Interventions to Promote Physical Activity and Healthy Digital Media Use in Children and Adolescents: A Systematic Review

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abstract

OBJECTIVES: To identify effective interventions that promote healthy screen time use and reduce sedentary behavior in school-aged children and adolescents (SACA) in all settings, over the last 20 years.

METHODS: Searches were conducted from 2000 until March 2021 using PubMed, Embase, Medline, PsycINFO, Ovid SP, The Cochrane Library, Cochrane Central Register of Controlled Trials, Cochrane Methodology Register, and the WHO regional databases, including Google Scholar and reference lists of relevant articles and reviews. Randomized-controlled trials and quasi-experimental studies assessing interventions to reduce sedentary behaviors and screen time in healthy SACA (aged 5-19.9 years) globally. Data were extracted by 2 reviewers and where possible, pooled with a random-effects model.

RESULTS: The review included 51 studies, of which 23 were included in meta-analyses with 16 418 children and adolescents. Nondigital randomized-controlled trials reported a small, but significant reduction of TV-specific screen time (minutes per day) (mean difference, −12.46; 95% confidence interval, −20.82 to −4.10; moderate quality of evidence) and sedentary behavior (minutes per day) (mean difference, −3.86; 95% confidence interval, −6.30 to −1.41; participants = 8920; studies = 8; $P = .002$; moderate quality of evidence) as compared with control groups. For quasi-experimental studies, nondigital interventions may make little or no difference on screen time (minutes per day) or sedentary behavior (minutes per day), given the high uncertainty of evidence. Most studies were conducted in a high-income country. Generalizability of results to low- and middle- income countries remain limited.

CONCLUSIONS: Public health policies and programs will be necessary to reduce excessive sedentary behavior and screen time, especially in the post-coronavirus disease 2019 reality.

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Ms Oh and Dr Carducci conceptualized and designed the study, screened the search results, screened the retrieved papers against the inclusion criteria, appraised the quality of papers, extracted the data, completed the data analysis, and drafted the initial manuscript; Dr Bhutta conceptualized and designed the study; and all authors reviewed, revised, and approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

The protocol for this review was registered within the International Prospective Register of Systematic Reviews (www.crd.york.ac.uk/prospero/) (identifier CRD42020213361).

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In recent decades, the rise in child and adolescent overweight and obesity is in part attributed to increases in sedentarism among children and adolescents, especially with increasing global urbanization.[1] Going further, the increasing trend of sedentary behavior is particularly concerning with regards to its effects on cognitive, socio-emotional and physical development in this age group, and its future effects on their health into adulthood.[2] Importantly, the measurement of sedentary time is operationalized as activities producing ≤1.5 metabolic equivalents and has often relied on convenient proxy measures such as self-reported screen time, negating the acknowledgment of other forms of sedentary behaviors such as reading, playtime, passive transport and eating, and objective measures using accelerometry.[3] A large body of evidence suggests that greater time spent in front of screens, such as televisions, computers, mobile devices (ie, smartphones and tablets) with apps and social media, and the Internet is associated with poorer cardiometabolic health, shorter sleep duration, unfavorable measures of adiposity and greater mental health outcomes in school-aged children and adolescents (SACA).[4] Moreover, it is also well-established that the abundant access to programming and online content can negatively impact SACA including exposure to risky lifestyle behaviors (eg, unhealthy food, beverage and alcohol consumption) through marketing and advertising,[5,6] issues of "digital dependency" or screen addiction, as well as, risks of exposure to cyberbullying, age-inappropriate and violent content, or sexual exploitation.[7,8] Because of these concerns, both American and Canadian Pediatric Societies issued a recommendation of no more than 2 hours per day of screen time in SACA.[9,10]

