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The effect of electronic health (eHealth) interventions for promoting physical activity self-efficacy in children: A systematic review and meta-analysis

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ABSTRACT

Background/objective: Physical activity (PA) self-efficacy plays a crucial role in maintaining and enhancing PA behaviors in children. However, the effectiveness of eHealth interventions in boosting PA self-efficacy among children remains uncertain. Furthermore, which behavior change techniques (BCTs) used in eHealth interventions can positively influence children's PA self-efficacy needs further exploration for designing tailored eHealth interventions. Therefore, this systematic review and meta-analysis aimed to identify the effectiveness of eHealth interventions and BCTs in promoting children's PA self-efficacy.

Methods: Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a comprehensive search was conducted across six databases (PubMed, Web of Science, EBSCOhost, Ovid, SPORTDiscus, PsycINFO) up to January 8, 2024. Inclusion criteria included randomized controlled trials (RCT), quasi-experimental, and two-group experiments that examined the effect of eHealth interventions on PA self-efficacy among healthy children aged 0–18 years. The Physiotherapy Evidence Database (PEDro) scale was utilized to assess the risk of bias. Random effects meta-analysis was performed to determine the effectiveness of eHealth interventions and BCTs in selected studies.

Results: Sixteen studies were screened, including 6020 participants with an average age of 11.58 years (SD = 2.87). The result showed small but significant intervention effects with high heterogeneity (I^2 = 92.34 %) for postintervention PA self-efficacy (*Hedges' g* = 0.315; 95 % CI = 0.069, 0.562, p = .012). Two BCTs were significantly associated with enhanced PA self-efficacy: *instruction on performing the behavior* (p = .003) and *behavior demonstration* (p = .036). Additionally, studies that adopted social support (unspecified) a nd prompt/cues were significantly less effective than studies that did not use these BCTs (p = .001).

Conclusions: The findings showed that eHealth interventions positively affect children's PA self-efficacy. This review is the pioneer in focusing on BCTs in eHealth interventions for children. The insights gained provide valuable knowledge about tailored BCTs incorporated into eHealth interventions that promote children's PA self-efficacy.

Trial registration: International Prospective Register of Systematic Review (PROSPERO): CRD42024512058.

1. Background

Childhood regular physical activity (PA) has many well-documented benefits, such as improving cardiovascular health, mental well-being, and overall quality of life.[1–3] An active childhood lays the foundation for chronic disease prevention in later years.[4] Yet, a cross-sectional survey conducted in 2016 indicated that 80 % of 1.6 million children and adolescents aged 11 to 17 in 146 countries fail to meet the World

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Health Organization's (WHO) guideline of at least 60 min of moderate-to-vigorous PA (MVPA) daily.[5,6] More than 90 % of girls in 27 countries were insufficiently active. For boys, the prevalence of insufficient PA increased significantly between 2001 and 2016, and this trend continues.[5] To encourage children's PA, it seems important to intervene from a psychological perspective. A longitudinal study found that autonomous motivation and self-efficacy had a significant relation to PA.[7] Another longitudinal study also indicated that intrinsic motivation can positively influence children's PA participation.[8]

Social cognitive theory (SCT), self-determination theory (SDT), and theory of planned behavior (TPB)[9–11] are the three most common psychological theories in promoting PA.[12] These theories have been found to be highly correlated with children's behavioral intention to engage in PA, emphasizing the importance of motivation and perceived autonomy in influencing children's PA.[10,13] Autonomous motivation is a key part of SDT and strongly predicts children's intentions and behaviors regarding PA.[14] It can be shaped by perceived autonomy support from peers or teachers, mediating the link between social support and activity intentions.[13] In terms of TPB, attitudes, subjective norms, and perceived behavioral control also predict these intentions and mediate the impact of autonomous motivation on activity behaviors.[15] SCT emphasizes self-efficacy as an essential element in affecting individuals' behaviors.[16] A study analyzed the relationship between the elements of SCT and PA concluded that self-efficacy and goal were consistently associated with PA.[17] A meta-analysis identified attitudes, norms, and self-efficacy as important determinants of intentions and behaviors.[18] However, only self-efficacy can directly affect individuals' behavioral choices.[16] Intervention in self-efficacy seems to be more efficient in children's PA. In addition, a systematic review pointed out self-efficacy was the only one positively associated with increased PA in both children and adolescents among various psychological factors.[19] A cross-sectional survey of 4779 children in Canada showed that children with higher self-efficacy tend to be more physically active.[20] Enhancing children's self-efficacy makes them more likely to participate in and maintain PA actively.[21]

Bandura defined self-efficacy as an individual's belief in their ability to perform a certain behavior or achieve a desired outcome.[22] In health promotion, self-efficacy has been widely recognized as a precondition and consequence of PA.[23–25] Voskuil and Robbins defined children's PA self-efficacy as their belief in their ability to participate in PA and choose PA in the presence of obstacles.[26] Higher PA self-efficacy can effectively regulate emotions and help children overcome difficulties in physical activities.[27] It is also closely related to the confidence in completing physical activities and the intrinsic motivation to enjoy them.[28] An experimental study showed that when children's self-efficacy is enhanced, they are more like to reduce their reliance on external motivation and enhance their confidence in their physical ability, thus increasing PA.[29] In another study, PA self-efficacy was found to have the largest total effect on PA in a structural equation model. It can directly or indirectly affect individuals' PA through self-regulation or social support and is an important factor in predicting and promoting PA.[30]

Many studies demonstrated the effectiveness of utilizing behavior change techniques (BCTs) in promoting PA self-efficacy. BCTs are common elements used in behavior change interventions, defined as 'indivisible, observable, and reproducible parts of an intervention intended to alter behavior'.[31] Three systematic reviews and meta-analyses showed that BCTs including "action planning," "providing guidance," "enhancing behavioral effort," "time management," "immediate self-monitoring of behavioral outcomes" and "planning social support/social change," "alternative experience," and "feedback" were significantly associated with higher PA self-efficacy.[32–34] However, the effectiveness of different BCTs in altering PA self-efficacy may vary across populations.[34] While existing literature primarily focuses on BCTs in adult populations' PA self-efficacy, there are limited insights into their impact on children.

