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Effectiveness of parent-based electronic health (*eHealth*) intervention on physical activity, dietary behaviors, and sleep in preschoolers: A systematic review

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ABSTRACT

Background: The lifestyles of preschoolers have become physically inactive and sedentary, their eating habits unhealthy, and their sleep routines increasingly disturbed. Parental involvement appears crucial to combat the unhealthy lifestyle of preschoolers. Because of the recognized barriers to traditional face-to-face interventions, easy access and lower costs make electronic health (eHealth) interventions appealing. However, whether parent-based eHealth intervention may be harnessed to improve the aforementioned lifestyle behaviors of preschoolers is currently unclear, a gap that this systematic review intends to address. This study aims to systematically review the current literature concerning the effectiveness of parent-based eHealth intervention on the physical activity, dietary behaviors, and sleep of preschoolers.

Method: This systematic review conforms to the Preferred Reporting Items for Systematic Reviews and Meta-analysis statement. Six databases (EMBASE, PubMed, MEDLINE, Web of Science, SPORTDiscus, and PsycINFO) were retrieved for the period from January 2000 to December 2022. Studies were eligible if 1 they were quantitative study design; 2 eHealth interventions in which parents were the change agents targeted children aged 3–6 years; 3 interventions examined the effectiveness of eHealth or incorporated eHealth as one of the intervention modalities; 4 at least one variable included in either primary or secondary outcome had to concentrate on the physical activity, diet, and sleep of preschoolers; 5 publication type was limited to the English language and peer-reviewed journal articles; 6 study settings were confined to family- or parent-based ones. The risk of bias was assessed, based upon Version 2 of the Cochrane risk-of-tool for randomized trials (RoB2).

Results: Twelve studies were screened. No significant group-by-time improvement in physical activity was found in studies related to physical activity outcomes. Two studies reported a significant difference between groups concerning motor ability, with one study indicating improved object control with the other reporting improvement in both object control and locomotor skills. Of the studies related to dietary behavior outcomes, six studies reported a significant difference at the posttest compared to the control group, in terms of vegetable and fruit intake, sugar-sweetened drinks, reduced candy consumption, and improved non-core food. Three studies reported a significant difference between groups in sleep duration at the end of the posttest, with the result of one study limited to preference-only participants. None of the reviewed studies found a significant difference between groups for sleep problems.

Conclusion: Parent-based eHealth interventions were not significantly effective in improving physical activity and reducing sleep problems in preschoolers, but the majority of studies have found that this type of intervention significantly improves the dietary behaviors and sleep duration of preschoolers. High-quality, robustly designed studies to balance the intervention dosage and sequence are needed to investigate the effectiveness of parent-based eHealth intervention on physical activity, dietary behaviors, and sleep in preschoolers, particularly those raised in other cultural background, which may significantly impact their lifestyle.

Trial registration: International Prospective Register of Systematic Review (PROSPERO): CRD42023418861.

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1. Introduction

The relationship between health and lifestyle has been highly considered, as 60 % of the factors associated with personal health and quality of life are estimated to be related to lifestyle.[1] The critical lifestyle dimensions of physical activity (PA), dietary behaviors (DB), and sleep have been crucial in reducing cardiovascular diseases,[2] promoting brain growth,[3] enhancing central nerve system,[4] preventing mental disorder,[5] and improving social interaction.[6] These three dimensions have been found to be interrelated. PA confers substantial benefits in not only reducing high-calorie consumption[7] but also improving sleep patterns and increasing sleep duration.[8] A healthy DB provides the energy needed to keep active throughout the day and the nutrients for growth and repair,[9] while a well-balanced DB was associated with decreased sleep-onset latency and slow-wave sleep.[10] Longer sleep duration was conducive to more engagement in PA[11] and less frequent intake of fast-food and sugar-sweetened beverages.[12] However, people's lifestyles have become physically inactive and sedentary, their eating habits unhealthy, and their sleep routines increasingly disturbed, contributing to the prevalence of non-communicable diseases (e.g., diabetes and obesity).[2] Behaviors acquired in the course of life resist change; therefore, improving an unhealthy lifestyle (e.g., physical inactivity, unhealthy eating patterns, and sleep problems) should begin as early in life as possible.[13]

In the early years of life, children are socialized primarily in the family environment with parents serving as 'gatekeepers' at home.[14] Parents are more likely to exert influences on children's PA, DB, and sleep through regulations and recommendations, while young children are still developing their autonomy and relying on parental supervision.[15] As such, previous studies have been proposed to combat young children's unhealthy lifestyle in the context of family and parental participation,[16–18] including home visits, in-person educational talk, and group meetings in communities or schools. Nevertheless, barriers to traditional face-to-face interventions are recognized, such as time commitment,[19] high travel burden,[20] limited parental work schedule flexibility,[21] and limited ability to be implemented,[22] all of which may further prevent parental engagement and potential successful interventions.

Alternative methods of delivery that allow flexible engagement, such as electronic health (eHealth) interventions, have the potential to overcome the aforementioned barriers and increase adoption and adherence to parent-based interventions.[23] eHealth, which is defined as the cost-effective and secure use of information and communications technologies in support of health and health-related fields, including healthcare services, health surveillance, health literature, and health education, knowledge and research,[24] provides wide-reaching support at low cost while retaining the capacity to offer comprehensive and tailored information necessary for promoting healthy behaviors.[25]

Hammersley, Jones, and Okely[26] systematically reviewed the effectiveness of the parent-based eHealth intervention on obesity prevention among children and adolescents. It is highlighted that parents as an agent of change in eHealth intervention may be a promising format in preventing children's obesity and improving children's PA, diet, sedentary behaviors, and screen time. A closer scrutiny of this review, however, revealed that 1 results were confined to children (aged from 5 to 15 years); 2 the 'sleep' variable was not examined; 3 this review did not include studies published from 2015 to 2022 when eHealth interventions are likely to increase substantially due to the rapid development of networks and mobile devices. Whether the parent-based eHealth intervention benefits preschoolers' PA, DB, and sleep remains unclear. Therefore, the objective of this review is to assess whether parent-based eHealth intervention improved PA, DB, and sleep in preschoolers (aged from 3 to 6 years). This review intends to answer the following research question: Does parent-based eHealth intervention significantly improve the PA, DB, and sleep of preschoolers?

2. Method

A systematic review was conducted to comprehensively synthesize the available research regarding the effectiveness of the parent-based eHealth intervention on preschoolers' PA, DB, and sleep. This systematic review, registered in the PROSPERO (registration ID: CRD42023418861), was reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA).[27]

2.1. Eligibility criteria

Eligibility criteria are shown as follows. 1 Study design: one-group pretest and posttest, two-group experiment, quasi-experiment, and RCT were included. 2 Participant: eHealth intervention targeting children aged 3–6 years, in which parents were agents of change, was considered. 3 Intervention: interventions that examine the effectiveness of eHealth (e.g., electronic health or mobile health) or that incorporated eHealth as one of the intervention modalities were included. 4 Outcome: at least one variable included in either primary or secondary outcome should be concentrated on the PA, diet, and sleep of preschoolers. Because motor abilities are the critical foundation for PA, outcomes related to motor ability are included as well. 5 Publication type was limited to the English language and peer-reviewed journal articles. 6 Publication time was confined from January 2000 to December 2022. 7 Study settings were confined only to family- or parent-based settings.

2.2. Exclusion criteria

The articles were excluded if (1) they were integrated interventions that combined communities and parents, or schools and parents; (2) they were other types of publications (such as conference abstracts, study protocols, dissertations, books, magazines, and editorial documents); (3) children were diagnosed as unhealthy (i.e., physical, mental, cognitive, and social disorder, and presence of diseases).