Furthermore, as screen use has increased considerably around the globe, especially among SACA, it is often at the expense of physical activity.[8] In fact, in a pooled analysis of 1.6 million adolescents (aged 11-17 years), approximately 81% were insufficiently physically active in 2016 globally.[11] In the same vein, the coronavirus disease 2019 (COVID-19) pandemic and its mitigation responses have perturbed routines and lifestyle activities, particularly with the closure of schools and transition to online learning, which may reinforce physical inactivity, sedentary time, and screen use.[12] With this in mind, the World Health Organization 2020 global guidelines call for children and adolescents to accumulate at least an average of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day, and muscle and bone strengthening activities should each be incorporated at least 3 days per week.[13]

On the contrary, digital technologies can also promote beneficial evidence-based outcomes in this population, when used in a safe, responsible, and healthy manner. For example, traditional and innovative media can promote novel ideas and knowledge, and increase social networking and support, opportunities to access health promotion messages and information, as well as interactive eSports participation.[14,15] Previous systematic reviews have investigated the impact of a variety of interventions (single and multicomponent) on sedentary behavior, screen time and physical activity outcomes, which include classroom-based health promotion curriculum, individual counseling for both parents and children, time budgets or time allowances for screen use, media usage diaries, and automated programs that control screen time usage.[16–23] However, these reviews, although insightful, did not exclusively focus on school-aged children and adolescents, and often pooled data from both normal, and overweight and obese participants. Moreover, a previous scoping review conducted by the present authors of this review highlighted the need to distinguish whether nondigital interventions aimed at reducing sedentary behavior and screen time were more effective with certain types of screen use than others. It was found that previous systematic reviews either focused on just one type of screen use (eg, TV use), or grouped all forms of screen time in one pooled analysis making it difficult to parse out distinct intervention effects.[16–22] Therefore, the authors of this review aim to update the knowledge base and evaluate the effectiveness of nondigital interventions to reduce screen use and sedentary behavior, in school-aged children and adolescents aged 5 to 19.9 years globally.

METHODS

Reporting and Protocol

The protocol for this review was registered within the International Prospective Register of Systematic Reviews (PROSPERO #: CRD42020213361). This review was originally designed to evaluate the effectiveness of both (1) nondigital interventions to reduce screen use and sedentary behavior, and (2) digital-based interventions for universal health promotion in school-aged children and adolescents. One search strategy was used (Supplemental Information), and eligible studies were screened together until the abstraction phase, at which time included studies were abstracted and analyzed separately between studies reporting nondigital interventions and those studies assessing digital-based

interventions. Given the large number of studies included, the review authors decided to report the evidence synthesis separately.[24] As guidance, we propose a socio-ecological conceptual framework for digital and nondigital health interventions (Fig 1).

Information Sources and Search Strategy

Searches were conducted using a specified search strategy (Supplemental Information) in the following databases: PubMed, Embase, Medline, PsycINFO, Cumulative Index to Nursing and Allied Health Literature, The Cochrane Library, Cochrane Central Register of Controlled Trials (CENTRAL), Cochrane Methodology Register, and the World Health Organization regional databases. The terms were combined with the Cochrane Medline filter for controlled trials of interventions. There were no limitations on geographical settings, publication language, or duration of intervention follow-up. The final search was completed March 16, 2021. Additional details about the search strategy development and other information sources are included in Vaivada et al.[25]

Screening and Selection Process

Although all screening was conducted by a single reviewer, full-text review and data abstraction were conducted in duplicate. Expanded details of the screening and selection process for this review can be found in Vaivada et al.[25] Specific eligibility criteria were used to screen and select studies for inclusion (Table 1).

Eligible study designs included randomized controlled trials (RCTs), quasi-experimental studies (QES), and nonrandomized trials that already assessed the feasibility of the intervention to evaluate the research question.[26] As such, small pilot or feasibility trials without any follow-up larger trials were excluded. Studies were eligible if published in 2000 or after. Classification of high-income countries (HIC) and low- and middle-income countries (LMIC) was conducted according to the World Bank's 2019 fiscal year country income classification. Studies that included both children and adolescent participants without disaggregating the age groups were included, where the majority of the study's sample age fell within the selected age range, or the average mean age reported was between 5 and 19.9 years.

