking curve values, with higher values indicating a higher probability of being among the most effective, and we clarify directionality for each outcome so that lower adiposity indicates benefit. To explore heterogeneity for BMI z score we performed univariate meta regression under a random effects model with prespecified moderators that included mean age, intervention duration in weeks, delivery method category school based, home based, or blended, presence of an active video game component, baseline BMI z score, and overall risk of bias. Where data permitted, we complemented meta regression with sensitivity subgroup analyses by age group, intervention duration, and delivery setting. Given the limited number of trials and uneven data within strata, these moderators' analyses are considered exploratory. We report coefficients, standard errors, 95% CI, p values, and changes in τ^2 before and after each moderator.

Network Meta-Analysis (NMA)

In analyzing the effect of gamification strategies on the prevention of obesity in children and adults, difference gratification strategies were reported in all the studies; as such, a network meta-analysis was chosen to compare the direct and indirect effects of these strategies with those of a control group using the "meta" and "netmeta" packages in R. The network graph, which shows the direct and indirect comparison of all the strategies with the control group, was generated using the "netgraph" function. A random effect model of a network meta-analysis with a 95% confidence interval and 5% level of significance was adopted. A heterogeneity check was performed using $I^{2,}$ and we ensured that there were closed loops in the network to check for inconsistency. Forest plots were generated to compare the pooled strategies for all outcome measures. A subgroup meta-analysis was then performed to correct for high heterogeneity.

Results

Study selection process

Our search strategy results are depicted in the PRISMA flowchart in Figure 1. An initial search of 4 databases resulted in 587 RCT articles. We carefully screened every article based on the abstract and title, excluding 538 unsuitable articles. After the removal of 20 duplicate articles, 29 RCTs were ultimately screened. Twelve articles were subsequently removed for fulfilling the exclusion criteria, which yielded 17 articles (24–40).

Study quality

We assessed the level of bias risk in studies using the Cochrane 6-domain Rob tool (Figure 2). Overall, the risk of bias was low. Furthermore, we evaluated the quality of each outcome individually. Three main findings emerged: nutritional knowledge, physical activity, and nutritional status. For each outcome, nutritional knowledge, physical activity and nutritional status were of good quality. However, small effect sizes were found in certain studies, such as counts per minute, where only two studies were available. Additionally, some outcomes exhibited high $I^{2 \text{ values}}$, such as moderate-vigorous physical activity (MVPA), steps in physical activity, and BMI z scores for nutritional status and nutritional knowledge. Nevertheless, moderate and high-quality outcomes were identified, suggesting that clinicians should consider these findings.

Characteristics of the included studies

All the studies were published between 2010 and 2022. The sample sizes in the studies ranged from 21 to 1133 participants, for a total population of 5951. The age of the patients is exclusively from children to adolescents. All patients included were eligible and exhibited overweight and obesity. Various types of gamification interventions were employed, such as gamification with support, interactive video game cycling, video game consumption, computer-based games, active video games, nutritional game applications, foodbot factories, alternate reality games, gamification with collaboration, and gamification with competition, with traditional methods used as controls. The intervention durations ranged from 5 days to 12 months. The characteristics of all included studies can be found in Table 1 below. Furthermore, we conducted a more in-depth analysis to review each specific programme and exercise in each study (Tables S4-S7)

Studies included in the NMA

The first Gamification strategy to examine was Gamification, for which support was reported by 4 studies and traditional methods were used as the control group. The next gamification strategy to be analyzed was active video games, which were reported by 5 studies, and digital games were compared with traditional methods in 2 studies. Nutritional games were compared with the control group in 4 studies, and active games were compared with the control group in 2 studies. The outcomes reported were body mass index (BMI), nutritional knowledge and daily steps of physical activity.

Network Meta-analysis

The network of the gamification strategies in comparison with the control group is shown in Figure 3. Additionally, the forest plot depicted in Figure 4 shows a direct comparison of different gamification strategies. Digital games, gamification + collaboration and AVG were compared with the control group in 3 studies each. Active video games (AVGs) were compared in 5 studies, and gamification + support and nutrition games were compared in 4 studies. The other groups were compared with the control group in 1 study each (Figure 3).

Consistency assessment

To examine local coherence, we performed node-splitting for the steps/day network. Figure 4 shows, for each evaluable comparison, the direct estimate (square) and the indirect estimate derived from the remainder of the network (diamond), each with 95% CIs;

Table 1. Characteristics of the Included Studies

Author(s), year	Country	Design	Participants	Intervention	Control	Duration of Study	Duration of Intervention Sessions	Findings
Adamo et al., 2010 (27)	Canada	RCT	30 families Age: 12-17 years 14 female, 12 male BMI > 95^{th}	Interactive video game cycling	Stationary bike music as control	10 weeks	Two 60 minutes sessions per week	The intervention significantly improved aerobic fitness and reduced body fat and cholesterol.
Banos et al., 2013 (28)	Spain	RCT	228 children Mean age: 11.2 57 males 34 females	ETIOBE Mates, video games console, computer to play games	Pamphlet as control	2 weeks	NR	Sustaining nutritional knowledge was significant in ETIOBE Mates compared to control.
Chagas et al., 2020 (29)	Brazil	RCT	319 participants Age 13-16 years 136 males 183 females	Digital game	Control group	7 – 17 days	NR	Digital games enhance autonomy and self-care among adolescents
Coknaz et al., 2019 (30)	Turkey	RCT	106 children	Active video game	Traditional method as control group	12 weeks	50–60 minutes, 3 days a week	Active video game group significantly showed favorable responses for weight, body mass index.
Comeras-Chueca et al., 2022 (31)	Spain	RCT	29 children Mean age: 10.1(0.84) years 13 young females 16 young males	Active video game	Control group	5 months	60 minutes per session	The intervention shows positive effect on PA.
Froome et al., 2020 (32)	Canada	RCT	83 participants Age: 8–10 years 46 male, 37 female	Foodbot Factory	Control group	1 – 5 days	10 – 15 minutes each day	Foodbot Factory improved the overall nutritional knowledge.
Gan et al., 2019 (33)	Philippines	RCT	Phase 1: 46 participants Mean age: 8.01(0.78) Phase 2 173 male, 187 female	Nutrition game application	Food group knowledge	2 weeks	30 minutes	Food group knowledge shows a higher score.
Irandoust et al., 2020 (34)	Iran	RCT	71 participants	Video game exercises Aquatic exercise	Control group	12 weeks	3 times a week Video Game group: 60 minutes Aquatic exercise: 70 minutes	Significant reduction in BMI and body weight was observed in intervention group.

Johnston et al., 2012 (35)	USA	RCT	115 students Mean age: 18.3(0.5) 85 male, 115 female	Alternate reality game	Exercise equipment	9 weeks	NR	Significant results were found in BMI and physical activity.
Mack et al., 2020 (36)	Germany	RCT	82 participants 50 female, 32 male Age: 9-12 years	Video game	Brochure about the food pyramid	2 weeks and 4 weeks follow-up	Two 45 minutes sessions	Knowledge in the area of nutrition was increase after intervention.
Staiano et al., 2018 (37)	USA	RCT	46 children	Gaming console that involves PA	Exergames following final clinic visit as control group	24-week	1 hour per session, three times a week	The intervention enhanced total cholesterol and improved PA.
Trost et al., 2014 (38)	USA	RCT	75 participants Mean age: 10(1.7) 34 male, 41 female	Program + Active gaming group	program-only	16-week program	60-90 minutes	Video gaming shows a significant positive effect on PA.
Verbeken et al., 2013 (39)	Belgium	RCT	44 children Age: 8-14 years 20 male, 14 female	EF Training Condition (Program) with game element	Care as usual only as control group	8 weeks and 12 weeks postintervention follow-up	40 minutes	Children in the intervention group showed significantly more improvement than the children in the care as usual only group.
Rosi et al., 2016 (40)	Italy	RCT	112 children Age: 8-10 years	Educational game GiOCAmpus	Not receiving any lesson	NR	1-hour educational session	Study showed a significant increase in the nutritional knowledge.
Maddison et al., 2011 (42)	New Zealand	RCT	322 overweight Age: 10-14 years.	Active video game upgrade	No exercise as Control group	24 Weeks	NR	An active video game intervention has a small but definite effect on BMI and body composition in overweight.
Viggiano et al., 2015 (43)	Italy	RCT	3110 participants Age: 9-19 years	Nutritional game	Control group	20 weeks	15 – 30 minutes	The intervention improved nutrition knowledge and dietary behavior.
Lakshman et al., 2010 (44)	UK	RCT	1133 children	Nutritional game	Control group	9 weeks	NR	The intervention facilitated the enjoyable delivery of nutrition education.

Abbreviations: EF = Executive functioning, PA = Physical activity, RCT = Randomized Controlled Trial, NR = Not reported, ETIOBE: E-Therapy for Obesity.