The emergence of electronic health (eHealth) interventions plays a significant role in promoting healthy lifestyles for children.[35–37] One systematic review revealed that eHealth active games positively influence children's PA self-efficacy.[38] Additionally, diverse eHealth strategies such as wearable devices, online social networks, and smartphone applications[35] show the ability to create customized PA content, offer real-time feedback, and adjust to individual needs positioning eHealth interventions as a promising method for enhancing children's PA self-efficacy.[36,39–41] Furthermore, studies pointed out that behavior change strategies as fundamental in designing digital health interventions for children.[42,43] Nonetheless, there is a lack of clarity regarding the effectiveness of eHealth interventions on PA self-efficacy in children and which specific BCTs adopted in current eHealth interventions contribute the most. Accordingly, this review is structured to address the following research questions.

(1) How effective are eHealth interventions at enhancing PA self-efficacy in children?
(2) What BCTs have been used in eHealth interventions are closely associated with increased PA self-efficacy in children?

2. Method

The review protocol was registered in PROSPERO (registration ID: CRD42024512058). Reporting of this review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[44]

2.1. Eligibility criteria

Studies written in English and published in English peer-reviewed journals were included. The selection criteria for studies were structured around the PICOS (participants, intervention, comparator, outcomes, and study design) framework, which is detailed as follows:

(a) Participants: healthy children aged 0–18 years; (b) Intervention: eHealth intervention (such as mobile phone, web-based, messages, video games); (c) Comparator: experiments with experimental and control groups (without any interventions) were included. (d) Outcomes: the main result must include PA self-efficacy; (e) Study design: Randomized controlled trial, quasi-experimental, two-group experiment, and the quantitative components of mixed-method studies.

Articles were excluded if: (a) Participants: studies with participants who were not aged 0–18 years or had mental or physical disabilities/disorders/condition; (b) Intervention: studies did not apply any eHealth approach in the intervention; (c) Comparator: studies without appropriate control conditions or groups. (d) Outcomes: the authors did not present pre-and post-test data on PA self-efficacy.

2.2. Search strategy

Article searches were conducted on January 8, 2024, utilizing six databases: PubMed, Web of Science, EBSCOhost, Ovid, SPORTDiscus, and PsycINFO. The range of publication dates covered was from inception through January 8, 2024. For details on the search strategy terms, refer to Table 1.

2.3. Data extraction

The principal and co-authors carried out the data extractions using Microsoft Office Excel 2019 (Microsoft, USA). The extracted data included the author, publication year, location, sample size, demographic characteristics, theoretical framework, study design, details of the intervention, information on experimental and control groups, measurements of PA self-efficacy, BCTs, and study results.

Table 1
Search strategy terms.

eHealth	Physical Activity	Self-efficacy	Children
Electronic health OR eHealth OR mobile health OR mHealth OR Digital health OR Telehealth OR Online* OR Virtual* OR Web* OR Internet* OR Smartphone OR phone OR APP OR chatbot OR "conversational agent" OR "social media" OR Facebook OR Exergame OR "technology" OR "video"	Physical activity OR Active* OR Fitness OR Exercise* OR Sport OR Active lifestyle OR Sports participation OR Workout	Self-efficacy OR Self-confidence OR Exercise confidence OR Physical activity Confidence OR PA confidence OR Self-belief	Pre-schooler* OR Schoolchild* OR School-age OR Child* OR Pediatric* OR Adolescent* OR Youngster* OR Teen* OR Minor* OR Youth OR Young person OR Juvenile*

2.4. Quality assessment

This review examined the quality of experimental methods using the Physiotherapy Evidence Database (PEDro) scale.[45] The PEDro scale contains 11 criteria to evaluate an experiment's internal and external validity. The principal and two co-authors evaluated the quality of each experiment on a scale of yes (1) and no (0). Studies with PEDro scores between 8 and 10 were rated methodologically excellent in quality; A score between 5 and 7 is high quality; A score between 3 and 4 is moderate quality; Those that score less than 3 are low-quality.[45]

2.5. Statistical analysis

The meta-analysis used data extracted from intervention and control/comparison groups across pre- and post-intervention periods. The standardized mean difference, accounting for sample sizes, means, and standard deviations (SD) in each group, was computed and converted to Hedges' g to estimate effect sizes.[46] Follow-up assessment data were not considered. Meta-analyses for PA self-efficacy and BCTs were conducted provided that at least three studies reported interventions addressing the same components and supplied adequate data for effect size calculation.

All statistical analyses were performed under the umbrella of a random-effects model, acknowledging the potential differences between studies that could influence the treatment effect,[47] and were conducted via the Comprehensive Meta-Analysis software (version 3; Biostat, Englewood, NJ, USA). Sensitivity analyses were conducted using random-effects models, with each study being removed from the pooled analysis in each instance. The effect size values are presented alongside their respective 95 % Confidence Intervals (CIs). Calculated effect sizes were interpreted using the following thresholds: small ($g < 0.40$), moderate ($g = 0.40–0.70$), and large ($g > 0.70$), according to the Cochrane Handbook.[48] Heterogeneity was quantified using the I-squared (I^2) statistic, with values of <25 %, 25–75 %, and >75 % interpreted as low, moderate, and high heterogeneity, respectively.[49] Publication bias was assessed through Egger's regression tests and the visual inspection of funnel plots.[50] All statistical tests were conducted at a significance level of $p < .05$.

3. Results

3.1. Preferred reporting items for systematic review and meta-analyses flowchart

The initial search found 2651 studies. After removing the duplicates, 1913 articles remained, of which 1531 were excluded due to not meeting the participant criteria. Of the remaining 380 articles, 364 articles were ineligible. Finally, 16 articles were selected for this review (see Fig. 1).

3.2. Study characteristics

A total of 6020 participants were included in this study. The sample size ranges from 40 to 3036 (see Table 2). The mean age of participants was 11.58 years old (SD = 2.87), and the average number of females included in each study was 50.91 %. There were four RCTs,[51–54] two cluster RCTs,[55,56] five quasi-experimental,[57–61] and five two-group experiments.[62–66] In addition, 12 different PA self-efficacy scales were employed in selected studies, and the scale developed by Mok et al. (2015) was the most frequently utilized instrument, appearing in four studies.[51,62,63,66] See Table 3 for a summary of all included studies.

4. Frequencies of BCTs used in studies

BCTs developed by Michie et al. (2015) include 16 clusters.[67] The clusters presented in this review are goals and planning, feedback and monitoring, social support, shaping knowledge, natural consequences, comparison of behavior, associations, reward and threat, and antecedents. In total, 20 BCTs were used in selected studies. The most used BCT is "Instruction on how to perform the behavior," applied in 68.75 % of the studies. Other frequently utilized techniques include "Goal setting (behavior)," "Social support (unspecified)," and "Adding objects to the environment," applied in over 50 % of studies. See Table 4 for the frequency of BCTs included in the intervention studies and see Appendix 1 for details.