Interventions were defined as any planned action, program, or policy that was implemented to promote healthy digital media use and to reduce sedentary behaviors, screen use, or screen time (Table 1). Eligible comparisons were no

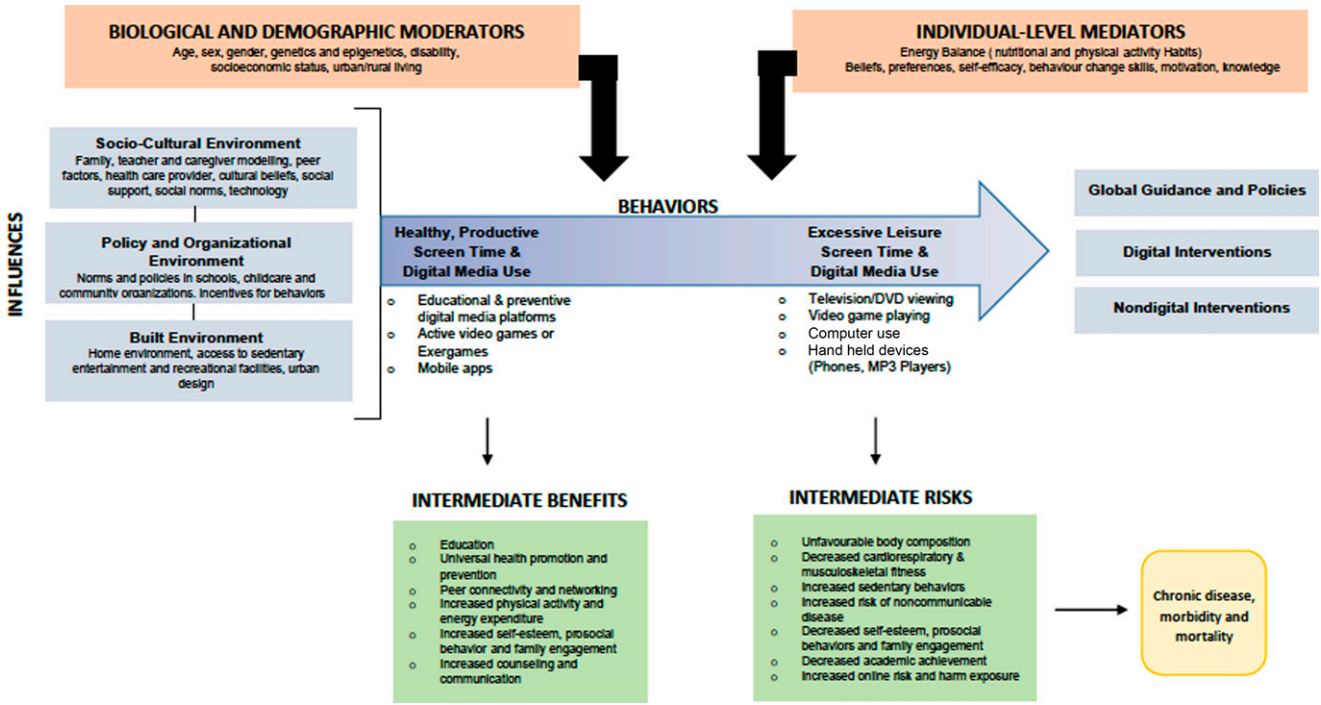

FIGURE 1

Conceptual framework. Child and adolescent screen time and sedentary behaviors are influenced by microenvironments, as well as mediation (individual-level), and moderation (biological/demographics) factors, leading to intermediate benefits or risks, long-term morbidity, and mortality. Such a framework helps illustrate the complexity of these behaviors, guides research, and supports intervention and policy development.