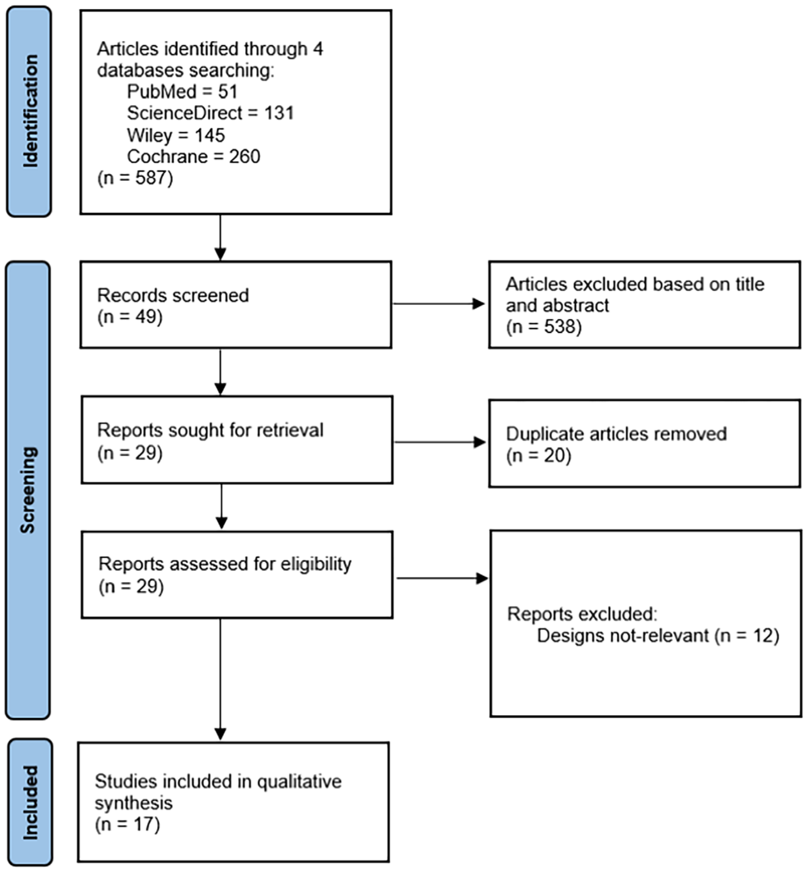

Figure 1. PRISMA flowchart for the literature search.

the grey dot denotes the mixed network estimate, and the right-hand column reports the p value for inconsistency (direct vs indirect). Because the network is predominantly star-shaped since most trials compare an intervention with control, only a limited number of loops were testable. Across those loops, confidence intervals overlapped, and no split indicated statistically significant inconsistency (all $p > 0.05$). Positive mean differences indicate more steps/day favoring the first-named treatment. Taken together, these findings suggest no material incoherence in the evaluable parts of the steps/day network, while acknowledging limited power to detect inconsistency given the sparse closed loops.

Subgroup analysis of effect on nutritional knowledge

Eight studies were included in the meta-analysis of gamification strategies for the prevention of obesity. The results showed that the experimental group (video game, nutritional game application) had a positive but non-significant effect on the nutritional knowledge of the participants (SMD = 2.71; 95% CI: -0.80 to 6.23), as the confidence interval crossed zero. This finding suggested that the intervention led to progress in nutritional knowledge (Figure 5).

Subgroup analysis of effect on physical activity

Seven randomized trials reported moderate to vigorous physical activity, five reported steps, and two reported counts per minute. Point estimates for moderate to vigorous physical activity shows no significant result. Because all confidence intervals include zero, these results are not statistically significant and should be interpreted cautiously given heterogeneity and sparse data as shown in Figure 6.

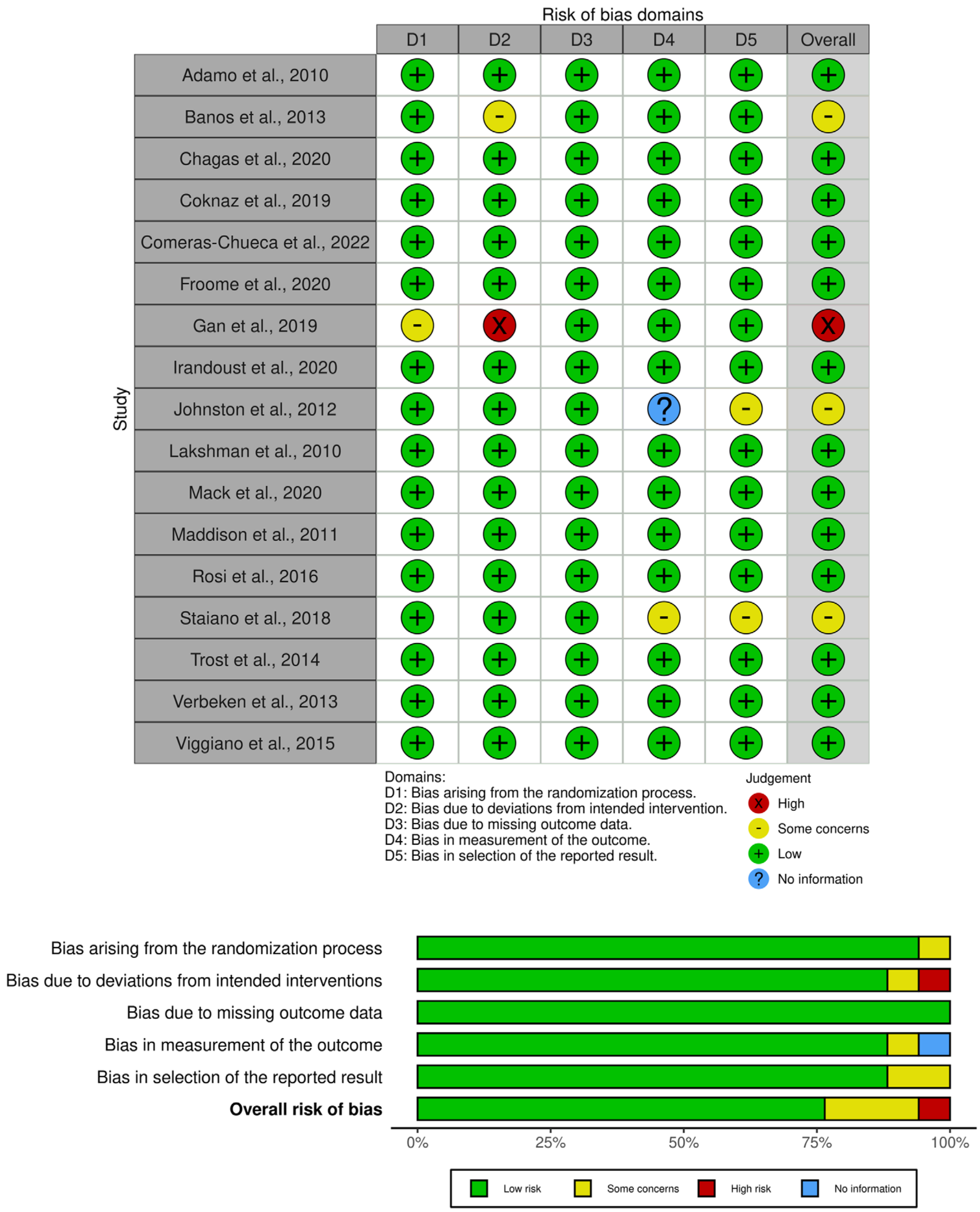

Figure 2. Quality assessment of the included studies using risk of bias (ROB).

Subgroup analysis of effects on nutritional status

When analyzing the nutritional status of the participants, 10 RCTs reported their BMI, BMI Z score and body fat percentage. The results showed that the intervention significantly reduced body mass index (BMI; SMD = -0.23, 95% CI: -0.39; -0.07). BMI Z score changes (SDM = -0.37, 95% CI; -1.16; 0.42) was not significant. Low and significant heterogeneity was found (BMI: I^2 = 0%, body fat percentage = 0%), but moderately high heterogeneity was found in the BMI Z score: I^2 = 97%) (Figure 7). For BMI z

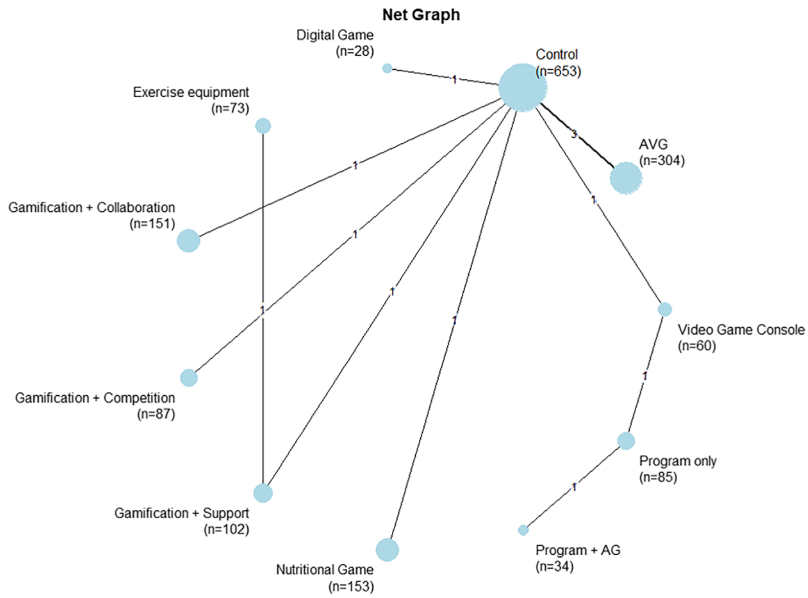

Figure 3. Network graphs of the intervention and control groups.

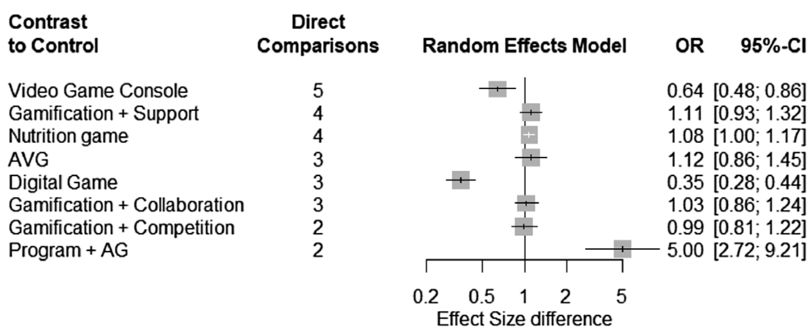

Figure 4. Forest plot showing direct comparisons of the gamification strategies and the control group.