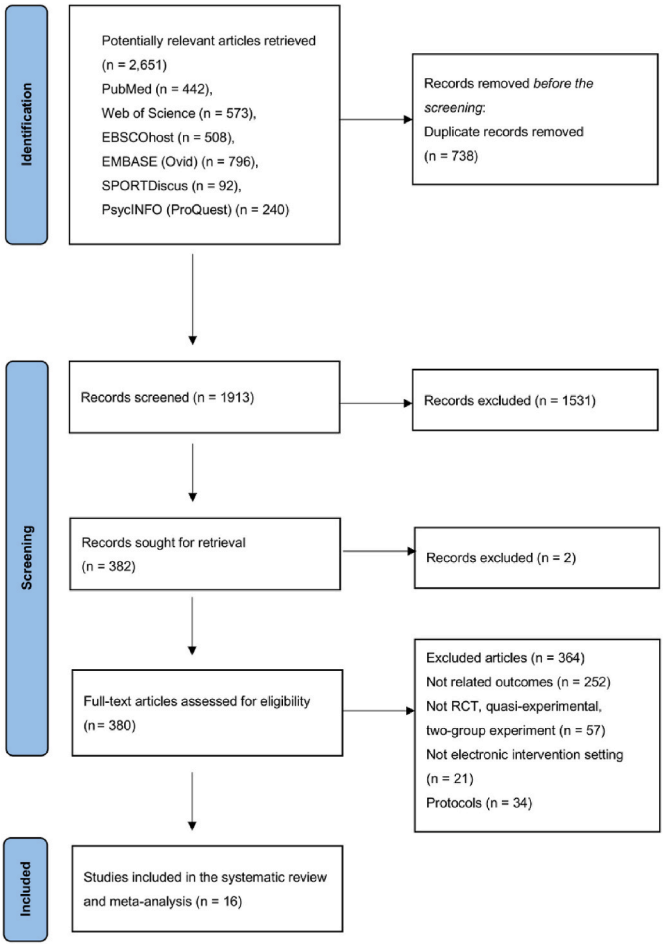

Fig. 1. Flow diagram of each stage of the study selection.

Table 2
Summary of the study characteristics.

Study characteristics	Frequencies
Participants numbers	
Mean number	376
Sum of number	6020
Range of number	51–3036
Number of studies	16
Participant characteristics	
Mean age	11.58 ± 2.87 years
Mean age range	8.24–17.28 years
Mean percentage of females	50.91 %
Intervention duration	
Mean duration	16 weeks
Range of duration	0.1–48 weeks
Study design	
RCT	4
Cluster-RCT	2
Quasi-experimental	5
Two-group experiment	5

4.1. Methodological quality

The methodological quality of the included studies was assessed using the PEDro Scale and presented in Table 5. It consists of 11 items that evaluate various aspects of study quality, including randomization, blinding, and statistical reporting. Each criterion the study meets receives a score of 1, while criteria not met are scored 0. The first criterion relates to external validity and is not included in the total score; thus, the maximum achievable score is 10.

The study by Direito et al. (2015) and Spook et al. (2016) indicated excellent methodology quality. Eight studies showed high-quality.[51,52,54,55,59,60,62,63] These studies generally succeeded in meeting criteria related to random allocation, baseline comparability, and providing point estimates and variability. Conversely, the studies with the lowest scores which indicated moderate quality[57,61,64–66,68] failed to meet several key criteria, such as concealed allocation, blinding of subjects, therapists and assessors, and intention to treat analysis. Overall, 62.5 % of studies were categorized as high in methodological quality.

4.2. Meta-analysis

A total of 18 experimental groups with Direito et al. (2015) and Staiano et al. (2013) had two eHealth intervention groups compared with the control group, reported changes in PA self-efficacy. eHealth interventions (*Hedges' g* = 0.315; 95 % CI = 0.069, 0.562) with high heterogeneity (I^2 = 92.34 %, p < .01) moderated PA self-efficacy. See Table 6 for the meta-analytic result of the effects on PA self-efficacy, and Fig. 2 for a forest plot of all included studies. This indicates that eHealth interventions are positively associated with enhanced children's PA self-efficacy, while the high heterogeneity warrants cautious interpretation.

4.3. BCTs associated with changes in PA self-efficacy

13 out of 20 BCTs were analyzed, other BCTs were used in less than 3 articles and could not conduct valid analysis. "*Instruction on how to perform the behavior*" showed a significant association with PA self-efficacy with moderate effect (*Hedges's g* = 0.436, *p* = .003), and showed considerable effectiveness compared to studies not including this BCT. Additionally, "*Demonstration of the behavior*" was found to have a significant association with PA self-efficacy, also showing a moderate effect size (*Hedges's g* = 0.527, *p* = .036), however no superior effect than studies not including this BCT. Specifically, studies that adopted *social* support *(unspecified)* and *prompt/cues* were significantly less effective than studies that did not use these BCTs (*Hedges's g* = 0.645, *p* = .001; *Hedges's g* = 0.475, *p* = .001). See Table 7 for the details.

BCT 1.1 and 12.5 had a small, non-significant effect on PA self-efficacy. The remaining BCTs (1.4, 2.1, 2.2, 2.3, 2.4, 5.1, 12.1) showed no significant association with increased PA self-efficacy; however, studies not including these BCTs had a significant effect on PA self-efficacy. See Table 7 for the details.

4.4. Sensitivity analysis

When the sensitivity analysis was carried out by excluding the studies one by one, the heterogeneity still remained high. After removing the five articles with the highest bias,[33,36,41,44,45] the heterogeneity was reduced to I^2 = 34.84 %, while the heterogeneity of RCT studies was 0 and that of non-RCTs was 61.75 %. See details in Appendix 2.

5. Discussion

This systematic review and meta-analysis aimed to examine the effectiveness of eHealth interventions on PA self-efficacy. Notably, this study was a pioneer in employing the BCT taxonomy to explain the specific effects of eHealth interventions on children's PA self-efficacy. The findings indicated that eHealth interventions had a small yet statistically significant effect on children's PA self-efficacy improvement. Among the 13 BCTs analyzed, Instruction on how to perform the behavior and Demonstration of the behavior were significantly associated with increased PA self-efficacy. The remaining BCTs showed small to moderate effect sizes and were not significantly linked to changes in self-efficacy.