2.3. Search strategy

The databases of Web of Science, MEDLINE, EMBASE, SPORTDiscus, PubMed, and PsycINFO were searched using terms in both title and abstract:

(i) "Electronic health" OR eHealth OR e-health OR "mobile health" OR mHealth OR m-health OR web* OR online* OR internet* OR phone OR application OR APP OR 'social media' OR 'social network' OR email OR technology OR eLearning OR e-learning OR digital
(ii) Famil* OR parent* OR carer* OR guardian*.
(iii) Preschool* OR kindergarten OR "young children" OR child* OR youth OR "early childhood".
(iv) "Physical activity" OR activ* OR diet* OR eating* OR nutrition OR sleep.

2.4. Study selection

The potential articles were uploaded to Endnote 20.1 (Hong Kong Baptist Univ, BID 17060). The authors independently screened the titles and abstracts after removing the duplicates, . The reasons for exclusion were recorded, and disagreements were discussed with other co-authors.

2.5. Data extraction

The principal and co-authors extracted the data containing the details of the author, publication time, location, sample size, theoretical foundation, study design, intervention details, control group information, and results.

2.6. Methodological quality

Individual RCT and cluster RCT test versions involved in the Version 2 of the Cochrane risk-of-tool for randomized trials (RoB2) were used to evaluate bias risk. The RoB2 (individual RCT) consists of five domains to assess the risk of bias: (1) randomization process, (2) deviations from intended interventions, (3) missing outcome data, (4) outcome measurement, (5) and selection of the reported result. One more domain, namely 'Timing of identification or recruitment of participants,' was included in the RoB2 (cluster RCT). Each domain included a series of questions aimed at eliciting information about features of the study relevant to the risk of bias. The questions included in each domain should be answered according to response options (i.e., 'yes,' 'probably yes,' 'probably no,' 'no,' and 'no information') by finding relevant information in the study being assessed. Then each domain is judged as either 'low risk,' 'some concerns,' or 'high risk,' based on the answers to the questions, which further results in a proposed overall risk judgment for the specific study being examined. The risk of bias was assessed using the Excel tool of individual and cluster RoB2, which can automatically generate the judgement of each domain and overall quality, based on answers to the questions. The two Excel tools and guidance on what questions mean and how to respond can be found in RoB2 website. (https://sites.google.com/site/riskofbiastool/welcome/rob-2-0-tool?authuser = 0&pli = 1)

3. Results

3.1. Study selection

The initial retrieve based on the title and abstract found 9,415 studies. After removing the duplicates, 7,040 studies remained, of which 4,941 studies were excluded due to not meeting the criteria. Of the remaining 2,099 studies, 2,082 were ineligible. Finally, 17 studies were identified for this systematic review (see Fig. 1)

3.2. Characteristics of the studies

Of the eligible 17 studies, eight can be categorized as three studies, namely 'MINISTOP,' 'EMPOWER,' and 'Healthy Habits' because the pilot study, main study, and follow-up study were published separately. As such, 12 studies were categorized and described based on the intervention name (see Table 1). These studies were conducted in the USA (study #2, #3, #5, #6, #7, and #12), Australia (study #1, #8, #10, and #11), New Zealand (study #9), and Sweden (study #4). Out of the 12 studies, 10 were published after 2015 (study #3 to #12). Of the 12 studies, 10 were RCT (study #1, #2, #3, #4, #5, #7, #8, #9, #10, and #12), one was a quasi-experiment (study #6), and another was a partially randomized preference trial (study #11, which allowed participants to select their intervention of preference first and then RCT). Intervention durations ranged from 4 weeks to 6 months, with three studies being ≤6 weeks (study #1, #3, and #9), six studies being 8 weeks–12 weeks (intervention #6, #7, #8, #11, #10, and #12), and three studies being 6 months (intervention #2, #4, and #5). Half of the studies (6/12) conducted follow-up to assess the maintenance of changes, with follow-up duration ranging from 3 months to 2 years (interventions #1, #3, #4, #8, #9, and #12).

3.3. The description of interventions

While 10 studies were developed based on the theoretical foundations, two were not (study #2 and #10). Of the studies with theory, seven were grounded upon social cognitive theory (SCT, study #3, #4, #5, #7, #8, #11, and #12), and socioecological theory underpinned the remaining (study #1), Connecting Activities, Routines, and Environments (C.A.R.E) Framework (study #9), and Actor-Partner Interdependence Model (APIM, study #6).

Six studies were delivered using the eHealth as sole mode, with one study using websites (study #3), three using software applications (study #4, #10, and #12), and two combining text messages, emails, website, and social media (study #5 and #7). The other six used eHealth in the combination of printed materials (study #1, #8, and #11), home visits (study #2), and face-to-face workshops (study #6 and #9).

Intervention deliveries can be categorized into two aspects. For one, participants were accessible to the intervention contents during the intervention program, without mentioning the frequency of delivery and the restrictions on intervention exposure (study #7, #9, and #10). For another, participants were provided the intervention contents regularly, with delivery frequency ranging from every week (study #1 #2, #3, #5, #6, and #12) to every two weeks (study #4, #8, and #11).

Interactive components, including evidence-based information, push

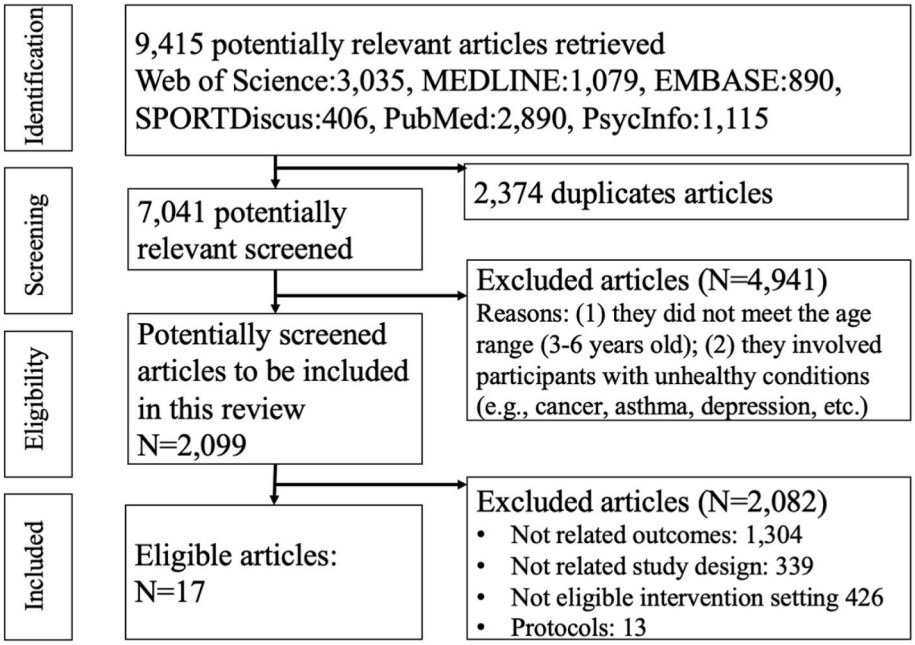

Fig. 1. Preferred reporting Items for systematic review and meta-analysis.

Table 1
Basic information of screened studies.