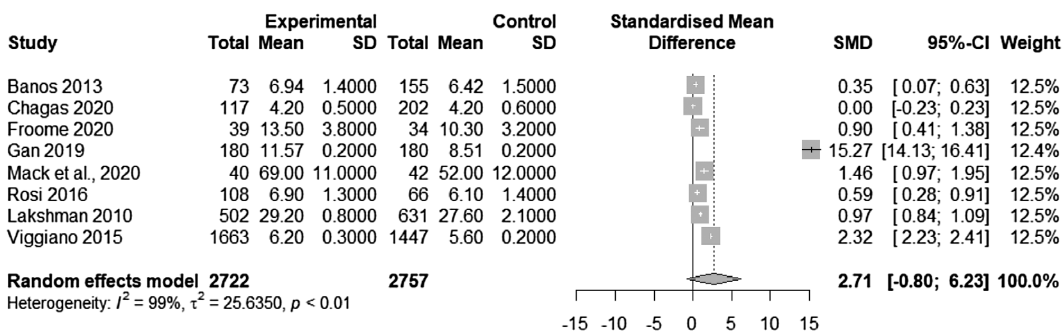

Figure 5. Forest plot of nutritional knowledge analysis.

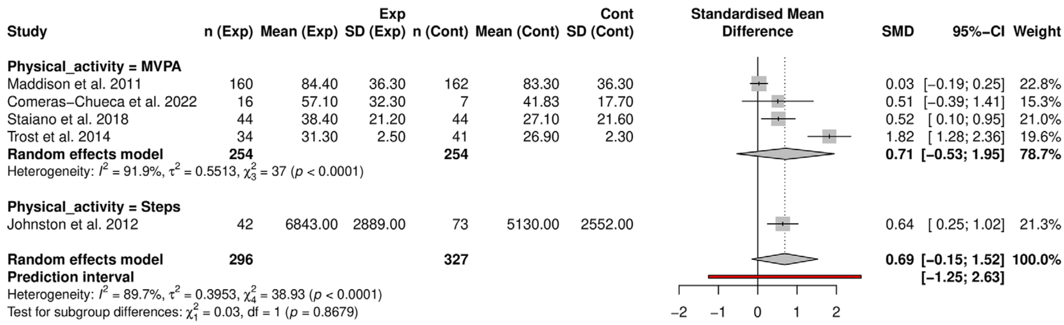

Figure 6. Forest plot of the outcome analysis: physical activity levels between the gamification strategies used in comparison with the control group.

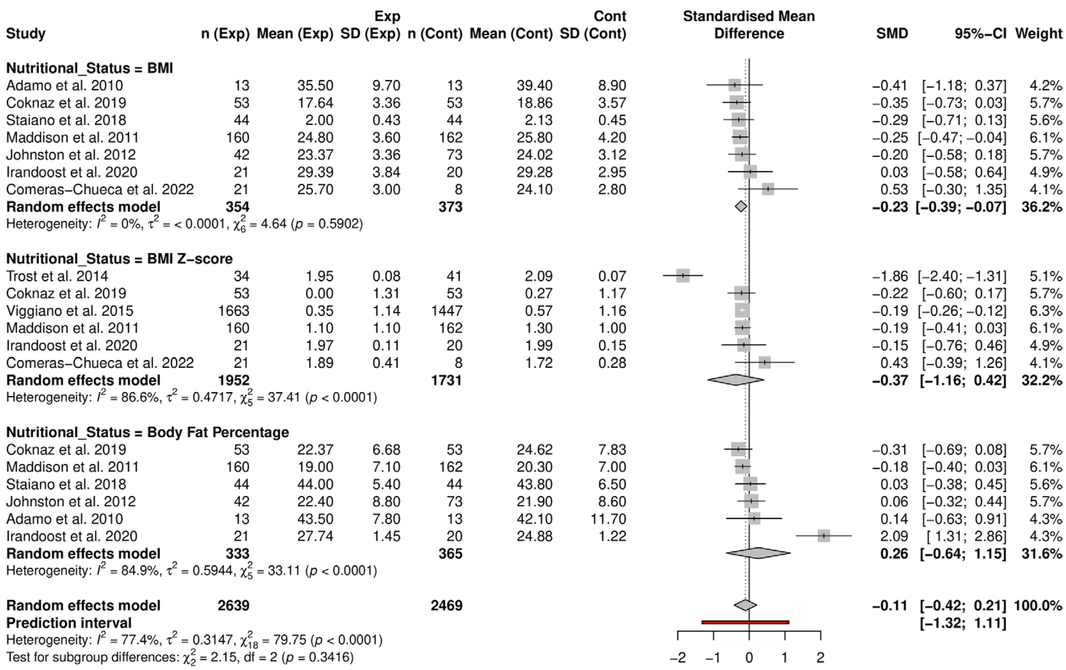

Figure 7. Forest plot of nutritional status analysis.

score, between-study heterogeneity was very high with I² equal to 97 percent. Readers are directed to the expanded discussion of plausible contributors and interpretive cautions. Age-stratified meta-analysis and sensitivity analysis were not feasible due to sparse age-specific data and uneven distribution of studies across child, adolescent, and adult strata. Under these constraints, such analyses would have been underpowered and at high risk of unstable estimates. The implications of this limitation are addressed in the Strength and Limitations sections.

Node-splitting of Body Mass Index

The network diagram illustrated in Figure 8 shows network comparison of treatments, Active video game vs 5 treatments and Control vs 3 treatments. The treatment with highest number of participants was Active video game (281) while stationary bike music was revealed to have the least number of patients (13). The netsplit plot for demonstrates that most pairwise comparisons among interventions did not yield statistically significant differences, as the majority of confidence

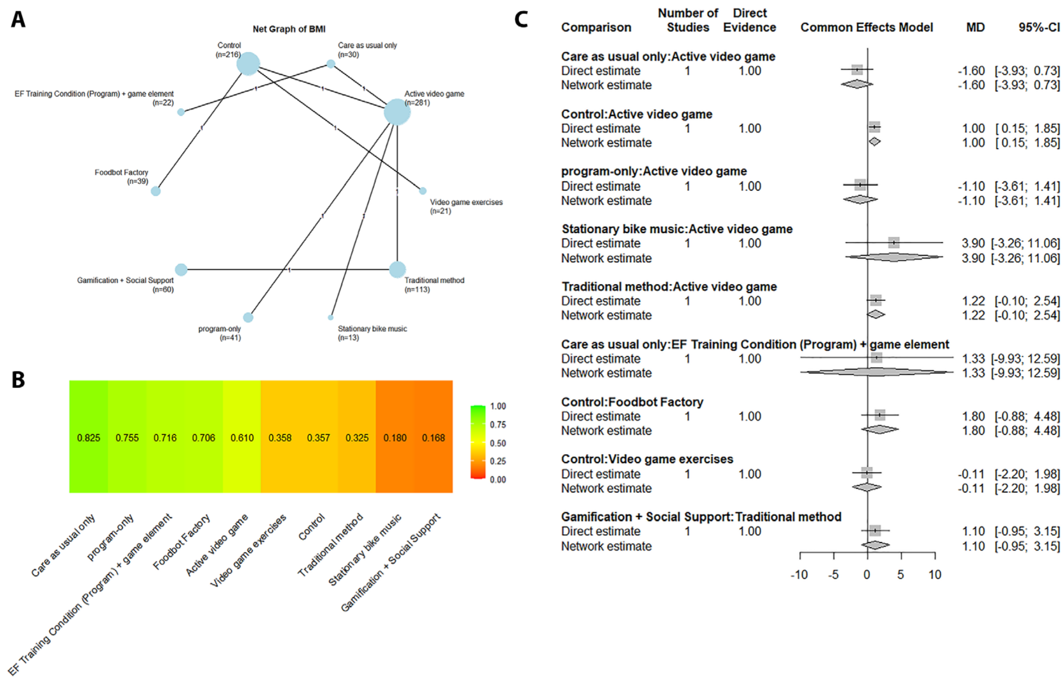

Figure 8. Node-splitting for Body Mass Index (BMI). Figure 8(A) shows the network graph of BMI; Figure 8(B) shows the SUCRA Plot of BMI; Figure 8(C) shows the netsplit forest plot of BMI.

intervals crossed the line of no effect. Specifically, the comparison between control and active video games showed a mean difference (MD) of 1.00 (95% CI: 0.15 to 1.85), favoring control, and was the only estimate to reach statistical significance. Other comparisons, such as care as usual versus active video games (MD = -1.60, 95% CI: -3.93 to 0.73), program-only versus active video games (MD = -1.10, 95% CI: -3.61 to 1.41), and traditional methods versus active video games (MD = 1.22, 95% CI: -0.10 to 2.54), suggested trends in either direction but did not achieve significance. Interventions like stationary bike music and EF training with game elements produced especially wide confidence intervals, reflecting high uncertainty and possible sample size limitations. Similarly, comparisons involving gamification and social support versus traditional methods (MD = 1.10, 95% CI: -0.95 to 3.15) and control versus video game exercises (MD = -0.11, 95% CI: -2.20 to 1.98) indicated no meaningful differences. Overall, the findings suggest that while control conditions may slightly outperform active video games in BMI outcomes, the evidence across most intervention comparisons remains inconclusive, with wide intervals underscoring the need for larger, more rigorous trials. The SUCRA plot for Body Mass Index (BMI) ranks interventions based on their probability of being the most effective. Care as usual only (SUCRA = 0.825), program-only (0.755), and EF training with game element (0.716) ranked highest, suggesting these interventions are most likely to increase BMI. In contrast, traditional methods (0.325), stationary bike music (0.180), and gamification with social support (0.168) ranked lowest, indicating limited relative effectiveness compared to other strategies in increasing BMI.

Node-splitting of Body Fat

The network diagram illustrated in Figure 9 shows network comparison of treatments, Active video game vs 4 treatments and Control vs 2 treatments. The treatment with highest number of participants was Active video game (260) while stationary bike music was revealed to have the least number of patients (13).