The high heterogeneity observed could be attributed to varied widely in participant numbers (ranging from 51 to 3036), intervention durations (ranging from 0.1 to 48 weeks), different study designs, and twelve PA self-efficacy scales used across the sixteen studies. These findings were strengthened by performing the sensitivity analysis.

6. eHealth interventions and PA self-efficacy

Pakarinen et al. (2017) initially explored the potential of eHealth interventions on children's PA self-efficacy and discovered eHealth active games can positively improve PA self-efficacy. This review further found a significant association between eHealth interventions and improvements in children's PA self-efficacy. Specifically, 62.5 % of studies in this review reported a significant enhancement in children's PA self-efficacy.[51,52,55,56,59,61–63,65,66] This result aligns with previous studies, highlighting the importance of eHealth in improving PA self-efficacy. A cross-sectional study noted that using eHealth for physical activities positively impacts self-efficacy.[69] Another survey indicated that self-efficacy mediates the relationship between eHealth use and healthy behaviors, eHealth can boost self-efficacy in turn.[70] A longitudinal study has also shown that digital interventions help improve self-efficacy by capturing experience, social persuasion, emotional and physical factors, providing cues and challenges for healthy behaviors.[71] Another longitudinal study pointed out that social support from family members has a stimulating effect on self-efficacy in using eHealth interventions.[72] However, these studies were all research on adults. This systematic review and meta-analysis systematically described the role of eHealth in promoting children's PA self-efficacy.

In this review, the results showed integrating face-to-face interactions with eHealth elements for children seems essential, as all the studies in this review were conducted in schools, homes, or clinics, except one study.[56] Interestingly, Brain Breaks Physical Activity Solutions (BBPAS), which adopted web-based structured PA breaks and short classroom videos, included the largest number of participants and countries, 3935 participants and 11 countries, and all six studies that adopted it showed a significant increase in PA self-efficacy.[51,59,61–63,66] Previous studies also highlighted the need to incorporate real-world settings into eHealth or mHealth interventions to promote health

Table 3
Study information including research participants, research design, sample size, intervention, and results.

Study and information	Study design	Intervention	Result (EG)
1. Mok et al. (2020) ● Croatia, Lithuania, Macedonia, Poland, Romania, Serbia, South Africa, and Turkey ● S: N = 3036 (Female: 50.7 %) ● HC ● Age: 8–11 years	● SD: RCT ● TF: Not mentioned ● Duration: 4 months ● Setting: School ● Delivered by: Teachers	● EG (N = 1914): BBPAS ● CG (N = 1122): Standard teaching and materials ● PA self-efficacy measurement: The Attitudes toward Physical Activity Scale (Mok et al., 2015) ● Data were collected before and after the intervention	● Self-efficacy in selecting video exercises (F = 366.258**, η^2 = 0.145) ● Interest in doing PA (F = 9.227**, η^2 = 0.003) ● Confidence in own fitness (ns) ● Perceived benefits of PA (F=53.175**, η^2 = 0.018) ● Orientation to personal best goals when engaging in PA (F = 25.539**, η^2 = 0.009) ● BMI (ns)
2. Kennedy et al. (2018) ● Australia ● S: N = 607 (Female: 50.1 %) ● HC ● Mean age: 14.1 ± 0.5 years	● SD: Cluster RCT ● TF: SCT, SDT ● Duration: 12 months ● Setting: Secondary schools ● Delivered by: Teachers	● EG (N = 353): Smartphone app ● CG (N = 254): Regular scheduled PE and curricular school sport ● PA self-efficacy measurement: The Behavioral Regulations in Exercise Questionnaire-2 (Markland & Tobin, 2004), Resistance training self-efficacy scale (Lubans et al., 2011) ● Data were collected at baseline, 6 months (post-program), and 12 months (follow-up)	● Self-efficacy for RT (6M: p = .002, 12M: p = .220) ● Muscular fitness Push-ups (6M: p = .001, 12M: p = .011) Standing long jump (6M: p = .397, 12M: p = .258) ● Weekday MVPA (6M: p = .953, 12M: p = .143) ● Autonomous motivation for PA (6M: p = .836, 12M: p = .043) ● Motivation for RT (6M: p = .184, 12M: p = .251) ● BMI z-score (6M: p = .061, 12M: p = .313)
3. Staiano et al. (2013) ● United States ● S: N = 54 (female: 55.6 %) ● BMI at or above the 75th percentile ● Age: 15–19 years	● SD: RCT ● TF: SCT ● Duration: 20 weeks ● Setting: The school-based wellness clinic ● Delivered by: Researchers	● Competitive exergame (N = 19): The Wii Active game (to compete against their opponent) ● Cooperative exergame (N = 19): The Wii Active game (to cooperate with their partner) ● CG (N = 16): Continued usual daily activities ● PA self-efficacy measurement: Exercise Confidence Survey (Sallis et al., 1988) ● Data were collected at baseline, 10 weeks, and 20 weeks	● PA self-efficacy cooperative group (p = .005) competitive group (p = .083) ● Peer support cooperative group (p = .010) competitive group (p = .001)
4. Direito et al. (2015) ● New Zealand ● S: N = 51 (female: 57 %) ● HC ● Age: 14–17 years	● SD: RCT ● TF: Not mentioned ● Duration: 8 weeks ● Setting: Home ● Delivered by: Researchers	● EG1 (N = 17): use of an immersive app (Zombies, Run) ● EG2 (N = 17): use of a nonimmersive app (Get Running) ● CG (N = 17): usual behavior ● PA self-efficacy measurement: Physical Activity Self-Efficacy Scale (Batholomew et al., 2006) ● Data were collected before and after the intervention	● PA self-efficacy EG1 (p = .99) EG2 (p = .96) ● Average daily time spent in MVPA (min) EG1 (p = .98) EG2 (p = .99) ● Average daily time spent in vigorous PA (min) EG1 (p = .90) EG2 (p = .99) ● Average daily time spent in moderate PA (min) EG1 (p = .98) EG2 (p = .96) ● Average daily time spent in light PA (min) EG1 (p = .91) EG2 (p = .99) ● Average daily time spent in sedentary activities (min) EG1 (p = .96) EG2 (p = .99)
5. Chen et al. (2011) ● United States ● S: N = 228 (female: 64.8 %) ● HC ● Mean age: 12.52 ± 3.15 years	● SD: RCT ● TF: SCT, the Transtheoretical Model–Stages of Change ● Duration: 8 months ● Setting: Community ● Delivered by: Researchers	● EG (N = 103): Web-based behavior program ● CG (N = 125): received general health information and not tailored ● PA self-efficacy measurement: Health Behavior Questionnaire (Edmundson et al., 1996; Matheson et al., 2004) ● Data were collected at baseline, 2 months, 6 months, and 8 months	● PA self-efficacy (p = .49) ● Physical activity knowledge (p = .008) ● Nutrition self-efficacy (p = .55) ● Nutrition knowledge (p = .001) ● BMI (p = .84)
6. Spook et al. (2016) ● Netherlands ● S: N = 231 (female: 62.8 %) ● HC ● Mean age: 17.28 ± 1.26 years	● SD: Cluster RCT ● TF: Self-regulation theory ● Duration: 4 weeks ● Setting: Online ● Delivered by: Researchers	● EG (N = 105): Balance It app ● CG (N = 126): No interventions were offered ● PA self-efficacy measurement: PA self-efficacy scale (Van der Horst et al., 2008) ● Data were collected before and after the intervention	● PA self-efficacy (R^2 = 0.02) ● Moderate PA (days) (R^2 = 0.00) ● Vigorous PA (days) (R^2 = 0.00) ● Active transport (days) (R^2 = 0.02)
7. Lee & Gao (2020) ● United States ● S: N = 157 (Female: 46.5 %) ● HC	● SD: Quasi-experimental ● TF: SCT ● Duration: 2 weeks ● Setting: Elementary schools	● EG (N = 77): Apps: Educreation, Coach's Eye, Scoreboard, GarageBand, Interval Timer and Stopwatch, Team Shake ● CG (N = 80): Traditional PE class	● SCT-related psychosocial beliefs Self-efficacy (p=.75) Outcome expectancy (p=.13) Social support (p=.94)