Study information	Intervention group	Control group	Outcomes and measurements (Preschoolers' PA, DB, and sleep related)	Results (Preschoolers' PA, DB and sleep related)
1. Intervention name: *'Healthy Habits'* • Medium: telephone calls & printed materials A. Pilot study:[28] • Australia • Pre-post study design without control group • Age: 3-5-year-old children • Sample size: 34 parent-child dyads • Duration: 4 weeks • Theory: Socioecological theory	N = 34 **Intervention content** • Availability and accessibility of foods within the home; role modelling of fruit and vegetable consumption; supportive family eating routines; summary of previously delivered three modules **Intervention delivery (every week)** • Each module lasted for 30 min, with components delivered following recommendations for child's DB, ways to improve child's DB, goal setting, review of goals.	Nil	• DB (i.e., dietary patterns, and fruit and vegetable intake) ◇ Measurement: parent-reported children's dietary questionnaire • Feasibility and acceptability ◇ Measurement: proportion of participants completing phone calls.	Data for pilot study was collected at 4 weeks after baseline • A significant increase in fruit and vegetable consumption in preschoolers was found (p = .027). • Insignificant decrease in the non-core foods consumption was found in preschoolers (p = .203). • Participants actively completed telephone contacts and perceived the intervention program as highly acceptable.
B. Main study:[29] • Cluster RCT • Age: 3-5-year-old children • Sample size: 394 parent-child dyads • Duration: 4 weeks • Theory: Socioecological theory C. 12- and 18 month follow-up:[30]	N = 208 **Intervention content** • Increase in fruits and vegetables consumption **Intervention delivery (every week)** • Received a workbook and other educational materials and weekly scripted 30-min telephone contacts over 4 weeks. • Telephone contact included 4 topics: change availability and accessibility of fruit and vegetables; family eating routines; parental role modeling; review of weeks 1–3, with different topics delivered per week. • The constructs of each topic delivered via telephone contained information learning, specific goal-setting, teaching parents to use cues, barrier identification, and review of behavioral goals.	N = 186 Received 22-page pamphlet, a national food guideline published by the Australian government department of health and aging	• Diet (i.e., fruit and vegetable consumption) ◇ Measurement: fruit and vegetable subscale of the children's dietary questionnaire	Data for main study was collected at 2 months and 6 months after baseline At 2-month postintervention (compared to control group) • Improvement in fruit and vegetable intake (95 % CI: [0.54, 2.03]; p < .001) At 6-month follow-up (compared to control group) • Improvement in fruit and vegetable intake (95 % CI: [0.12, 1.49]; p = .021). Data for follow-up study was collected at 12 months and 18 months after baseline 12-month follow-up (compared to control group) • Improvement in fruit and vegetable consumption (95 % CI: [0.88, 2.33]; p < .001) 18-month follow-up (compared to control group) • Improvement in fruit and vegetable consumption (95 % CI: [-0.17, 1.18]; p = .14)
2. Intervention name: *'Healthy Habits, Happy Homes'*[31] • Medium: telephone calls & home-visit • USA • RCT • Age: 2-5-year-old children • Sample size: 121 parent-child dyads • Duration: 6 months • Theory: Not mentioned	N = 62 **Intervention content** • Eating meals together • Obtaining sufficient sleep • Limiting screen time • Removing the electronic device from children's bedroom **Intervention delivery** • 4 Home visits (review progress and setbacks to behavioral changes, goal settings, and ways to support behavioral changes) • 4 monthly health coaching phone calls (assessments of goal setting, providing strategies for behavioral changes) • Mailed educational materials • Text messages twice weekly for the first 16 weeks and 1 text message weekly for the last 8 weeks	N = 59 Received monthly mailed packages that included educational materials	• Sleep duration (e.g., average amounts of daily sleep) ◇ Measurement: Parents-reported duration of pre-schoolers' sleep)	Data was collected at baseline and 6-month post baseline. At 6-month postintervention (compared to control group) • Sleep duration: A significant difference was found (95 % CI: [0.06–1.44]; p = .03), with intervention group increasing by 0.56h/day and control group decreasing by 0.19 h/day,
3. Intervention name: *'EMPOWER'* • Medium: internet-based program A. Main study:[32] • USA	N = 29 **Intervention contents** • Daily 120-min PA • Daily 5cups of fruits and vegetables • Replacing sugar-sweetened drinks with sugar-free drinks • No more than 120-min screen time every day **Intervention delivery (every week)**	N = 28 Received general health knowledge regarding the four topics via newsletters, without interactive components	• PA (e.g., duration) • Fruits and vegetables intake • Sugar-free drinks consumption ◇ Measurement: An online specifically developed instrument with tested validity and reliability was used. In this instrument,	Data collected in main study at 4 weeks and 8 weeks after baseline, between this two measure points, there was a booster session (lasting for 2 weeks). At 4-week postintervention (compared to control group)

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Table 1 (*continued*)

Study information	Intervention group	Control group	Outcomes and measurements (Preschoolers' PA, DB, and sleep related)	Results (Preschoolers' PA, DB and sleep related)
• RCT • Age: 4-6-year-old children • Sample size: 57 children • Duration: 4 weeks • Theory: Social cognitive theory B. 1-year follow-up:[33] C. 2-year follow-up:[34]	• Each module was delivered via online audiovisual session, along with interactive online worksheets and newsletters. • Each module followed 5 SCT constructs: environment (parents' role modelling), emotional coping (strategies to conduct target behaviors), expectation (benefits of target behaviors), self-control (goal settings), self-efficacy (improving participants' confidence)		scores of 5 SCT constructs were calculated to measure each behavior.	• PA (p = .309) • Fruit and vegetable consumption (95 % CI: [0.698 to 2.529]; p < .001) • Reduction in sugar-sweetened drinks (p = .252) At 4-week postintervention (intervention group time effect) • Improvement in PA (95 % CI: [7.716 to 57.604]; p = .006) • Improvement in fruit and vegetable consumption (95 % CI: [0.698 to 2.529]; p < .001) • Reduction in sugar-sweetened drinks (95 % CI: [0.324 to 1.816]; p < .001) At 8-week postintervention (compared to control group) • PA (p = .309) • Fruit and vegetable consumption (95 % CI: [0.698 to 2.529]; p < .001) • Reduction in sugar-sweetened drinks (p = .252) At 8-week postintervention (intervention group time effect) • Improvement in PA (95 % CI: [7.716 to 57.604]; p = .006) • Improvement in fruit and vegetable consumption (95 % CI: [0.698 to 2.529]; p < .001) • Reduction in sugar-sweetened drinks (95 % CI: [0.324 to 1.816]; p = .003) At 1-year follow-up (compared to control group) • PA (p = .092) • Fruit and vegetable consumption (95 % CI: [1.207 to 2.498]; p < .001). • Reduction in sugar-sweetened drinks (p = .999) At 1-year follow-up (intervention group time effect) • PA (95 % CI: [-31.996 to 57.906]; p = .999) • Fruit and vegetable intake (p = .012). • Reduction in sugar-sweetened drinks (95 % CI: [-0.988 to 1.238]; p = .999) At 2-year follow-up (compared to control group) • PA (95 % CI: [12.600 to 38.657]; p = .313) • Fruit and vegetable intake (95 % CI: [1.113 to 2.248]; p < .001) • Sugar-free drinks (95 % CI: [-0.545 to 0.731]; p = .772) At 2-year follow-up (intervention group time effect) • PA (p = .999) • Fruit and vegetable intake (p = .032). • Reduction in sugar-sweetened drinks (p = .772)
4. Intervention name: *'MONISTOP'* • Medium: software application	N = 156 **Intervention content** • 10 diet-related modules • 1 PA-related module • 1 sleep-related module	N = 159 Received information and advice about a healthy diet and PA via a 4-page pamphlet	• PA (i.e., MVPA and duration) ◇ Measurement: wGT3X-BT accelerometer. • Food intake (e.g., intake of fruits, candy)	Data for the main study was collected at 6 months after baseline. At 6-month postintervention (compared to control group)