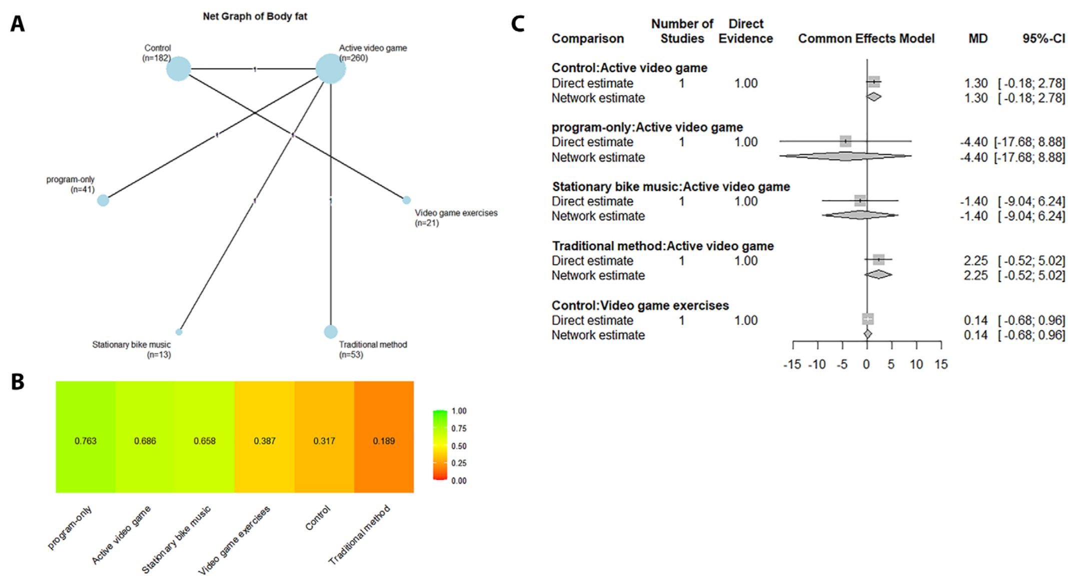

Figure 9. Node-splitting for Body Fat. Figure 9(A) shows the network graph of Body Fat; Figure 9(B) shows the SUCRA Plot of Body Fat; Figure 9(C) shows the netsplit forest plot of Body Fat.

The SUCRA plot for Body Fat ranks program only (SUCRA = 0.763), active video game (0.686), and stationary bike music (0.658) ranked highest, suggesting these interventions are most likely to decrease body fat. In contrast, traditional methods (0.189), indicating limited relative effectiveness compared to other strategies. This netsplit plot shows a network meta-analysis comparing the effects of different interventions on body fat. Each row represents a pairwise comparison between an intervention and the "Active video game" or "Video game exercises," with results reported as mean difference (MD) and 95% confidence intervals (CIs). For example, the comparison of Control vs. Active video game yielded a small positive effect (MD = 1.30, 95% CI: –0.18 to 2.78), suggesting slightly higher body fat in the control group, but the CI crosses zero, indicating no statistically significant difference. Program-only vs. Active video game shows a negative MD (–4.40, 95% CI: −17.68 to 8.88), implying a possible body fat reduction with the program-only intervention, but the wide CI highlights great uncertainty. Stationary bike music vs. Active video game also trends negative (–1.40, 95% CI: –9.04 to 6.24), again non-significant. The Traditional method vs. Active video game comparison shows a small positive trend (MD = 2.25, 95% CI: –0.52 to 5.02), but still not significant. Finally, Control vs. Video game exercises shows a negligible effect (MD = 0.14, 95% CI: –0.68 to 0.96). The overall results suggest that no intervention demonstrated a statistically significant effect on body fat compared to active video games, with wide confidence intervals reflecting the small number of studies and limited precision of the evidence.

Node-splitting of body weight

The network diagram illustrated in Figure 10 shows network comparison of treatments, Active video game vs 5 treatments and Control vs 2 treatments. The treatment with highest number of participants was Active video game (281) while stationary bike music was revealed to have the least number of patients (13). This netsplit plot summarizes a network meta-analysis of interventions on the body weight, and the mean difference (MD) and 95% confidence intervals (CI) show whether interventions led to more or less weight change relative to the comparator. For *Care as usual only vs. Active video game, the MD was –5.20 (95% CI: –13.41 to 3.01), suggesting a possible reduction in weight with usual care, though not statistically

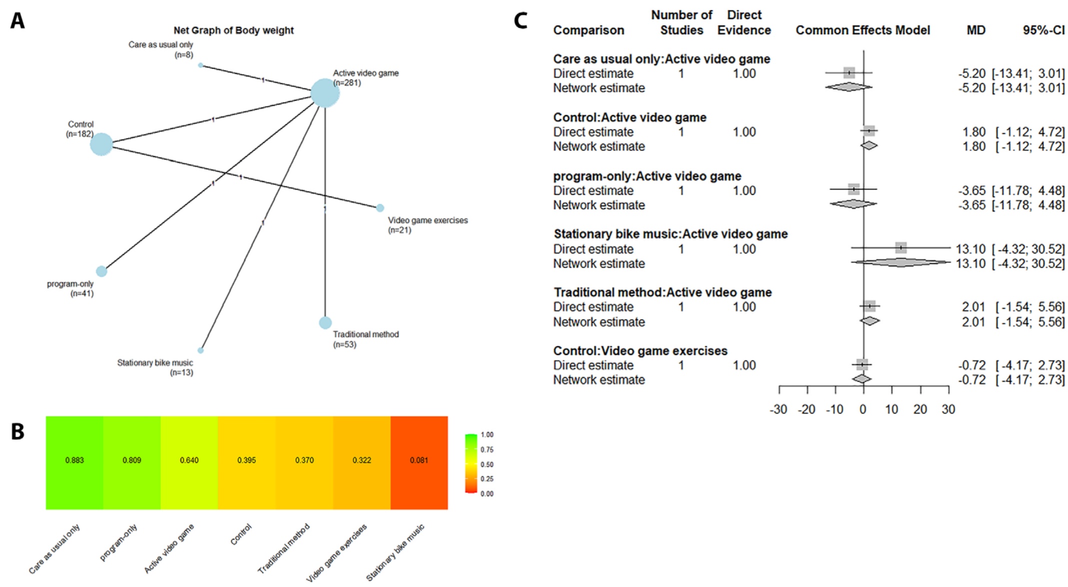

Figure 10. Node-splitting for Body Weigh. Figure 10(A) shows the network graph of Body Weight; Figure 10(B) shows the SUCRA Plot of Body Weight; Figure 10(C) shows the netsplit forest plot of Body Weight.

significant due to the wide CI. Control vs. Active video game showed a small non-significant increase (MD = 1.80, 95% CI: −1.12 to 4.72). Program-only vs. Active video game leaned toward weight reduction (MD = −3.65, 95% CI: −11.78 to 4.48), again inconclusive. Stationary bike music vs. Active video game stood out with a large positive trend (MD = 13.10, 95% CI: −4.32 to 30.52), indicating higher body weight, but the CI was very wide, reflecting high uncertainty. Traditional method vs. Active video game showed a small positive trend (MD = 2.01, 95% CI: −1.54 to 5.56), while Control vs. Video game exercises had a negligible effect (MD = −0.72, 95% CI: −4.17 to 2.73). Overall, none of the comparisons reached statistical significance, and the wide intervals highlight limited precision. The evidence suggests no clear advantage of one intervention over another for body weight outcomes, though stationary bike music showed the largest but highly uncertain difference. The SUCRA plot for Body weight ranks care as usual (SUCRA = 0.883), program only (0.809), and active video game (0.640) ranked highest, suggesting these interventions are most likely to decrease body weight. In contrast, stationary bike music (0.081), indicating limited relative effectiveness compared to other strategies.

Node-splitting of nutritional knowledge

The network diagram illustrated in Figure 11 shows network comparison of treatments, video game & Nutritional game vs 2 treatments each and Control vs 6 treatments. The treatment with highest number of participants was Control (2502) while foodbot factory was revealed to have the least number of patients (39). The SUCRA plot for nutritional knowledge ranks brochure about food pyramid (SUCRA = 1.0), food group knowledge (0.875), and control (0.687) ranked highest, suggesting these interventions are most likely to positively affect nutritional knowlege. In contrast, foodbot factory (0.004), indicating limited relative effectiveness compared to other strategies in nutritional knowledge. The netsplit plot shows the estimated mean differences (MD) between various interventions, with 95% confidence intervals (CI) displayed for each comparison. The "Video game: Brochure about the food pyramid" has an MD of 17.00 (CI: [12.02, 21.98]), indicating a strong positive impact on nutritional knowledge. On the other hand, interventions such as "Control: Foodbot Factory" and "Control: Nutritional game" show negative MD values (-3.20 and -0.60, respectively), suggesting a minimal or detrimental effect