(*continued on next page*)

Table 3 (*continued*)

Study and information	Study design	Intervention	Result (EG)
● Age: 9–11 years	● Delivered by: Teachers	● PA self-efficacy measurement: A six-item self-efficacy on PA questionnaire (Gao et al., 2010) ● Data were collected before and after the intervention	Enjoyment (p=.43) ● Light PA (p<.001) ● MVPA (p=.004) ● Sedentary bahavior (p=.07)
8. Liang et al. (2020) ● Hong Kong ● S: N = 87 (Female: 37.9 %) ● HC ● Mean age: EG = 10.5 ± 0.7 years, CG = 10.4 ± 0.8 years	● SD: Quasi-experimental ● TF: Not mentioned ● Duration: 8 weeks ● Setting: Primary school ● Delivered by: Researchers	● EG (N = 30): Kinect® and Xbox 360® gaming console ● CG (N = 57): Continued with their usual activities ● PA self-efficacy measurement: PA self-efficacy questionnaire (Liang et al., 2014) ● Data were collected before and after the intervention	● Psychosocial variables (enjoyment, PA self-efficacy, and social support) (ns) ● Waking time PA and sedentary behavior MVPA (p=.12) MPA (p=.06) VPA (p=.86) LPA (p=.01) Sedentary time (p=.07) ● After-school time PA and sedentary behavior MVPA (p=.07) MPA (p=.08) VPA (p=.16) LPA (p<.01) Sedentary time (p=.01) ● Percentage body fat (p=.71) ● zBMI (p=.42)
9. Balasekaran et al. (2021) ● Singapore ● S: N = 113 (Female: 58.4 %) ● HC ● Mean age: EG: 9.71 ± 0.99 years, CG: 9.66 ± 0.94 years	● SD: Quasi-experimental ● TF: Not mentioned ● Duration: 10 weeks ● Setting: School ● Delivered by: Teachers	● EG (N = 48): BBPAS ● CG (N = 65): Continued their academic lessons without video intervention ● PA self-efficacy measurement: Attitudes toward Physical Activity Scale questionnaire (Motl et al., 2000) ● Data were collected before and after the intervention	● Self-efficacy in Learning with Video Exercises (p < .001) ● Self-efficacy in Selecting Video Exercises (p < .001) ● Importance of Exercise Habit (p=.001) ● Exercise Motivation and Enjoyment (p < .001) ● Self-confidence on Physical Fitness (p < .001) ● Trying to do Personal Best (p=.003)
10. Robbins et al. (2020) ● Hong Kong ● S: N = 84 (Female: 50.6 %) ● HC ● Mean age: EG = 11.3 ± 0.8 years, CG = 11.9 ± 0.8 years	● SD: Quasi-experimental ● TF: SDT ● Duration: 12 weeks ● Setting: School ● Delivered by: Researchers	● EG (N = 39): Private Facebook group ● CG (N = 45): Usual activities ● PA self-efficacy measurement: The 6-item Perceived PA Self-Efficacy Scale (Dishman et al., 2010) ● Data were collected before and after the intervention	● PA Self-efficacy (p = .58) ● Percent body fat (p = .68) ● PA Measured MVPA (p = .17) Social support (p = .10) Autonomous motivation (p = .01) Controlled motivation (p = .15) Amotivation (p = .35) ● Diet quality (ns) ● Healthy eating self-efficacy (p = .03) ● BMI (ns)
11. Rizal et al. (2019) ● Malaysia ● S: N = 322 (Female: 50.6 %) ● HC ● Mean age: 10.53 ± 0.5 years	● SD: Quasi-experimental ● TF: The transtheoretical model ● Duration: 12 weeks ● Setting: Schools ● Delivered by: Teachers	● EG (N = 177): BBPAS ● CG (N = 145): Not involved in the BBPAS intervention ● PA self-efficacy measurement: 18-item exercise self-efficacy scale (Kim, 2007) ● Data were collected before and after the intervention	● PA Self-efficacy Internal feelings (p = .031) Competing demand (p = .240) Situational (p = .748) ● PA behavior (p = .007)
12. Emeljanovas et al. (2018) ● Lithuania ● S: N = 181 (Female: 45.9 %) ● HC ● Mean age: 8.24 ± 1.10 years	● SD: Two-group experiment ● TF: Not mentioned ● Duration: 3 months ● Setting: Primary school ● Delivered by: Teachers	● EG (N = 93): BBPAS ● CG (N = 88): Continued their regularly scheduled physical education for 45 min twice weekly ● PA self-efficacy measurement: The attitude toward physical activity scale (Mok et al., 2015) ● Data were collected before and after the intervention	● PA Self-efficacy (p < .01) ● Fitness (p < .01) ● Personal Best (p < .01) ● Interest (p < .01) ● Importance (p < .01) ● Benefits (p < .01) ● Learning (p < .01) ● Health (p < .01)
13. Glapa et al. (2018) ● Poland ● S: N = 326 (Female: 47.9 %) ● HC ● Mean age: 9.7 ± 1.06 years	● SD: Two-group experiment ● TF: Not mentioned ● Duration: 4 consecutive months ● Setting: Schools ● Delivered by: Teachers	● EG (N = 264): BBPAS ● CG (N = 62): did not have breaks with Brain Brakes videos ● PA self-efficacy measurement: The attitude toward physical activity scale (Mok et al., 2015) ● Data were collected before and after the intervention	● Self-efficacy on learning with video exercises (p < .01) ● Promoting the holistic health (p = .09) ● Importance of exercise habit (p = .49) ● Exercise motivation and enjoyment (p = .22) ● Self-confidence on physical fitness (p = .67) ● Trying to do personal best (p = .13)
14. Gao et al. (2019) ● United States ● S: N = 81(Female: 48.1 %)	● SD: Two-group experiment ● TF: SCT ● Duration:9 months	● EG (N = 36): Kinect® and Xbox 360® gaming console ● CG (N = 45): Continued their regular recess activities	● Self-efficacy (p=.90) ● METs (p < .01) ● Kilocalories per day (p < .01)