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Table 1 (*continued*)

Study information	Intervention group	Control group	Outcomes and measurements (Preschoolers' PA, DB, and sleep related)	Results (Preschoolers' PA, DB and sleep related)
A. Main study:[35] • Sweden • RCT • Age: 4-year-old • Sample size: 315 children • Duration: 6 months • Theory: Social cognitive theory B. 12-month follow-up study:[36]	**Intervention delivery (every second week)** • Received a module delivered via a software application • Each module contained ◆ Information ◆ Tips ◆ Strategies for behavioral changes ◆ Feedback ◆ Automated comments		◇ Measurement: objectively measured using Tool for Energy Balance in Children.	• Time spent in MVPA (p = .589) • Reduced intake of sweetened beverage (p = .049) • Intake of fruits (p = .262) • Intake of vegetables (p = .538) • Intake of candy (p = .106) At 6-month postintervention (within intervention group) • Increased composite score for MVPA and 6 DBs (fat mass index; the intake of fruits, vegetables, candy, and sweetened beverages; the time spent sedentary) (OR:1.99; 95%CI:1.20,3.30; p = .008) Data for the follow-up study was collected at 12 months after baseline. At 12-month follow-up (compared to control group) • Time spent in MVPA (p = .43) • Reduced intake of sweetened beverage (p = .71) • Intake of fruits (p = .17) • Intake of vegetables (p = .10) • Intake of candy (p = .23) At 6-month postintervention (within intervention group) • Increased composite score for MVPA and 6 DBs (95% confidence interval:0.77,2.04; p = .36)
5. intervention name: *'Smart Mom'*[37] • Medium: mobile website & text messages • USA • RCT • Age: 3-5-year-old children • Sample size: 51children • Duration: 6 months • Theory: Social cognitive theory	N = 27 **Intervention content** • Targeting maternal dietary behaviors that would, in turn, promote positive changes in children's dietary intake. **Intervention delivery (every week)** • Received weekly goals, self-monitoring, kick-off session, website and lessons, weekly tailored feedback, monthly progress check-ins, tips, motivational messages, goal progress assessment text messages, and child reinforcement charts via text messages, emails, and websites	N = 24 Waitlist	• Dietary intake (i.e., sugar-sweetened beverages intake) ◇ Measurement: weekday in-person 24-h dietary recall	Data was collected at 3-month midpoint and 6-month postintervention At 3-month midpoint (compared to control group) • Reduction in sugar sweetened beverages (p < .01) At 6-month postintervention (compared to control group) • Reduction in sugar sweetened beverages (p < .01)
6. intervention name: *'Facebook-based program'*[38] • Medium: social media (Facebook) & face-to-face workshop • Quasi experiment • USA • Age: 3-5-year-old children • Sample size:69 parent-child dyads • Duration: 10 weeks • Theory: Actor-Partner Interdependence Model	N = 39 **Intervention content** • Efficacy of intervention on preschoolers' BMI, fruits and vegetables intake, MVPA, and screen time **Intervention delivery (schedule was not mentioned)** • Weekly provision of healthy information • Weekly positive communication with peers • Face-to-face caregiver meetings • Center-based preschoolers' program • Weekly assessment letters.	N = 30 Received usual care activities in the kindergartens	• PA (i.e., MVPA) ◇ Measurement: ActiGraph GT3X-plus accelerometer. • Diet (i.e., Preschooler's fruit and vegetable intake) ◇ Measurement: Block kids foods screeners questionnaire	Data collection was conducted at 10 weeks after baseline At 10-month postintervention (compared to control group) • Preschooler's MVPA (d = .42, $d_{adjusted}$ = .66, p > .05) • Fruit consumption (d = .42, $d_{adjusted}$ = .16, p > .05) • Vegetable intake (d = .38, $d_{adjusted}$ = .25, p > .05) At 10-month postintervention (intervention group) • Increase in preschoolers'MVPA by 17.88 min/day, fruit intake by 0.14 cups/day, vegetable intake by 0.13 cups/day. • However, nonsignificant changes in PA and DB were observed
7. intervention name: *'Jump2Health'*[39]	N = 15 **Intervention content** • Focusing on more fruit and vegetable healthy habit.	N = 15 Did not receive access to the website or social media, only text	• Diet (i.e., increasing accessibility and intake of fruits and vegetables)	Data was collected at mid-point (week 5) and post-intervention (week 10) after baseline

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Table 1 (*continued*)

Study information	Intervention group	Control group	Outcomes and measurements (Preschoolers' PA, DB, and sleep related)	Results (Preschoolers' PA, DB and sleep related)
• Medium: mobile website, Facebook & text messages • RCT • USA • Mean age: 3-year-old children. • Sample size: 30 parent-child dyads • Duration: 10 weeks • Theory: Social cognitive theory	• Increasing accessibility of fruits and vegetables (i.e., increasing the number of times children were served fruits and vegetables). **Intervention delivery (schedule was not mentioned)** • Intervention contents were accessible during the program. • Received a link to the 'Jump2Health' website (containing PA, sleep, diet and screen time content, this study only focused on diet). • Facebook provided reinforced information. • Text messages about ways to encourage more vegetable and fruit consumption	messages regarding PA were sent to participants	◇ Measurement: Veggie Meter, a valid and reliable measurement tool in assessing fruit and vegetable derived carotene levels in youths and adults.	• Veggie Meter values for preschoolers and parents showed significant week-treatment interaction values in the intervention group for preschoolers ($p < .001$) and adults ($p < .001$) for mid-point and postintervention. • mHealth ***'Jump2Health'*** intervention showed its potential in increasing the healthy behaviors of eating more fruits and vegetables.
8. Intervention name: *'Time2bHealth'*[40] • Medium: website, printed materials, Facebook & Email. • Australia • RCT • Age: 2-5-year-old children • Sample size: 86 parent-child dyads • Duration: 11 weeks • Follow-up: 6 months after baseline • Theory: Social cognitive theory	N = 42 **Intervention content (6 modules)** • Introduction • Nutrition (n = 2) • PA • Sleep • Screen time **Intervention delivery (every two weeks)** • Watching videos • Reading materials • Completing activities • Emails as reminders • Quizzes • Goal setting • Revision of goal • Feedback	N = 44 Received fortnightly emails that link to the website involving general health information, without interactive components.	• PA (i.e., intensity and duration) ◇ Measurement: ActiGraph GT3X/accelerometer) • Diet (e.g., frequency of intake of discretionary foods) ◇ Measurement: Parent-reported questionnaire. • Sleep problems (e.g., sleep latency) ◇ Measurement: Parent-reported questionnaire. • Sleep duration (e.g., sleep time, wake time) ◇ Measurement: ActiGraph GT3X	Data was collected at baseline, 3 and 6 months post baseline. At 3-month postintervention (compared to control group) • Improvement in frequency of consumption of discretionary foods (95 % CI: [−2.42 to −0.43]; p = .01) • No significant improvements in PA (MVPA: p = .21; LPA, MPA, and VPA: p = .47) and sleep problems (sleep reluctance: p = .11; sleep latency: p = .35) and sleep duration (p = .84) were found At 6-month follow-up (compared to control group) • Improvement in frequency of consumption of discretionary foods (95 % CI: [−2.34 to −0.26]; p = .02) • Sleep duration (95 % CI: [-1.01 to −.03]; p = .04) • No significant improvements in PA (MVPA: p = .38; LPA, MPA, and VPA: p = .90) and sleep problems (sleep reluctance: p = .18; sleep latency: p = .24) were found
9. Intervention name: *'3 Pillar Study (3 PS)'*[41] • Medium: a studying website & face-to-face workshop • RCT • New Zealand • Age: 2-4-year-old children • Sample size: 54 parent-child dyads •Duration: 6 weeks with 12-week follow up •Theory: Connecting Activities, Routines, and Environments (C.A.R.E) framework	N = 27 **Intervention content** • Creating routines that support the development of healthy lifestyle behaviors in the long by helping parents build a positive and reciprocal attachment with their child. **Intervention delivery (schedule was not mentioned)** • 1 half-day face-to-face workshop • A study website including sleep, family meals, and free play will be provided to participants for 6 weeks.	N = 27 Waitlist control group	• Sleep (e.g., time the child goes to bed, how long it takes for the child to fall asleep, etc.) ◇ Measurement: Brief screening questionnaire for sleep problems (BISQ)	Significant improvements (compared to control group) • Median time during the night the child is awake at 6-week postintervention (p = .022), but not sustained over 12-week follow-up (p = .171). • Longest duration of uninterrupted sleep during the night at 6-week post-intervention (p = .036) and at 12-week follow-up (p = .004).
10. Intervention name: *'Moovosity'*[42] • Medium: software application • RCT • Australia • Age: 3-6-year-old children • Sample size:34 parent-child dyads • Duration: 8 weeks	N = 17 **Intervention content** • Increasing fundamental motor skills (FMS) in preschoolers using 'Moovosity', an app includes 5 FMS domains (Fitness, Rhythm, Agility, Coordination, and Balance), with each domain involving 5 to 6 active games that promote child and parent co-participation in PA. **Intervention delivery (schedule was not mentioned)** • Parent-child dyads were free to use app, but must finish at least 3 active games per week, with no restrictions on selections of domains.	N = 17 Waitlist control group	• PA (e.g., the amount of time their child spent playing) ◇ Measurement: parent-reported Burdette outdoor playtime checklist • FMS (i.e., locomotor skills and object control) ◇ Measurement: Test of Gross Motor Development 2nd Edition (TGMD-2)	Data was collected at 8 weeks after baseline At 8-week postintervention (compared to control group) • PA (95 % CI: [-2.2 to −1.8]; p = .858) • Locomotor skills (95 % CI: [0.5 to 7.6]; p = .085) Children in intervention group performed significant improvements in locomotor skills, while children in