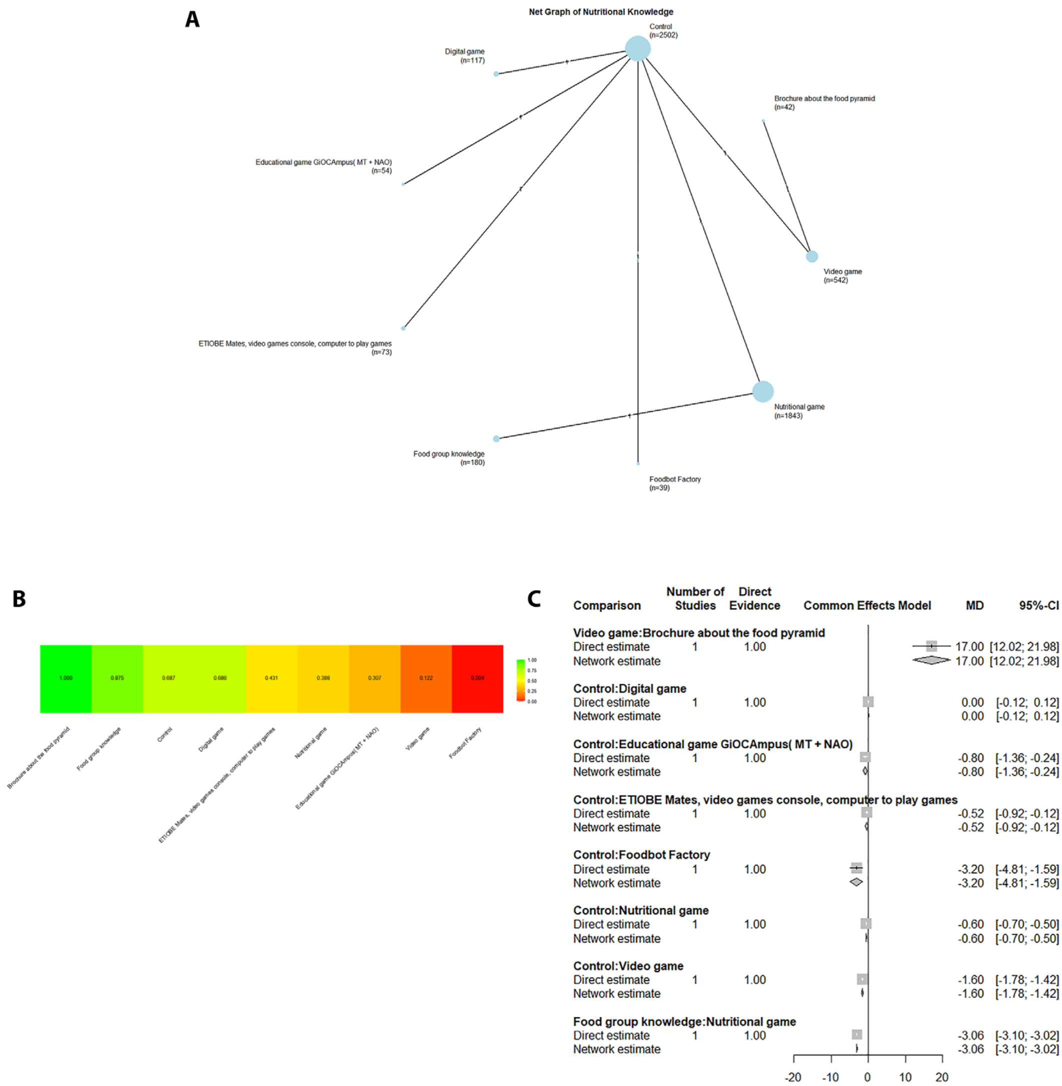

Figure 11. Node-splitting for Nutritional Knowledge. Figure 11(A) shows the network graph of Nutritional Knowledge; Figure 11(B) shows the SUCRA Plot of Nutritional Knowledge; Figure 11(C) shows the netsplit forest plot of Nutritional Knowledge.

on nutritional knowledge. The network estimates for all interventions follow a similar trend to the direct estimates, reflecting consistent results across both methods.

Node-splitting of physical activity

The network diagram illustrated in Figure 12 shows network comparison of treatments, active video game vs 3 treatments each and Control vs 4 treatments. The treatment with highest number of participants was Control (1787) while gaming console was revealed to have the least number of patients (23). The SUCRA plot ranks care as usual only (SUCRA = 0.856), ETIOBE (0.831), and program only (0.5) ranked highest, suggesting these interventions are most likely to affect nutritional knowledge positively. In contrast, active video game (0.237), indicating limited relative effectiveness compared to other strategies in nutritional knowledge. The physical activity netsplit plot compares the effects of various interventions involving active video games and other digital tools on

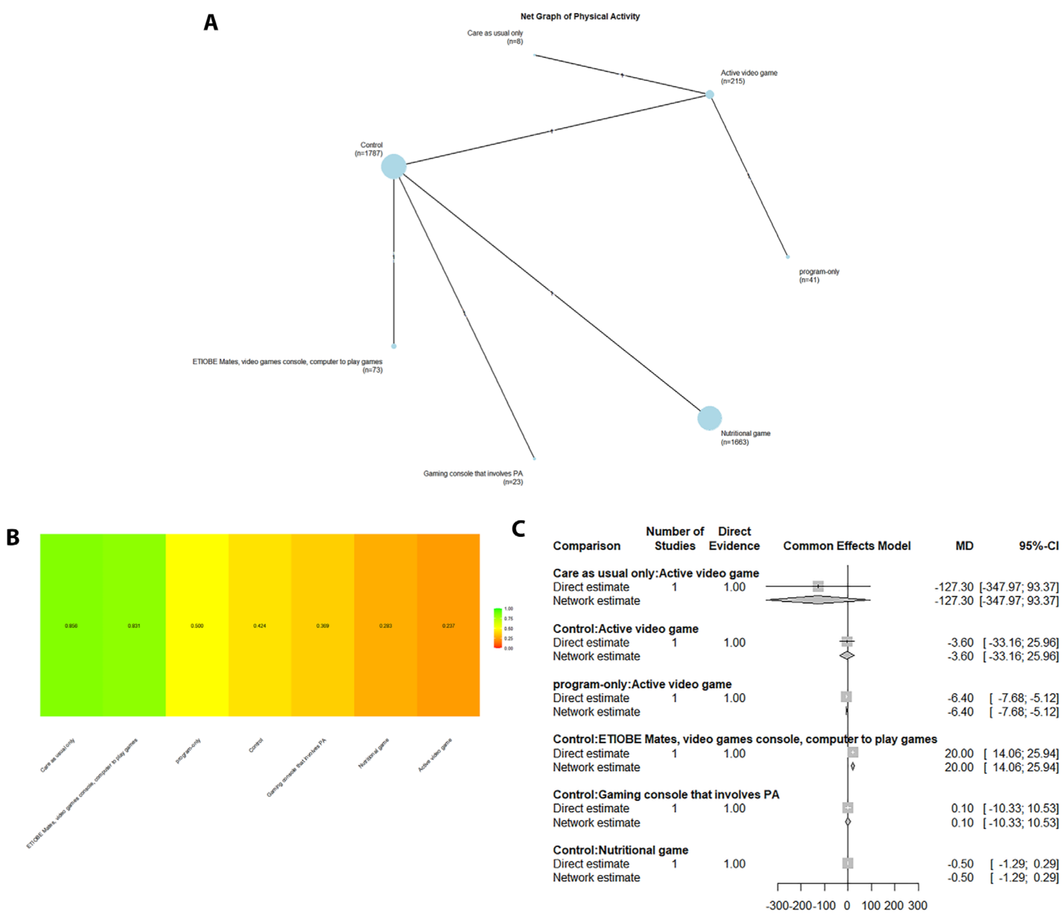

Figure 12. Node-splitting for Nutritional Knowledge. Figure 12(A) shows the network graph of Nutritional Knowledge; Figure 12(B) shows the SUCRA Plot of Nutritional Knowledge; Figure 12(C) shows the netsplit forest plot of Nutritional Knowledge.

physical activity. The graph shows the estimated mean differences (MD) for different comparisons, with 95% confidence intervals (CI) presented for each. For example, the "Care as usual only: Active video game" shows a large negative MD of -127.30 (CI: [-347.97, 93.37]), indicating that this intervention has a significant negative effect, potentially due to a lack of sufficient engagement or positive outcomes. Conversely, the "Control: ETIOBE Mates, video games console, computer to play games" shows a positive MD of 20.00 (CI: [14.06, 25.94]), suggesting that this intervention has a beneficial impact on physical activity. Other comparisons, such as "Control: Active video game" and "Control: Nutritional game," show small negative or neutral effects, with MDs around -6.40 and -0.50, respectively, reflecting minimal changes. Overall, the plot visually captures the relative effectiveness of these interventions on physical activity levels.

Meta-regression analysis

Meta-Regression of Body Mass Index

In the meta-regression analysis, the results indicate that for every one-unit increase in mean age, the Body Mass Index (BMI) decreases by 1.1308 units (Table 2). This effect is statistically significant, as the p-value is less than 0.05. Conversely, for every one-unit increase in sample size, BMI increases by 0.1228 units; however, this relationship is not statistically significant since the p-value exceeds 0.05. Similarly, each additional female participant is associated with

Table 2. Meta-Regression Analysis

Outcome	Group	Meta-Regression Estimate	SE	*p-value*
Body Mass Index (BMI)	Age	-1.1308	0.4472	0.0114
	Sample	0.1228	0.5995	0.8378
	Duration	-1.8000	1.3971	0.1979
	Female	-0.0033	0.0105	0.9955
Body Fat	Age	-1.4795	2.3511	0.5292
	Sample	-0.0095	0.4744	0.9841
	Duration	1.4000	4.0434	0.7292
	Female	-0.1078	0.4024	0.7884
Body Weight	Age	2.0866	3.2991	0.5271
	Sample	0.3600	1.4050	0.7978
	Duration	-13.1000	8.9171	0.1418
	Female	0.1263	1.2794	0.9214
Nutritional Knowledge	Age	1.6000	1.5848	0.3127
	Sample	3.8739	2.1652	0.0736
	Duration	3.2000	1.9688	0.1041
	Female	3.6255	2.0579	0.0784
Physical Activity	Age	6.4000	13.4038	0.6330
	Sample	-2.1671	5.5667	0.6971
	Duration	4.2638	2.1331	0.0456
	Female	-2.0769	5.5027	0.7059

a decrease in BMI of 0.0033 units, but this effect is also not statistically significant ($p > 0.05$). Lastly, an increase of one unit in the duration of treatment corresponds to a decrease in BMI of 1.8 units, yet this effect is not statistically significant ($p > 0.05$).