(*continued on next page*)

Table 3 (*continued*)

Study and information	Study design	Intervention	Result (EG)
● HC ● Mean age: EG: 9.42 ± 0.77 years, CG: 9.09 ± 0.42 years	● Setting: Elementary schools ● Delivered by: Teachers	● PA self-efficacy measurement: A six question survey assessed children's self-efficacy (Sallis et al., 1999) ● Data were collected at baseline and at the 4th and 9th months	● Outcome expectancy ($p < .05$) ● Social support ($p = .08$)
15. Wang et al. (2017) ● Hong Kong ● S: N = 179 (42.5 %) ● HC ● Mean age: 10.2 years	● SD: Two-group experiment ● TF: SCT, SDT, Elaboration likelihood models ● Duration: 8–10 weeks ● Setting: Primary schools ● Delivered by: Researchers	● EG (N = 95): Escape from Diab (exergame) ● CG (N = 84): Adopted general diet and PA information and behaviours as usual ● PA self-efficacy measurement: PA self-efficacy scale (Jago et al., 2009) ● Data were collected at baseline, about 8–10 weeks after baseline (post 1), and 8–10 weeks after the game (post 2)	● Self-efficacy for PA ($p < .01$) ● Self-reported PA ($p < .05$) ● Objective PA ($p > .05$) ● PA motivation ($p = .04$) ● PA preference ($p < .05$) ● Intrinsic motivation for FVW ($p < .05$) ● Self-efficacy for FVW ($p < .05$) ● FVW preference ($p < .05$)
16. Popeska et al. (2018) ● The Republic of Macedonia ● S: N = 283 (Female: 45.2 %) ● HC ● Mean age: EG = 9.18 ± 1.13 years, CG = 9.24 ± 0.82 years	● SD: Two-group experiment ● TF: Not mentioned ● Duration: 3 months ● Setting: School ● Delivered by: Teachers	● EG (N = 152): BBPAS ● CG (N = 131): With no intervention ● PA self-efficacy measurement: Attitudes toward Physical Activity Scale (Mok et al., 2015) ● Data were collected before and after the intervention	● Self-efficacy in learning with video exercises ($p = .009$) ● Self-confidence on physical fitness ($p = .000$) ● Exercise motivation and enjoyment ($p = .002$) ● Importance of exercise habit for health ($p = .003$) ● Training for personal best and motivating others ($p = .001$) ● Promoting holistic health ($p = .041$) ● Knowledge and self-awareness for individual ($p = .102$)

Note. S = sample; TF = theoretical foundation; SD = study design; EG = experiment group; CG = control group; RCT = randomized controlled trial; PA = physical activity; PE = physical education; HC = healthy children; ES = effect size; SCT = social cognitive theory; SDT = self-determination theory; FVW = motivation for fruit, vegetables, and water; AVG = active video games; BBPAS = Brain Breaks Physical Activity Solutions; RT = resistance training; BMI = body mass index; CBT = cognitive and behavioral treatment; Intent to treat: ITT; Without outlier: WO; LPA = light physical activity; MVPA = moderate to vigorous physical activity; VPA = vigorous physical activity; ns = not significant at 0.05; MET = metabolic equivalent task; PAS = perceived autonomy support; PCS = perceived competence support; PRS = Perceived relatedness support.

Table 4
Frequencies of BCTs used in studies.

Behavior Change Techniques	PA Self-efficacy (k = 16)	
	N	%
1. Goals and planning		
1.1 Goal setting (behaviour)	9	55.25 %
1.2 Problem solving	1	6.25 %
1.3 Goal setting (outcome)	1	6.25 %
1.4 Action planning	5	31.25 %
2. Feedback and monitoring		
2.1 Monitoring of behaviour by others without feedback	4	25 %
2.2 Feedback on behavior	6	37.5 %
2.3 Self-monitoring of behaviour	4	25 %
2.4 Self-monitoring of outcome(s) of behavior	1	6.25 %
2.7 Feedback on outcome(s) of behaviour	3	18.75 %
3. Social support		
3.1 Social support (unspecifed)	10	62.5 %
4. Shaping knowledge		
4.1 Instruction on how to perform the behaviour	11	68.75 %
5. Natural consequences		
5.1 Information about health consequences	3	18.75 %
6. Comparison of behaviour		
6.1 Demonstration of the behaviour	5	31.25 %
7. Associations		
7.1 Prompts/cues	6	37.5 %
8. Repetition and substitution		
8.1 Behavioural practice/rehearsal	2	12.5 %
8.7 Graded tasks	2	12.5 %
10. Reward and threat		
10.3 Non-specific reward	1	6.25 %
10.8 Incentive (outcome)	1	6.25 %
12. Antecedents		
12.1 Restructuring the physical environment	5	31.25 %
12.5 Adding objects to the environment	8	50 %

behaviors in children.[73] Individual (e.g., feedback, goal-setting, reward) and social interaction (e.g., social sharing, competition) are the two kinds of support for eHealth interventions that affect self-efficacy.[74,75] Feedback and other ways can help individuals understand the progress of physical activities, enhance the awareness of their own abilities, and promote self-efficacy.[76,77] For social interaction, peer encouragement positively influences children's self-efficacy and physical performance.[78] Children who received peer encouragement regularly reported higher self-efficacy and performed better in physical tasks compared to those who did not receive encouragement.[78] Interestingly, peer support and self-efficacy can interact to predict PA.[79] Children who perceive strong social support are more likely to overcome barriers to PA.[80]