(*continued on next page*)

Table 1 (*continued*)

Study information	Intervention group		Control group	Outcomes and measurements (Preschoolers' PA, DB, and sleep related)	Results (Preschoolers' PA, DB and sleep related)
• Theory: not mentioned	• Parent-child dyads completed active games independently, without communicating to other participants • They were sent messages to check use of app and enquire if they were experiencing any problems with using the app. • Children were rewarded with points and shared the achievements with family and friends through SMS.				waitlist group exhibited minimal change. • Object control (95 % CI: [2.3 to 9.7]; p = .0025) Children in intervention group performed significant improvements in object control skills, while children in waitlist group performed a modest decline in object control.
11. intervention name: 'Time for Healthy Habit'[43] • Medium: website, printed materials, Facebook, Email & telephone calls • Parallel partially randomized preference trial • Australia • Age: 2-6-year-old children • Sample size: 458 parent-child dyads • Duration: 3 months • Theory: social cognitive theory	N = 95 **Intervention #1 content** • Focusing on healthy eating and movement behaviors (PA, screen time and sleep) **Intervention delivery (every two weeks)** • 6 20- to 30-min telephone calls over 3 months • Module components include barrier identification, goal setting, self-monitoring, prompts, cues.	N = 218 **Intervention #2 content** • Focusing on healthy eating and movement behaviors (PA, screen time and sleep) **Intervention delivery (every two weeks)** • 6 30-min modules on-line intervention over 3 months • Module components include written content, practical activities, videos, goal setting and communication in social media.	N = 145 Received written information on current recommendations for child healthy eating and movement behaviors.	• PA (e,g., the amount their child was engaging in PA) ◇ Measurement: National nutrition and physical activity survey • Diet (i.e., fruit and vegetable intake) ◇ Measurement: (i) The fruit and vegetable subscale of the Children's dietary questionnaire (CDQ) (ii) NSW child health survey questions (iii) Serve-based measure data • Sleep (e.g., sleep time) ◇ Measurement: Children's sleep habits questionnaire	Data was collected at 9-month post baseline Significant improvements (within two intervention groups) • Fruit and vegetable subscale score (p < .0001) • Fruit and vegetable intake (p < .0001) • Meeting fruit and vegetable guideline (p < .0001) Findings (compared to control group) • A significant improvement on non-core food intake (p < .001) was found in the intervention #1. • A significant improvement on non-core food intake (p = .038) was found in the intervention #2. • No significant improvements in child's fruit and vegetable intake were found in any of the intervention groups compared to control group. • No significant improvements in child's achievement of fruit and vegetable guidelines were found in any of the intervention groups compared to the control group.
12: Intervention name: *'Promoting Lifelong Activity in Youth (PLAY)'*[44] • Medium: software application • RCT • USA • Age: 3-5-year-old children • Sample size: 72 parent-child dyads • Duration: 12-week intervention with 12-week follow-up • Theory: Social cognitive theory	N = 35 **Intervention content** Focusing on 6 motor skills • Hop • Throw • Slide • Kick • Jump • Catch **Intervention delivery (every week)** • Using Motor Skill app including • Peer modelling videos. • Push notifications. • Practices. • Reinforcement.		N = 37 Control group • Focusing on unstructured PA Delivery (same to the amount to the intervention group) • Have access to the lessons and videos of unstructured PA in the app. • Creating active home environment • Goal setting • Reinforcement.	• PA (e.g., MVPA) ◇ Measurement: ActiGraph GT3X+BT • Motor ability (i.e., fundamental motor skills) ◇ Measurement: Test of Gross Motor Development 3rd Edition (TGMD-3)	Data was collected at baseline, end-of-intervention (week 12), at the end of follow-up (week 24) Findings in PA (compared to control group) • Light PA (p = .43) • MVPA (p = .74) • Light PA+MVPA (p = .70) Significant improvements in motor ability (compared to control group) • Locomotor skills (p < .01) • Ball skills (p < .01) • Total score (p < .01) • Gross motor index (p < .01)

notifications/reminders, social interaction, goal settings, barriers to the behavioral changes, and personalized feedback were included in ten studies but not in two (study #9 and #10).

Active control groups were conducted in all studies except study #5, #9, and #10 in which a waitlist control group was set. Of the studies with an active control group, a majority of control groups regularly received printed evidence-based information pamphlets or text messages matching the content of intervention groups, without interactive components (intervention #1, #2, #3, #4, #7, #8, and #11). One control group conducted normal face-to-face activities in kindergartens (intervention #6), and one was provided the difference content compared to the intervention group (i.e., unstructured PA vs. motor ability; study#12).

The focus of outcomes differed between studies, with seven studies focusing on one variable (study #10 and #12 focusing on PA-related outcomes; study #1, #2, and #7 focusing on DB-related outcomes; and study #2 and #9 focusing on sleep-related outcomes), three on PA and DB (study #3, #4, and #6), and two on PA, DB, and sleep (study #8

and #11).

3.4. Results of studies

3.4.1. PA-related outcomes

PA-related outcomes were assessed in seven studies (study #3, #4, #6, #8, #10, #11, and #12), of which, four conducted follow-up studies (study #3, #4, #8, and #12).