Meta-Regression of Body Fat

For every one-unit increase in mean age, Body Fat decreases by 1.4795 units; however, this effect is not statistically significant ($p > 0.05$). Similarly, for every one-unit increase in sample size, Body Fat decreases by 0.0095 units, which is also not statistically significant ($p > 0.05$) (Table 2). Additionally, for each additional female participant, Body Fat decreases by 0.1078 units, but this effect is not statistically significant ($p > 0.05$). Lastly, for every one-unit increase in duration of treatment, Body Fat increases by 1.4 units; this effect is also not statistically significant ($p > 0.05$).

Meta-Regression of Body Weight

For every one-unit increase in mean age, Body Weight increases by 2.0866 units, but this is not statistically significant ($p > 0.05$). A one-unit increase in sample size corresponds to a 0.3600-unit increase in Body Weight, which is not statistically significant ($p > 0.05$). Similarly, each additional female participant is associated with a 0.1263-unit increase in Body Weight, though this effect is not statistically significant ($p > 0.05$). Lastly, for every one-unit increase in duration of treatment, Body Weight decreases by 13.1 units, but this effect is not statistically significant ($p > 0.05$).

Meta-Regression of Nutritional Knowledge

For every one-unit increase in mean age, Nutritional Knowledge increases by 1.6 units, but this effect is not statistically significant ($p > 0.05$) (Table 2).

Similarly, a one-unit increase in sample size results in a 3.8739-unit increase in Nutritional Knowledge, which is not statistically significant ($p > 0.05$). Each additional female participant is associated with a 3.6255-unit increase in Nutritional Knowledge; however, this effect is not statistically significant ($p > 0.05$). Lastly, for every one-unit increase in duration of treatment, Nutritional Knowledge increases by 3.2 units, but this effect is not statistically significant ($p > 0.05$).

Meta-Regression of Physical Activity

For every one-unit increase in mean age, Physical Activity increases by 6.4 units, but this effect is not statistically significant ($p > 0.05$). For every one-unit increase in sample size, Physical Activity decreases by 2.1671 units; this effect is not statistically significant ($p > 0.05$). Each additional female participant is associated with a decrease of 2.0769 units in Physical Activity, which is also not statistically significant ($p > 0.05$). However, for every one-unit increase in duration of treatment, Physical Activity increases by 4.2638 units, and this effect is statistically significant ($p < 0.05$).

Discussion

Our study investigated the role of gamification as an intervention strategy for obesity-related outcomes spanning knowledge, behavior, and physiology. The findings show encouraging signals in several areas, yet some results require a more cautious interpretation. Between-study heterogeneity influences both the magnitude and the certainty of pooled effects, most notably for BMI z score. All syntheses used random-effects models to account for this variance. Several factors likely contributed to the wide dispersion of true effects across trials, including differences in intervention content and intensity, variation in setting and supervision across school, home, community, and clinical environments, diversity in delivery mode such as individual or group and technology assisted or in person, duration and dose of exposure, differences in baseline characteristics including age distribution and baseline BMI z score, and outcome ascertainment that ranged from device-based measures to self-report. These design and population differences can inflate I^2 even when the average effect is favorable. We therefore interpret pooled estimates with caution, place weight on the direction and consistency of effects across outcomes and acknowledge the breadth of plausible effects.

Notably, the effect of gamification on nutritional knowledge, while large in magnitude (SMD = 2.71), did not reach statistical significance due to wide confidence intervals (95% CI: -0.80 to 6.23) crossing the null. This findings highlight the importance of interpreting effect sizes alongside their precision and underscore the need for further well-powered studies to establish definitive conclusions.

However, gamification did show statistically significant improvements in BMI which was associated with narrow confidence intervals not crossing the null. These outcomes indicate that gamification may contribute to modest but meaningful improvements in nutritional status, particularly when interventions include active game components. Our network meta-analysis also revealed that the combination of structured programs with active games ("Programme + Active Game") emerged as the most effective strategy. While statistical significance was not consistently achieved across all outcomes, this approach demonstrated consistently positive trends. This highlights the potential of combining behavioral structure with interactive components to optimize engagement and outcomes.

Gamification refers to the application of game design elements such as points, levels, leaderboards, and rewards into non-game settings to enhance user engagement and motivation (41, 42). These elements simplify complex behaviors into manageable actions and reinforce goal-directed performance. Common mechanics include personalization, feedback, and social features that collectively aim to support behavioral change (29, 43).

The interactive and motivational nature of gamification offers sustained engagement, particularly among children and adolescents who are already immersed in digital environments (26, 27, 30, 43). Beyond promoting adherence, gamification may also support cognitive and social development by fostering learning, attention, and social interaction (45). However, gamification is not without risks. Excessive engagement may lead to behavioral addiction or divert users from the intended health goals. Additionally, some users may trivialize the educational content, particularly if the design lacks seriousness or age-appropriate interfaces (46). Older adults, for instance, may find complex gamified systems less intuitive, highlighting the importance of inclusive and user-centered design (42, 47).

Various game methods are currently used in the development of gamification techniques. Essentially, these diverse gaming methods adhere to the fundamental principles of gamification. To illustrate, the present study examines the efficacy of several gamification strategies aimed at reducing BMI in individuals. These strategies encompass the utilization of video games such as exergames or augmented reality games (ARGs), which increase calorie expenditure, hence transforming periods of inactivity into active moments (39, 48). In addition, BMI reduction is accomplished by fostering enhanced nutritional knowledge through card, board, or video games, which serve to facilitate learning rather than directly altering lifestyle and dietary preferences (45).

In terms of cost-effectiveness, some gamified interventions, particularly those using mobile apps, are low-cost and accessible (40, 49, 50). Others, especially those requiring gaming consoles or wearables, may pose financial barriers (25, 36). Unfortunately, none of the included studies reported formal economic evaluations, limiting our understanding of their practical scalability.

Since 2010, gamification has been increasingly applied across diverse sectors—including education, business, environmental sustainability, and healthcare—with its adoption in health promotion further accelerated by the COVID-19 pandemic (41, 42). Traditional health awareness strategies, such as seminars and posters, are progressively being replaced by gamified tools aimed at enhancing user motivation and engagement, especially in areas like self-monitoring and chronic disease management. This shift is driven by challenges such as limited healthcare access, treatment noncompliance, and rising healthcare costs (44). While gamification tends to be more effective among younger individuals familiar with digital platforms, its use among older adults is expanding through user-centered design (UCD) approaches (51). These methods tailor systems to the needs of aging populations by ensuring accessibility, simplifying interfaces, and incorporating features that address physical and cognitive limitations—thus promoting broader adoption across age groups (42).

Lastly, the ethical implementation of gamification requires clear regulations to ensure transparency, user autonomy, and data protection. Designers must avoid manipulative practices, such as exploiting psychological triggers or using random rewards that may promote addictive behaviors (52, 53). All objectives, mechanics, and potential rewards should be openly disclosed, with explicit user consent for data use. Upholding confidentiality, legal compliance, and continuous monitoring for unintended consequences is essential (54). Ultimately, gamification should prioritize ethical standards, user well-being, and meaningful engagement (55).

This network meta-analysis provides a comprehensive evaluation of gamification strategies in addressing obesity-related outcomes. A key strength of this study lies in the statistically significant improvements observed in objective markers of nutritional status, specifically BMI, supporting the efficacy of gamified interventions in reducing adiposity. The large cumulative sample size, global representation across 13 countries, and the use of rigorous methods such as GRADE assessment and RoB 2.0 further enhance the robustness and generalizability of our findings. The use of network meta-analysis allowed for both direct and indirect comparisons across a wide range of gamification strategies, enabling identification of the most promising intervention model—Programme + Active Game—as a superior approach for obesity reduction.

Strength and limitations

This review synthesizes evidence across knowledge, behavior, and physiological outcomes using both pairwise and network meta-analysis under random-effects models. Outcome instruments were mapped, and we clarified whether physical activity was measured with devices or self-report, improving interpretability. We added a network graph and a node-splitting assessment to compare direct and indirect evidence, increasing transparency about coherence in the evaluable parts of the network. Methods and reporting were aligned to contemporary guidance, and results are presented with an emphasis on magnitude and certainty rather than significance alone. Several limitations should temper interpretation. Some behavioral and cognitive outcomes, including nutritional knowledge and physical activity measures, did not reach statistical significance, partly due to wide confidence intervals and heterogeneity in study designs, durations, and participant age groups. Long-term follow-up data were absent, limiting assessment of sustainability, and economic outcomes such as cost-effectiveness were not reported. The network was predominantly star-shaped, with most comparisons against control, restricting closed loops and limiting power to detect inconsistency. Across outcomes, trials varied in intervention content and intensity, delivery setting and supervision, delivery mode, duration and dose, baseline characteristics, and outcome ascertainment—likely contributing to the wide dispersion of true effects and the high I^2 observed for some outcomes, particularly BMI z score (I^2 = 97%). The dataset did not support reliable meta-regression, subgroup modeling, or age-stratified/sensitivity analyses due to sparse strata and incomplete reporting of moderators. Standard tests for small study effects were underpowered, so any absence of asymmetry should be interpreted cautiously. Future trials should prespecify age strata, report age-specific results, standardize measurement for physical activity and nutritional knowledge, describe intervention dose and delivery in detail, and incorporate long-term follow-up and economic evaluation to enable more robust moderator assessment and generate precise, generalizable estimates.