Furthermore, the mobile application (Balance It) used by Spook et al. (2016) also demonstrated significant improvements in children's PA self-efficacy.[56] The design utilized various motivational strategies such as goal setting, feedback, and reinforcement through virtual rewards which likely contributed to its success. This aligns with findings from Schwarz et al. (2023) and Johnson et al. (2022), which highlighted that mobile app features such as rewards, social interaction, personalized challenges, self-monitoring, and customization options can enhance user engagement.[42,81] With the increasing frequency of smartphone usage among children,[82] it is important to transform smartphones into positive intervention tools. Future research could focus on integrating real-world settings with effective mobile health interventions to maximize the effectiveness of interventions.

7. BCTs and PA self-efficacy

The effectiveness of BCTs in increasing PA self-efficacy in adults and obese individuals in both digital and non-digital interventions is documented in many studies.[83–86] However, no previous review has systematically and quantitatively examined effective BCTs specifically in eHealth interventions for promoting PA self-efficacy in children.

In this review, two BCTs were significantly associated with

Table 5
PEDro score.

Author	Criteria											Total
	1	2	3	4	5	6	7	8	9	10	11	score (10)
Wang et al. (2017)	1	0	0	1	0	0	0	1	0	1	1	4
Robbins et al. (2020)	1	1	1	1	0	0	0	1	1	1	1	7
Rizal et al. (2019)	1	0	0	1	0	0	0	1	0	1	1	4
Popeska et al. (2018)	0	0	0	1	0	0	0	1	0	1	1	4
Kennedy et al. (2018)	1	1	1	1	0	0	0	1	1	1	1	7
Lee & Gao, (2020)	1	0	0	1	0	0	0	1	0	1	1	4
Liang et al. (2020)	1	0	0	1	0	0	0	1	0	1	1	4
Mok et al. (2020)	0	1	1	1	0	0	0	1	0	1	1	6
Emeljanovas et al. (2018)	0	0	0	0	0	1	1	1	1	1	1	6
Glapa et al. (2018)	0	1	0	1	0	0	0	1	0	1	1	5
Gao et al. (2019)	1	0	0	0	0	0	0	1	0	1	1	3
Balasekaran et al. (2021)	1	1	0	1	0	0	0	1	0	1	1	5
Staiano et al. (2013)	1	1	0	1	0	0	0	1	1	1	1	7
Direito et al. (2015)	1	1	1	1	0	0	0	1	1	1	1	8
Spook et al. (2016)	1	1	1	1	0	0	0	1	1	1	1	8
Chen et al. (2011)	1	1	0	1	0	0	0	1	1	1	1	7

Item score: 1 = meets criteria, 0 = does not meet criteria; Criteria: 1 = Eligibility criteria, 2 = Random allocation, 3 = Concealed allocation, 4 = Baseline comparability, 5 = Blind subjects, 6 = Blind therapists, 7 = Blind assessors, 8 = Adequate follow-up, 9 = Intention to Treat Analysis, 10 = Between-group comparisons, 11 = Point estimates and variability; NR = Not Reported.

Table 6
Meta-analytic results of the effects of eHealth interventions on PA self-efficacy.

Outcome	Number of studies	Meta-analytic effect size			Heterogeneity		
		Hedges's g	95%CI	p value	I^2%	Q	p value
PA self-efficacy	18	0.315	[0.069, 0.562]	0.012	92.34	221.98	<0.001

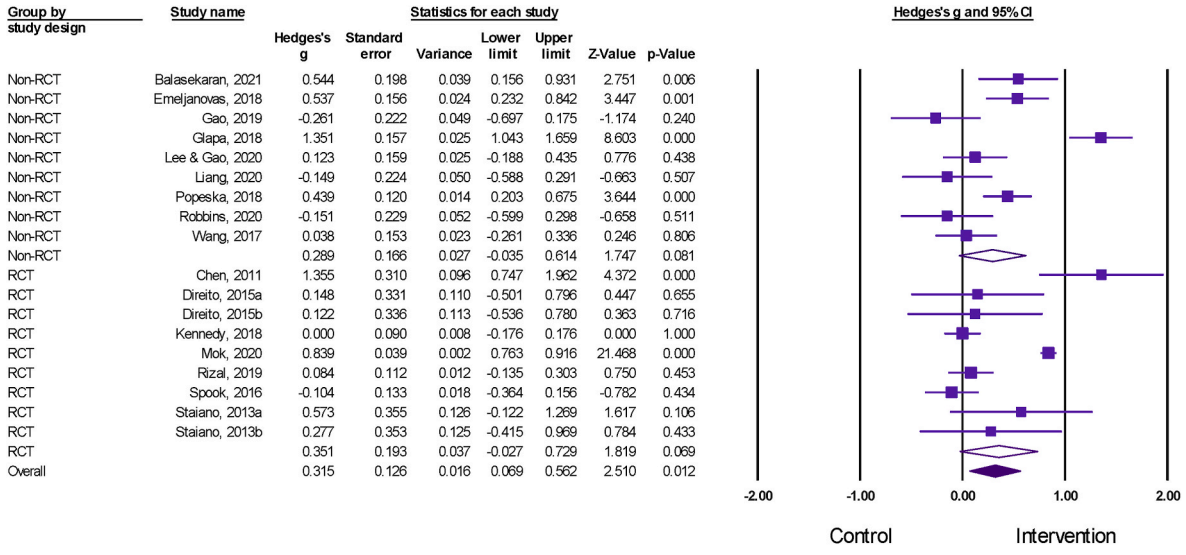

Fig. 2. Forest plot showing PA self-efficacy effect sizes with 95 % CI.