Two studies (study #3 and #4) indicated a significant improvement in PA within the intervention group (p = .006–.008) at postintervention. None of the included seven studies reported a significant difference between groups for PA from baseline to postintervention, and this insignificant effect was also reported in the follow-up period.

Regarding the motor ability, one study (study #10) demonstrated a significant improvement in object control (p = .0025) but not in locomotor skills (p = .085) at the posttest in comparison to the control group. While significant differences in both object control and locomotor skills between the two groups were found at posttest in study #12, which were sustained over a 12-week follow-up.

3.4.2. DB-related outcomes

DB-related outcomes were assessed in eight studies (study #1, #3, #4, #5, #6, #7, #8, and #11) of which four collected follow-up data to examine the maintenance of changes after intervention completion (study #1, #3, #4, and #8).

Six studies investigated the consumption of vegetables and fruits (study #1, #3, #4, #6, #7, and #11), with inconsistent results reported. Three studies (study #1, #3, and #7) found a significant improvement in vegetable and fruit intake at the end of the intervention compared to the control group (p = .001–.036). Additionally, study #1 indicated that these significant changes were sustained at the 6-month (p = .021) and 12-month follow-up (p < .001), but not at the 18-month follow-up (p = .14). Study #3 demonstrated that the promotion in vegetable and fruit intake was not maintained at 8-week follow-up (p = .306) but reached statistical significance at the 1-year (p < .001) and 2-year follow-ups (p = .033). While the other three studies (study #4, #6, and #11) reported an insignificant difference between groups in terms of vegetable and fruit consumption (p > .05), though study#4 and #11 reported that significant improvement was found within the intervention at the post-intervention (p = .0001–.008).

Three studies examined the intake of sugar-sweetened beverages (study #3, #4, and #5). Study #3 found that participants allocated to the eHealth intervention group significantly reduced the intake of sugar-sweetened beverages at the end of intervention (p < .001), but this change was not statistically different compared to that in the control group (p = .252). Both study #4 and #5 reported a significant difference between groups regarding the reduced intake of sugar-sweetened drinks at the posttest (p = .01-.049). However, study #4 reported that this change was not maintained at the end of 1-year follow-up (p = .71).

Two studies assessed the intake of discretionary food (such as candy/confectionary, study #4 and #8). While candy consumption was significantly decreased within the intervention group at the posttest (p = .008), the effects on reduced intake of candy were not significant between groups (p = .106, study #4). Moreover, no significant group-by-time difference was found at the end of 1-year follow-up (p = .23, study #4). Conversely, reduced intake of discretionary food was found compared to that in the control group at the end of the intervention (study #8), and this significant improvement was further sustained at 3-month follow-up (study #8).

One study (#11) with two intervention groups reported that the telephone-based intervention group significantly improved consumption of non-core food compared to that in the control group at the end of the intervention (p=<.001), whereas this change was not found in the online intervention group (p = .038).

3.4.3. Sleep-related outcomes

Sleep-related outcomes were evaluated in four studies (study #2, #8, #9, and #11), of which, two conducted follow-up studies (study #8 and #9).

Two studies (study #2 and #9) reported a significant improvement in sleep duration between groups at the posttest (p = .03–.036), with study #9 indicating that this change was maintained at 12-week follow-up (p = .004). No significant group-by-time difference in sleep duration at the end of intervention was found in study #8 (p = .84), but a significant change between the two groups in sleep duration was reported a 12-week follow-up (p = .04). Study #11, in which participants were initially allowed to choose the interventions (i.e., telephone-based and online) they liked and in which the remaining participants were randomized, reported that only participants who selected the interventions they liked significantly promoted their sleep duration compared to the control groups (p = .028).

Only one study (study #8) reported the outcomes related to sleep problems, which indicated that sleep reluctance (p = .11) and sleep latency (p = .35) were not significantly improved compared to that in the control group at the end of the intervention. Additionally, these insignificant changes were sustained to the end of the 12-week follow-up (sleep reluctance: p = .18, sleep latency: p = .24).

3.5. Summary of results of studies

No significant group-by-time improvement in PA was found in studies related to PA outcomes. Two studies reported significant differences between groups concerning motor ability, with one study indicating improvement in object control while the other reporting improvement in both object control and locomotor skills. Of the studies related to DB outcomes, six studies reported a significant difference at the post-test compared to the control group, in terms of vegetable and fruit intake, sugar-sweetened drinks, reduced consumption of candy, and improvement in non-core food. Three studies reported a significant difference between groups in sleep duration at the end of the posttest, with the result of one study limited to preference-only participants. None of the studies reviewed for sleep problems found a significant difference between groups.

3.6. Methodological quality

The methodological quality of the main study was assessed if the intervention results were published separately (i.e., pilot, main, and follow-up study). According to the study design, 11 studies were evaluated using an individual RCT version while one study was examined using the cluster RCT version. The whole screening process was finished by answering the questions included in the RoB2 Excel worksheets, which can automatically generate biased results after the relevant information was inserted in the corresponding forms. The rating for each domain of screened studies is shown in Fig. 2.

Overall, of the studies with individual RCT, five were considered ‘low risk,’ two indicated ‘some concerns,’ and four reported ‘high risk.’ In terms of D1, two studies (study #6 and #11) showed ‘high risk’ because the allocation sequence was either not concealed or randomized. Regarding the D2, three studies were judged as ‘some concerns’ as it was reported that either the participants or the people delivering the intervention were aware of the intervention allocation, while three studies, judged as ‘high risk,’ did not mention the information with regard to sample size calculation. One study was considered ‘high risk’ in the D3 because the dropout rate reported was high (34 % attrition rate). Two studies were judged as ‘high risk’ in the D4 because they did not provide information about whether the outcome assessors acknowledged the intervention the participants received. All studies reported the reliability and validity of the measurements used, resulting in ‘low risk’ in the D5. The study with cluster RCT has been judged as overall ‘some concerns’ because it reported that participants were informed of the

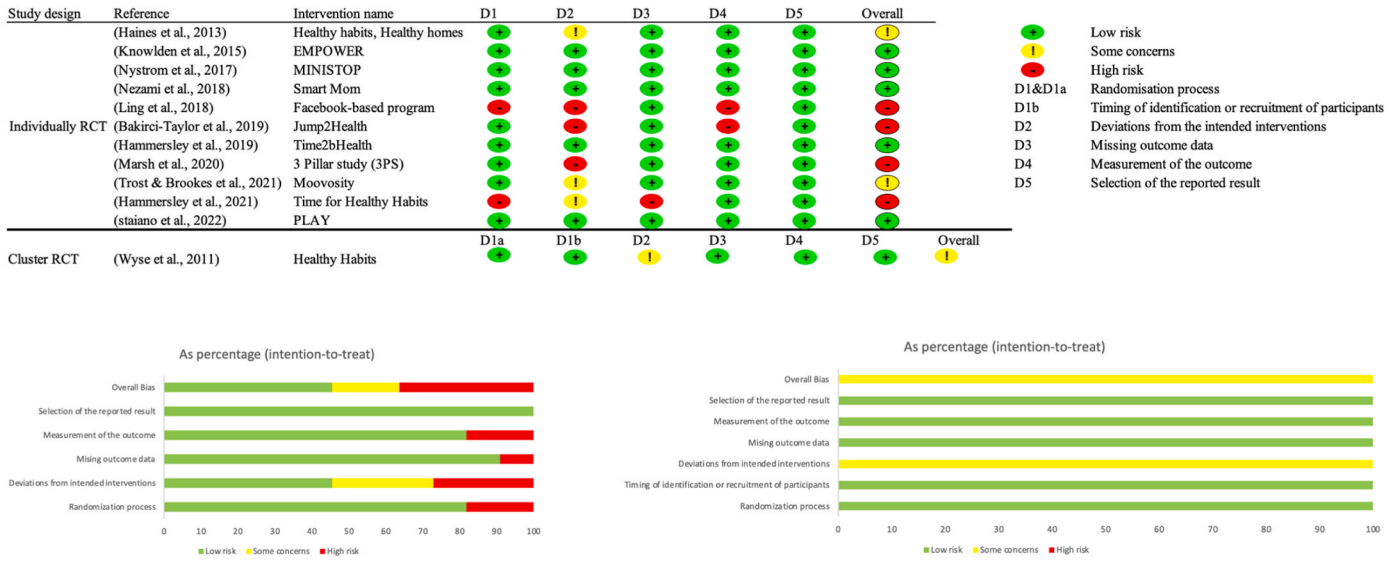

Fig. 2. Methodological quality.

intervention allocated (D2).