Conclusion

This study concludes that gamification strategies, especially those involving structured programs combined with active games, may be effective in reducing BMI among individuals with overweight or obesity. These findings support for more rigorous research, specifically active games. Although gamification also showed promising trends in enhancing nutritional knowledge and increasing physical activity, these outcomes did not reach statistical significance and should be interpreted with caution. Future research is warranted to explore these behavioral outcomes more robustly, evaluate long-term sustainability, and determine cost-effectiveness. The inclusion of gamification in clinical and public health guidelines for obesity management—particularly in preventive strategies—may offer a novel and engaging avenue to support healthier lifestyles. This study suggests that gamification strategies, particularly structured programs incorporating active games, may reduce BMI among individuals with overweight or obesity. However, the effect sizes were small to moderate, and their clinical relevance remains uncertain. Although favorable trends in nutritional knowledge and physical-activity levels were noted, these did not reach statistical significance and should be interpreted with caution. Consequently, more rigorous research is needed, employing larger samples, longer follow-up periods, and standardized outcome measures to confirm efficacy, evaluate long-term sustainability and cost-effectiveness, and explore the true impact on behavior change. If these findings are validated, the targeted inclusion of gamified components could represent an innovative adjunct to existing obesity-prevention and management strategies

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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Appendix

Table S1. PICO Framework.

PICO Element	Description
Patient	Individuals at risk for or diagnosed with obesity.
Intervention	Gamification strategies (such as mobile apps, video games, reward systems, etc.) aimed at promoting healthy behaviors, physical activity, and dietary changes.
Control	Traditional or standard methods of obesity prevention and treatment, such as diet and exercise recommendations without gamification, or without any intervention.
Outcome	Nutritional status (BMI), nutritional knowledge, and physical activity levels.

Table S2. Inclusion and exclusion criteria

Category	Criteria
Inclusion	Randomized controlled trial (RCT) design Studi with participants at risk for or diagnosed with overweight or obesity Study with gamification used as the intervention Reported at least one relevant outcome: nutritional knowledge, physical activity, or nutritional status
Exclusion	1. Studies without a control group 2. Studies focusing on health habits unrelated to nutrition or physical activity 3. Studies with mixed interventions (not solely gamification) 4. Full text not freely accessible 5. Review articles and study protocols

Table S3. Search strategy

Database	Keywords
PubMed	#1 Obesity [MeSH Terms] #2 ((obesity*[Title/Abstract]) OR (overweight*[Title/Abstract])) #3 #1 OR #2 #4 "gamification"[Supplementary Concept] #5 ((gamification*[Title/Abstract]) OR (game*[Title/Abstract])) #6 #4 OR #5 #7 ((nutrition*[Title/Abstract]) OR ("feeding behavior"[Title/Abstract]) OR (food*[Title/Abstract]) OR (diet*[Title/Abstract]) OR ("physical activity"[Title/Abstract]) OR (exercise*[Title/Abstract]) OR ("body mass index"[Title/Abstract]) #8 #3 AND #6 AND #7 #9 #3 AND #6 AND #7, Filter : Clinical Trial #10 #3 AND #6 AND #7, Filter : Clinical Trial, Randomized Controlled Trial
ScienceDirect	(obesity* OR overweight*) AND ("gamification" OR game*) AND (nutrition* OR "feeding behavior" OR food* OR diet* OR "physical activity" OR exercise* OR "body mass index") AND ("randomized-controlled trial" OR "RCT")
Cochrane	#1 MeSH descriptor: [obesity] explode all trees #2 (obesity* OR overweight*):ti, ab, kw #3 #1 OR #2 #4 ("gamification" OR game*):ti, ab, kw #5 #3 AND #4 #6 (nutrition* OR "feeding behavior" OR food* OR diet* OR "physical activity" OR exercise* OR "body mass index"):ti, ab, kw #7 #5 AND #6 #8 #7 AND ("randomized-controlled trial" OR "RCT")
Wiley	(obesity* OR overweight*) AND ("gamification" OR game*) AND (nutrition* OR "feeding behavior" OR food* OR diet* OR "physical activity" OR exercise* OR "body mass index") AND ("randomized-controlled trial" OR "RCT")

Table S4. Exercise Type Description

Study	Descriptive Explanation of The Type of Program or Exercise
Adamo et al., 2010 (27)	GameBike (Cat Eye Electronics Ltd., Boulder, Colo.) connected to a Sony PlayStation 2 (Sony Computer Entertainment America Inc., Foster City, Calif.) with a handlebar controller for race-based games that are given to play while cycling. The GameBike determined speed based on cycling cadence. Participants learned to adjust bike resistance and could choose exercise intensity and duration. They attended two 60-minute sessions per week for 10 weeks.
Banos et al., 2013 (28)	ETIOBE Mates is an e-therapy platform with Clinical Support System (CSS), Home Support System (HSS), and Mobile Support System (MSS) featuring serious games for teaching nutritional knowledge. It covers terms, dietary recommendations, nutrients, food choices, and diet-disease links. ETIOBE Mates has sections like Cooking (5 recipes), Feeding (10 interactive pages on food knowledge), Moving (activity and energy balance info in 4 pages), and Playing (3 serious games).
Chagas et al., 2020 (29)	The intervention employed a custom-developed digital game named Rango Cards. This title merges the Brazilian term for food ("rango") with the concept of card games ("cards"). Its aim is to promote a healthy diet aligned with the Brazilian Dietary Guidelines. The game mechanics resemble Hearthstone® (Blizzard Entertainment), a 2017 Google Play awardee. In Rango Cards, matches occur on a dining table, featuring characters with a blend of Japanese anime and American comic book aesthetics for familiarity. The game draws from social cognitive theory, emphasizing factors influencing eating behavior, like knowledge and self-efficacy. Set in a school environment, the narrative unfolds across seven phases, covering topics like food classification, healthy eating practices, cooking's significance, countering deceptive food marketing, and understanding nutritional labels. Designed for learning, Rango Cards is available for free in Portuguese on Android and iOS devices via Google Play and the App Store since April 2017.

Study	Descriptive Explanation of The Type of Program or Exercise
Coknaz et al., 2019 (30)	Children in AVG group alternatively played Nintendo Wii® AVGs from sports (boxing, tennis, golf, baseball, and bowling), balance (ski slalom, heading ball, balance bubble, ski jumping and penguin playing), aerobics (rhythm boxing, hula-hoop, cycling, step, and run), resort (jet-skiing, water skiing, table tennis, basketball, swordplay, archery, canoeing and frisbee) and training (rhythm kung fu, snowball, turning ball, Segway circuit, perfect 10, skateboard, major, obstacle course and bicycle) categories for 50–60 min, 3 days a week, for 12 weeks in laboratory environment supervised by three experienced personnel between March and May 2013. Children in the C group did not play games.
Comeras-Chueca et al., 2022 (31)	The AVG group underwent a 5-month intervention involving thrice-weekly, 60-minute sessions. These combined AVG with multicomponent training. Sessions began with a 10-minute warm-up encompassing various exercises. The main exercise segment (45 minutes) alternated dynamic circuit training between AVG and multicomponent exercises. A 5-minute cool-down followed, focusing on static flexibility. The multicomponent exercises targeted overall physical fitness aspects like cardiorespiratory fitness, strength, agility, and coordination. Two weekly sessions improved cardiorespiratory fitness, one enhanced muscular fitness, with one cardio session including muscle strength. Utilized AVGs included Xbox 360® with Kinect ("Kinect Adventures," "Kinect Sports"), Nintendo Wii® ("Wii Sports," "Just Dance," "Mario and Sonic at the Olympic Games"), dance mats ("Dance Dance Revolution" and adapted "Mario and Sonic at the Olympic Games"), and BKOOL® interactive cycling with HUAWEI MediaPad T5 AGS2-W09. Warm-ups involved balance, coordination, and agility exercises.
Froome et al., 2020 (32)	Intervention Group (Foodbot Factory): The intervention involved daily engagement with Foodbot Factory's learning modules: Drinks (Day 1), Whole Grain Foods (Day 2), Vegetables and Fruits (Day 3), Animal Protein Foods (Day 4), and Plant-based Protein Foods (Day 5). Each module lasted 15 minutes, with an available voiceover feature for accessibility. Foodbot Factory's development process was discussed elsewhere. Control Group: The control group used the "My Salad Shop Bar" mobile app, focused on gamified healthy food prep, including salads, smoothies, and whole grain breads. Despite each level typically taking five minutes, the control group had a 15-minute playtime to match the intervention group's consistency.
Gan et al., 2019 (33)	Squire's Quest! is a 10-session interactive game, each 25 minutes. Players aid 5A Lot kingdom against Slimes and Mogs. Challenges involve consuming fruits, veggies, and 100% fruit juice. Virtual cooking empowers the army. Wizard and robot guide, Chef Mog complicates. Players choose FJV or snack. Goals set, dragon-scale points earned, all achieve knighthood. Shaped by focus groups, aligning with preferences and developers' advice.
Irandoust et al., 2020 (34)	In the VGG group, participants engaged in Xbox Kinect games (Microsoft Corp., Redmond, WA, USA) for three weekly sessions lasting 60 minutes each. The intensity, measured on the Borg scale (6–20), was set at 11–13 AU. Participants could select Xbox games like Wii Sports, Kinect Ultimate Sports, Wii Fit, and Just Dance. Research staff supervised the training, with three stations having Xbox devices and televisions for the participants. Game levels marked as "difficult" were chosen to maintain intensity. Preexercise heart rate (RHR) and peak heart rate (MHR) were recorded during each session. The aquatic aerobic exercise intervention encompassed warm-up, main exercises, and a cool-down phase, occurring thrice weekly. All sessions took place from 10:00 AM to 12:00 PM over 12 weeks. The Control Group (CG) did not participate in any structured physical activity during the study period.
Johnston et al., 2012 (35)	This study assessed the impact of Alternate Reality Games (ARGs) on college students' physical activity (PA). The ARG, named The Skeleton Chase, incorporated game design and behavior models, guided by social cognitive theory. The game included weekly challenges, character interactions, and step goals. Teams solved the game's mystery, earning points through correct answers and challenges. ActiPed devices tracked steps, with cumulative scores determining rankings over seven weeks. A comparison group attended fitness sessions with pedometers for baseline and postintervention PA data collection.
Mack et al., 2020 (36)	The Intervention Group (IG) engaged in a 45-minute game twice in 2 weeks, with investigator presence. The game created a medieval world with competitive and supportive elements, focused on nutrition and healthy lifestyle knowledge. Players controlled avatars through physical movement and completed tasks by touching screens. Topics included nutrition, physical activity, and stress coping, covering the food pyramid, sugar content, satiety factors, and DED-P concept. Daily food analysis tool and stress-relief exercises were included. The Control Group (CG) received a healthy lifestyle brochure initially; later got the intervention due to ethics.