improvements in PA self-efficacy, *Instruction on how to perform the behavior* and *Demonstration of the behavior*. When referring to exercise, Michie et al. (2015) code these two and behavioral practice/rehearsal as a series. These two are also the most used in other studies of BCTs on health behavior change among children.[87–89] This prevalence may be due to children's developing cognitive skills,[90] necessitating clear instructions and demonstrations to help form healthy behaviors.[91] Demonstrations by teachers or in eHealth tools can aid skill acquisition,[92] and serve as persuasive cues for PA opportunities.[93]

Aside from *instructions on behavior*, *goal setting (behavior)* and *social* support *(unspecified)* were most frequently used. Prior review reported on eHealth-based interventions identified *goal setting* as an effective technique to promote health behavior change.[86,94] To boost self-efficacy, goal-setting theories suggest that specific and challenging goals lead to better performance than vague objectives,[95] and specific goal setting is crucial for turning intentions into actions.[32]

In the social support cluster, 10 studies adopted *social* support *(unspecified)*. However, the studies that did not include this BCT showed significant results, which is inconsistent with the findings of previous studies.[96,97] It is commonly believed that social support from parents could be a positive mediator that impacts children's PA self-efficacy. However, the impact is complex for adolescents in puberty, who want to escape the restrictions set by their parents but also crave their help when they encounter difficulties.[97] In this review, children aged 11.58

Table 7
Comparison between PA self-efficacy, according to whether specific techniques are included in the eHealth intervention or not.

BCT	BCT included					BCT not included					Test of moderators	
	k	g	Lower 95 % CI	Upper 95 % CI	Test of null (*p*-value)	k	g	Lower 95 % CI	Upper 95 % CI	Test of null (p-value)	Q_M *P*-value	
1. Goals and planning												
1.1 Goal setting (behavior)	11	0.309	−0.014	0.632	0.060	7	0.328	−0.073	0.728	0.109	0.944	
1.4 Action planning	5	0.175	−0.484	0.835	0.602	13	0.367	0.102	0.633	0.007*	0.597	
2. Feedback and monitoring												
2.1 Monitoring of behaviour by others without feedback	4	0.435	−0.210	1.079	0.186	14	0.279	0.004	0.554	0.047*	0.663	
2.2 Feedback on behavior	7	0.224	−0.171	0.619	0.267	11	0.380	0.053	0.708	0.023*	0.549	
2.3 Self-monitoring of behaviour	5	0.259	−0.186	0.705	0.254	13	0.335	0.064	0.607	0.016*	0.776	
2.4Feedback on outcome(s) of behaviour	3	0.667	−0.033	1.367	0.062	15	0.248	0.034	0.461	0.023*	0.262	
3. Social support												
3.1 Social support (unspecified)	12	0.082	−0.088	0.252	0.344	6	0.645	0.358	0.931	0.000**	0.001*	
4. Shaping knowledge												
4.1 Instruction on how to perform the behavior	12	0.436	0.145	0.728	0.003*	6	0.036	−0.123	0.195	0.656	0.018*	
5. Natural consequences												
5.1 Information about health consequences	3	0.232	−0.071	0.535	0.133	15	0.336	0.058	0.613	0.018*	0.622	
6. Comparison of behavior												
6.1 Demonstration of the behavior	5	0.527	0.035	1.019	0.036*	13	0.207	0.020	0.394	0.030*	0.234	
7. Associations												
7.1 Prompts/cues	6	0.043	−0.165	0.250	0.688	12	0.475	0.196	0.755	0.001**	0.015*	
12. Antecedents												
12.1 Restructuring the physical environment	5	0.043	−0.205	0.290	0.736	13	0.397	0.118	0.675	0.005*	0.063	
12.5 Adding objects to the environment	9	0.389	−0.013	0.790	0.058	9	0.253	−0.084	0.589	0.142	0.611	

± 2.87 years, maybe in puberty or pre-puberty,[98] could be why *social* support *(unspecified)* is not significantly related to PA self-efficacy. Another study also pointed out that perceived parental control is negatively related to self-efficacy beliefs and enjoyment of PA among adolescents.[99] Cheng et al. (2020) suggested that parental co-participation, transport, or positive comments can improve adolescents' self-efficacy.[100] This requires that the design of social support should consider the differences in physical and mental changes across different age ranges of children.

Compared with BCTs adopted in promoting adults' PA self-efficacy, most BCTs for children require the involvement of others to guide and support children's PA behaviors. However, BCTs for adults require relatively high individual ability, and stimulating adult behaviors also needs to be approached from multiple dimensions, such as through self-monitoring behaviors, graded tasks, and social incentives.[84,86] Considering the differences in cognition, behavior and understanding ability, BCT selection for children may require more direct rewards and clear guidance, which also emphasizes the need to pay attention to age-appropriate BCT selection. In addition, Michie et al. (2009) cautioned that combinations of large numbers of techniques could dilute the impact of the most effective ones and compromise delivery fidelity.[101] Therefore, BCTs should be selected carefully, considering the determinants and each BCT's effectiveness.[102]

8. Strengths and limitations

This systematic review pioneers a thorough examination of the effects of eHealth interventions on children's PA self-efficacy, analyzing the employed BCTs and identifying the most effective components. Strengths include a rigorous search strategy, involvement of at least three independent researchers at critical stages, and the high methodological quality of the included studies (62.5 % high-quality).

The limitations include the limited number of articles and the high heterogeneity. The small number of studies in the meta-analysis reduces its power, and some studies lacked sufficient intervention descriptions, making it difficult to identify the BCTs used. Furthermore, the considerable heterogeneity may be due to varied widely in their participant numbers and intervention durations, as well as diverse PA self-efficacy measurement tools used across studies. Future research should design more rigorous studies and adopt standardized measures of PA self-efficacy to enhance comparability and reliability, improving understanding of eHealth interventions' impact on children's PA self-efficacy.

9. Conclusion

This systematic review and meta-analysis investigated the effect of eHealth intervention and specific BCTs on enhancing PA self-efficacy in children. The findings show there is small but significant eHealth intervention effects were found for postintervention PA self-efficacy. Instruction on performing the behavior and behavior demonstration were significantly associated with the improvement of children's PA self-efficacy. Given the limited number of studies and insufficient intervention descriptions in some studies, these findings need to be interpreted with caution. Overall, this review is the pioneer to focus on BCTs in eHealth interventions for children. The insights gained provide valuable knowledge about tailored BCTs incorporated into eHealth interventions designed for children.

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Declaration of competing interest

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Appendix A. Supplementary data

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