4. Discussion

This systematic review sought to examine the effectiveness of parent-based eHealth intervention on the PA, DB, and sleep of preschoolers. Overall, at postintervention, 86 % of studies (6/7) that aimed to improve the PA of preschoolers produced significant intervention effects, but this impact was not significantly different compared to the control group. Of the studies investigating the DB of preschoolers, 88 % (7/8) were effective in improving diet quality compared to the control group. Of the studies exploring the sleep duration of preschoolers, 75 % (3/4) resulted in significant improvements in comparison to the control group. Surprisingly, significant group-by-time improvements in the diet-related outcomes and sleep duration were subjectively measured by questionnaires while nonsignificant group-by-time promotions in the PA and sleep duration were objectively measured by accelerometer. This finding concurs that the self-report nature of the survey measurement may yield errors in outcomes estimates, and parent report of the child's intake and sleep duration may result in bias.[45]

The majority of reviewed studies (10/12) explicitly cited a behavioral modification theory (i.e., 7*SCT, 1*socioecological theory, 1*C.A.R.E Framework, and 1*API Model) as a foundation in the design of the intervention content. These theoretical foundations consistently involved some components, including evidence-based knowledge, push notifications, interactive activities (e.g., quizzes or communication), self-monitoring, goal-setting, feedback, and goal adjustment/reinforcement. A previous study indicated that the behavioral change framework could inform researchers of the most influential mediating variables of the target behaviors. Through intervening on these influential mediating variables, participants would be more likely to initiate behavior modification.[46] Although two studies did not design the intervention based on the theory, these two studies consisted of educational information, reminders, peer communication, monitoring, text messages, personalized goal setting, and feedback. This may be because interactive delivered contents have been indicated as potentially exposure-improving and active involvement elements.[47] Chronologically, the primary method of delivering parent-based eHealth interventions in preschoolers has evolved from multiple modalities delivery (i.e., text messages/phone calls/emails combined with home visits/workshops/group sessions/camp activities) to single platform delivery that integrates comprehensive components of the intervention (i.e., social media/specifically developed software applications or websites). This changing trend may reflect that when parents receive more than one mode of intervention, the information becomes too complex and diffused, and therefore less well received and understood as compared to that provided through only one mode of intervention.[48] The incorporation of more of these interactive components in future electronic platforms with comprehensive functions may improve PA, DB, and sleep in preschoolers.

Most of the studies (11/12) in this review used the RCT study design. Only one study was a quasi-experiment (study #6), and interestingly, was the only study that did not find significant changes in any variables examined (i.e., PA and DB) at the posttest either within the intervention group or between the two groups. Nonsignificant improvements within the intervention group may be that parents were not provided with intervention contents related to parental monitoring. A systematic review of Hesketh and colleagues[49] has demonstrated that among 44 determinants of changes in lifestyle in 0–6-year-old children, only parental monitoring consistently showed a positive association with promotions in lifestyle. A nonsignificant difference between groups may be attributed that participants in both intervention and control groups attended the same activities in the kindergartens recruited. The intervention group was additionally provided with interactive components during the intervention period (i.e., 3 face-to-face group meetings, Facebook interactions, and weekly mails). It is plausible that control group participants who received the same activities and information significantly increased their PA and DB, making a modest difference between the two groups at the posttest.[50] Study #6 also highlighted that participants allocated to both the intervention and the control groups were from the same kindergartens, contamination of intervention contents between the two groups may cause no significant group-by-time changes.[38]

4.1. Effectiveness of parent-based eHealth intervention on preschoolers' PA-related outcomes

All RCT studies that investigated the PA of preschoolers (study #3, #4, #8, and #11) have reported that parent-based eHealth intervention did not significantly improve the PA of preschoolers compared to that in the control group. No significant differences between groups in study #3, #4, #8, and #11 may be due to the imbalanced intervention modules and failure to consider the influence of the intervention sequence on the intervention outcomes. Specifically, study #3 included four intervention modules (i.e., PA × 1, diet × 2, and screen time × 1), study #4 included 12 modules (i.e., PA × 1, diet × 10, and sleep × 1), study #8 comprised six modules (i.e., PA × 1, nutrition × 2, introduction × 1, screen time × 1, and sleep × 1), and study #11 included two

intervention groups, which both consisted of six modules (i.e., PA × 1, diet × 2, restrictions on screen time × 1, bedtime routine × 1, and parental role-modelling × 1). Limited PA intervention contents during the intervention period in these four studies may contribute to insignificant differences between the two groups. A systematic review by Hammersley, Jones, and Okely[26] supported this point of view, indicating that parent-based eHealth studies screened did not improve PA in children (mean age: 7–15 years old) compared to those in the control group. These screened studies related to PA also consisted of fewer intervention modules in PA compared to other variables. However, a study by Chen, Weiss, Heyman, Cooper, and Lustig,[51] in which modules of PA and dietary intake were balanced, reported that the PA of children was enhanced after engaging in parent-based website intervention (effect size = 12.46, $p = .02$) compared to the control group, and this change was sustained over 8-month follow-up ($p < .05$). As such, positing that participants insufficiently exposed to the PA modules during the intervention period may not significantly improve their PA is reasonable. Additionally, PA modules were distributed at the beginning of the intervention period. In this case, when the posttest was conducted, participants may be more familiar with the intervention content distributed at the end of the intervention period, thus producing favorable outcomes regarding these later-distributed modules compared to other previously distributed ones.

Notwithstanding, the motor ability of preschoolers, which is identified as the "building blocks" of complex and specialized movement competencies required in PA,[52] was significantly promoted at the end of parent-based eHealth intervention compared to that of the control group (study #10 and #12). Both of these two studies intended to increase motor ability (primary outcome) using software applications (i.e., PLAY & Moovosity) that were specifically designed for the respective studies. Game components in the applications that included a set of digital libraries of age-appropriate motor skills may be attractive for preschoolers engaging in such interventions. Given that children's perceived enjoyment has been found to predict children's motor ability,[13] it is posited that a game's fun and entertaining nature triggers positive observation. Notably, study #10 reported a significant difference between groups on object control skills but not on locomotor skills. This coincides with the findings concluded from previous study,[53] which demonstrated that preschoolers have more developed locomotor skills (i.e., run, gallop, hop, leap, horizontal jump, and slide) compared to the object control skills (i.e., striking a stationary ball, stationary dribble, catch, kick, throw, and roll), making it difficult to elicit changes in locomotor skills.