Table S4 (*Continued*)

Study	Descriptive Explanation of The Type of Program or Exercise
Staiano et al., 2018 (37)	Participants in GameSquad were given a Kinect® and Xbox 360® console, Xbox Live subscription, and four exergames. Within a week of randomization, coaches set up the equipment and initiated engagement through a joint gaming challenge. GameSquad aimed for 60 minutes of daily moderate-to-vigorous physical activity (MVPA) over 24 weeks. Exergames were played three times weekly, following a curriculum booklet's challenges of increasing intensity and duration (10 to 60 minutes). Exergaming sessions were limited to 60 minutes. Telehealth included weekly video meetings with participants, parents, and a coach for the initial 6 weeks, biweekly thereafter. Fitbit Zip trackers monitored steps. The control group maintained regular activity for 24 weeks, receiving Xbox equipment and games poststudy. $25 compensation covered travel at baseline and follow-up.
Trost et al., 2014 (38)	All randomized participants engaged in the JOIN for ME family-based pediatric weight management program, which aligns with established childhood obesity treatment principles. Adaptations were made for cost-effectiveness: combined child-parent dyads, 60-minute sessions, and sessions led by trained facilitators without obesity treatment background. This study adjusted the program. Participants, in groups of 5 to 11 child-parent dyads, attended 16 weekly sessions. These involved weigh-ins, progress assessment, new content, and goal setting. Topics covered included self-monitoring, calorie targets, food categorization ("LESS" or "YES!") based on nutritional value, reduced screen time, goal setting, and increased activity. The P + AG group, beyond JOIN for ME, received an Xbox console, Kinect device, and an active sports game (Kinect Adventures!) in session two. Another active game (Kinect Sports) was given in week nine. No specific gaming instructions were provided. After the 16-week program, the PO group got the gaming hardware and two games.
Verbeken et al., 2013 (39)	The intervention centers on cognitive executive function training integrated into a game called 'Braingame Brian'. It consists of 25 sessions, each lasting approximately 40 minutes, with two blocks of training tasks in each. These tasks focus on working memory and inhibition training. Over 6 weeks, the child trains about four times a week, with one session per day. Task difficulty adjusts based on performance, and completing blocks expands the game world. During breaks and before/after training, the child explores the extended game world, aiding village residents. The game is played at the clinic after school, supervised by a research assistant. The child maintains a diary and receives a daily token for completing sessions.
Rosi et al., 2016 (40)	Three northern Italian primary schools joined the study. Two schools, part of the Giocampus project, formed intervention groups. The third school, not in any nutrition program, served as control. Both intervention groups had a 1-hour nutritional class, mixing theory and play. Theoretical parts built on nutrition topics, like 'importance of carbohydrates' from Giocampus Scientific Committee's priorities. 'Learning through play' used the 'GiOCAmpus' game as in a previous study. MT group had sessions led by the MT, a Giocampus nutritional education figure. In MT + NAO, MT interacted with NAO, a humanoid robot from Aldebaran Robotics, Paris. NAO was tailored for education, explaining nutrition concepts and engaging in the game. NAO's traits aimed at teaching effectiveness. 'GiOCAmpus' game and NAO are integral to the study's context.
Maddison et al., 2011 (42)	Games with levels automatically managed. Participants are to achieve physical activity goals (step counts or time on MVPA) or nutritional status (weight check in or others). The rewards are given using the economic behavioral change with components as: (1) Precomtiment pledge (daily step goals to assess the chosen goals and increased gradually); (2) Weekly points and Loss framing (daily weight check in and loss of points if goals not met); (3) Level progression (patients could go up and down levels with goal achievements); (4) Physician reports (monthly reports with details). Other than that, social interactions are supported with collaboration goal achievement, competition leaderboard, and support for family and friends.
Viggiano et al., 2015 (43)	The study conducted assessments at baseline, 12 weeks, and 24 weeks. Trained researchers administered standardized assessments individually at a central location. Measurements included height, weight, waist circumference, and body composition through bioelectrical impedance analysis. The 20-meter shuttle test evaluated cardiovascular fitness. Participants wore accelerometers for 7 days postassessment, tracking physical activity, and completed diaries detailing game usage and snack consumption. The study staff collected these from participants' homes. Serious adverse events requiring hospitalization were monitored at 12 and 24 weeks. The assessments comprehensively collected data on physical activity, fitness, dietary habits, and adverse events to evaluate intervention effects.

Study	Descriptive Explanation of The Type of Program or Exercise
Lakshman et al., 2010 (44)	The study employed a two-group design with a treatment group and a control group. It spanned pretreatment, one posttreatment, and two subsequent posttreatment assessments. Among the 20 participating schools, random division into two groups occurred. The treatment group had weekly 15-30 minute Kaledo board game sessions for 20 weeks. The interactive educational game aimed to be inclusive, conducted in classrooms. Teachers were trained and directed the sessions, accommodating absentees. The intervention was integrated into the treatment group's curriculum, while the control group had no such sessions.
Adamo et al., 2010 (27)	'Top Grub'® card game teaches healthy eating, featuring food items, nutritional info, pictures, fun facts, and color-coded dots based on healthiness. Players aimed to win cards by comparing nutritional values. The game could be adapted for activities like identifying high-fat or high-sugar cards and discussing healthier options. The 33-card set covered common kid's food, including healthier alternatives.

Table S5. GRADE Nutritional Knowledge

Certainty assessment							**№ of patients**		**Effect**			
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Gamification**	**control**	**Relative (95% CI)**	**Absolute (95% CI)**	**Certainty**	**Importance**
Gamification												
8	randomized trials	not serious	serious[a]	not serious	not serious[b]	None	2722	2757	-	SMD 2.71 SD higher (0.8 lower to 6.23 higher)	⨁⨁⨁◯ Moderate	CRITICAL

Abbreviations: CI: confidence interval; SMD: standardized mean difference. *Note:* a. I squared = 99%, b. One study, Gan et al 2019, had large effects. Author(s): Lakshman et al 2010(44), Banos et al 2013(28), Viggiano et al 2015(43), Rosi et al 2016(40), Gan et al 2019(33), Mack et al 2020(36), Chagas et al 2020(29), Froome et al 2020(32).

Table S6. GRADE physical activity

Certainty assessment							№ of patients		Effect			
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Gamification**	**Control**	**Relative (95% CI)**	**Absolute (95% CI)**	**Certainty**	**Importance**
MVPA (Moderete-Vigorous Physical Activity),												
7	randomized trials	not serious	serious[a]	not serious	serious[b]	strong association	551	429	-	SMD 0.37 SD higher (0.12 lower to 0.86 higher)	⊕⊕⊕◯ Moderate	CRITICAL
The Steps												
8	randomized trials	not serious	serious[c]	not serious	serious[d]	strong association	368	382	-	SMD 0.13 SD higher (0.35 lower to 0.6 higher)	⊕⊕⊕◯ Moderate	CRITICAL
Counts Per Minutes												
2	randomized trials	not serious	not serious	not serious	serious[e]	none	144	87	-	SMD 0.02 SD higher (0.25 lower to 0.29 higher)	⊕⊕⊕◯ Moderate	CRITICAL

Abbreviations: CI: confidence interval; SMD: standardized mean difference. *Abbreviations:* a. I squared = 87%; b. Trost et al 2014 had large effects; c. I squared = 88%; d. Two studies had negative true effects; Patel et al 2019 and Patel et al 2021; e. Small effects studies and CIs for which the confidence interval crosses the established threshold. Author(s): Amaro et al 2016(49), Baranowski et al 2011(60), Baranowski et al 2012(61), Comeras-Cueca et al 2022(31), Maddison et al 2011(42), Staiano et al 2018(37), Trost et al 2014(38), Agarwal et al 2021(26), Garde et al 2016(62), Johnston et al 2012(35), Patel et al 2019(14), Patel et al 2021(41).

Table S7. GRADE nutritional status

Certainty assessment							№ of patients		Effect			
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Gamification**	**control**	**Relative (95% CI)**	**Absolute (95% CI)**	**Certainty**	**Importance**
BMI												
10	randomized trials	not serious	not serious	not serious	not serious	strong association	471	498	-	SMD 0.24 SD lower (0.37 lower to 0.11 lower)	⊕⊕⊕⊕ High	CRITICAL
BMI Z score												
10	randomized trials	not serious	serious[a]	not serious	serious[b]	very strong association	2620	2155	-	SMD 0.3 SD higher (0.88 lower to 0.27 higher)	⊕⊕⊕⊕ High	CRITICAL
Body Fat Percentage (%)												
8	randomized trials	not serious	not serious	not serious	not serious	strong association	438	478	-	SMD 0.16 SD lower (0.3 lower to 0.02 lower)	⊕⊕⊕⊕ High	CRITICAL

Abbreviations: CI: confidence interval; SMD: standardized mean difference. *Note:* a. I squared = 97%; b. Two studies had negative large effects, while two studies had positive large effects. Author(s): Martinez-Lopez et al 2022(52), Adamo et al 2010(27), Coknaz et al 2019(30), Irandoust et al 2020(34), Baranowski et al 2011(60), Comeras-Cueca et al 2022(31), Maddison et al 2011(42), Staiano et al 2018(37), Trost et al 2014(38), Johnston et al 2012(35), Lambrick et al, 2015(63), Oh et al 2022(64), Simons et al 2015(65), Zask et al 2012(66).