4.2. Effectiveness of parent-based eHealth intervention on preschoolers' DB-related outcomes

The RCT studies that examined dietary variables have reported a significant difference between groups in regard to improvement in at least one DB-related outcome (i.e., consumption of fruits and vegetables and non-core food, as well as reduced intake of sugar-sweetened drinks and confectionary foods) at the posttest. This result was consistent with a previous systematic review,[54] which reported that interventions involving parental participation at young ages did find significant effects in healthy diet consumption. A previous parent-based meta-analysis by Hammersley, Jones, and Okely[26] indicated that interventions in which parents were provided only one delivery mode generated better results than those with more than one modality of delivery.[54] This may have been the case for the positive changes related to DB in two studies (study #5 and #7). Similarly, another four studies (study ##3, #4, #8, and #11) also found significant differences in DB. This finding may be occurring because intervention modules related to DB were more than those related to other variables (e.g., PA and sleep). More exposure to the diet modules involved in these studies, relative to the fewer other two modules, may yield outcomes favoring the diet variables. This explanation is in line with the findings of a previous study, which indicated that a high proportion of program time dedicated to the healthy eating modules contributed to a greater opportunity for vicarious learning.[40]

Notably, study #1 produced significant changes in fruit and vegetable intake within such a short intervention time (i.e., 4 weeks), and this observation was further maintained in up to 12-month follow-up. This finding is at odds with the previous study, which indicated that behavioral modification needs at least 2–3 months.[55] This result might be related to two reasons. The parents recruited in this study had higher levels of socioeconomic status (SES), which is associated with high diet quality during childhood.[56] Parents with higher SES were more likely to role model healthy eating patterns to their children, had more rules about fruit and vegetable intake, and increased accessibility and availability of fruits and vegetables at home, all of which were beneficial to cultivate a healthy diet in childhood.[56] Additionally, a previous study indicated that parents' gatekeeping behaviors may directly affect children's DB by providing the foods they would like their children to eat and adding more foods to children's plates even if their children are stuffed or display neophobia to certain food.[54]

While the present review demonstrated consistent evidence supporting the efficacy of improving DB in preschoolers through parent-based eHealth intervention, the scope of DB measurements was limited to fruits and vegetables (4/7), non-core food (1/7), sweetened drinking (1/7), and sugary food (1/7). Future studies investigating comprehensive DB in preschoolers (such as food fussiness, emotional eating, and reduced sodium, etc.) are suggested.

4.3. Effectiveness of parent-based eHealth intervention on preschoolers' sleep-related outcomes

Two studies (study #2 and #9), which solely emphasized the sleep duration, reported significant improvements between groups in sleep duration at the posttest. This result is inconsistent with the finding of the previous systematic review,[57] which demonstrated that children's (specifically school-aged children) sleep duration was not enhanced in the studies with parental involvement compared to the control group's. This contrasting finding may reflect that parents' influences on children's lifestyles can be attenuated as children grow up.[15] However, eHealth delivered the intervention contents involved in these two studies in combination with traditional mode, such as home visits and face-to-face workshops. Determining which characteristics of the intervention (eHealth or traditional modality) have positively changed sleep duration is difficult. Additionally, study #2 and #9 subjectively measured sleep duration by parent-reported questionnaires, possibly contributing to exaggerated improvements in behavioral change.[31] Furthermore, study #2 reported that the finding was limited to participants with low income and ethnic minorities while study #9 was not powered to detect statistically significant differences in sleep outcomes, because no sample size calculation was conducted. Study #11, in which the preference RCT trial was conducted, indicated that a positive promotion in sleep duration was restricted only to those who selected their preferred interventions. Partially randomized preference trial initially allows participants to choose the intervention they prefer and avoid the treatment to which they are strongly averse, which may increase adherence and engagement and ultimately yield favorable results.[58] Study #8 found significant improvement between groups in neither sleep duration nor sleep problems at the posttest. It is possible that the effectiveness of the parent-based eHealth intervention on sleep duration and sleep problems could have been diluted owing to the multiple behavioral emphasis and limited dosage of intervention related to sleep content.[40] It is worth noticing that the sleep duration was found significantly different between the two groups at the end of the 3-month follow-up. This result may be due to the fact that the intervention group received a booster session (i.e., participants in the intervention group were provided emails every two weeks after the completion of the intervention while those in the control group were not). Boosters that

are not as intense as the initial intervention can be an important reminder, which may reinforce and sustain treatment effects.[59]

4.4. Recommendations for enhancing related interventions

To begin with, the synthesized findings of study #6 concerning the PA and DB may refer to a potential problem in the underpowered trial due to the poor study design that possibly disclosed intervention contents between two groups. It is therefore recommended that future studies with larger sample sizes include RCT in their design as it remains the golden standard for evidence of the effectiveness of eHealth interventions.[60] Additionally, more than half of the studies were guided by Social Cognitive Theory, with these studies highlighting a significant improvement between groups in at least one of three variables (i.e., PA, DB, and sleep). This provides a reference for selecting a theoretical framework for future-related studies. Moreover, comprehensive characteristics mentioned in a majority of studies (10/12) include delivery of evidence-based health recommendations for preschoolers, social media, personalized goal setting, instant feedback, and subsequent goal revision. These previous commonly used features in the eHealth intervention that has been found to be effective in promoting preschoolers' healthy lifestyle may be useful to optimize the development of future intervention. Furthermore, studies reviewed have either emphasized on one variable or failed to balance the dosage of PA, diet, and sleep modules or considered the influence of intervention sequence on outcomes during the intervention period. Therefore, they may have been inadequately powered. Future studies should consider intervention dosage and sequence. In the end, the results reported based on the studies conducted in Western culture may be a product of its milieu and may not be generalized to other cultures. More studies examining whether the effect of parent-based eHealth intervention on preschoolers' PA, DB, and sleep in other countries are therefore warranted.

4.5. Strengths and limitations

This systematic review provides a comprehensive understanding of the effect of parent-based eHealth intervention on the main lifestyle dimensions of PA, DB, and sleep in preschoolers, with the whole reporting process adhering to the PRISMA statement. Additionally, two authors conducted the abstract and full-text review to ensure consistency. However, the present systematic review contains several limitations. The studies reviewed were heterogeneous in terms of study design, the nature of comparison group, and intervention contents and dosage, thus impeding our ability to draw definitive conclusions. Our review included only peer-reviewed full-text journal articles in the English language, and the studies published in other languages may be overlooked.

5. Conclusion

This systematic review found no significant improvement in PA and sleep problems from parent-based eHealth interventions compared to that of the control group. Two studies found a significant promotion between groups in motor ability and half of the included studies demonstrated significant improvements between groups in DB-related outcomes. Three studies reported a significant difference in sleep duration compared to that in the control group. Our conclusion based on the findings of the previous studies screened should be interpreted with caution due to the fact that the reviewed studies varied in terms of quality (i.e., 7 out of 12 were judged as either 'high risk' or 'some concern'), outcome measurements (i.e., subjective vs objective), study design (i.e., quasi-experiment and RCT), and intervention delivery (i.e., combined with traditional and eHealth sole). Studies investigating the effect of the parent-based eHealth intervention on PA, DB, and sleep in preschoolers raised in other cultural contexts were absent. High-quality, robustly designed studies to balance the intervention dosage and sequence are needed to investigate the effectiveness of parent-based eHealth intervention on PA, DB, and sleep in preschoolers, particularly those raised in other cultural backgrounds.

Statement

All authors agree with the content of the article and approve of its submission to the journal;

The material contained in the manuscript has not been previously published and is not being concurrently submitted elsewhere;

The experiments reported in the article were undertaken in compliance with the current laws of the country in which the experiments were performed. Authors will be held responsible for false statements.

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