TABLE 1 PICO

	Inclusion	Exclusion
Population	Healthy, male and female children (5–9.9 y) and adolescents (10–19.9 y) with no chronic or existing medical condition, living in a low, middle or high- income country	Unhealthy population, including but not limited to acute or chronic conditions/diseases, genetic diseases Mean age of participants <5 y or >19.9 y
Intervention	Nondigital interventions that aim to reduce screen time and sedentary behavior, with data collected in or after the year 2000 Eligible study designs: Randomized controlled trials (RCTs) Quasi-experimental studies (QES) and nonrandomized trials (NRTs) ■ natural experiment designs ■ controlled before-after ■ regression discontinuity designs ■ interrupted time series	Irrelevant study designs: observational and cross-sectional studies, feasibility studies, reviews
Comparator	No intervention (placebo) Standard arm of care (e.g., existing school programs, activities, or initiatives) Other intervention arms in the case of a multicomponent intervention (e.g., nutrition education arm versus nutrition education + digital component)	
Outcomes	Primary outcomes Screen time or screen use, as author defined (continuous and dichotomous outcomes), including digital dependency, screen addiction or excessive screen use Sedentary behavior Secondary Outcomes Physical activity: all outcomes as author defined pertaining to the measurement of physical activity and energy expenditure	

intervention (placebo), standard arm of care (eg, existing school programs, activities, or initiatives), or other intervention arms in the case of a multicomponent intervention (eg, nutrition education arm versus nutrition education + digital component). Studies were excluded if the primary aim of the intervention(s) was treatment, therapy, and/or management of existing chronic disease (ie, weight loss or treatment of diagnosed overweight and obesity). Only interventions that specifically measured our primary outcomes of interest (screen time and sedentary behavior, as author defined) were included. Although we are aware that physical activity-focused interventions may address sedentary behavior in terms of increases in physical activity or aerobic performance, these metrics were not primary outcomes of interest for this review.

Data Synthesis and Statistical Analysis

Statistical analysis was conducted using Review Manager 5.4 software. Randomized controlled trials and cluster-randomized controlled trials were analyzed separately from quasi-experimental study designs. Meta-analyses were conducted for each outcome of interest, only when there were data fora minimum of 3 studies. Where multiple measures were reported for an outcome in a single study, we used the most commonly reported measure across all included studies. To mitigate heterogeneity within included studies, a random effects meta-analysis was used for all pooled outcomes. Overall effect estimates were considered statistically significant if the associated P value was $<.05$.

Because of variation in when studies evaluated outcomes after intervention, when given the choice between after intervention and an alternative, and longer follow-up period, we reported the time point that immediately followed the end of the intervention. This was done where possible across all studies for more consistent and generalizable synthesis. Where possible and appropriate, unit conversions were conducted; this was largely done for screen time and sedentary behavior outcomes where screen time was

measured differently (ie, hours/day versus minutes/day). We did not adjust estimates for clustering if cluster-randomized-controlled trials did report adjusted estimates. Sensitivity analyses were not conducted given the lack of studies that could be isolated and provide any meaningful or valuable additional synthesis.

Risk of Bias Assessment

Assessment of risk of bias for included studies were conducted according to criteria and tools outlined in the Cochrane Handbook for Systematic Reviews of Interventions[26] and the Cochrane Effective Practice and Organization of Care guidelines[27] for randomized trials, nonrandomized trials, controlled before-after and interrupted time series. C.O. and B.C. independently assessed risk of bias for each study. These scores were compared and a final score decision was made.

Specifically, randomized trials were assessed using the Cochrane Risk of Bias tool[26,28] across the following domains: randomization process, deviations from the intended interventions (blinding of personnel, participants, and outcome assessment), missing outcome data, outcome measurement, the selection of the reported result, and disclosure of funding and conflicts of interest. Studies were assigned an overall risk of bias judgement accordingly (low risk, high risk, or some concerns).

Quasi-experimental study designs were assessed using the Risk of Bias tool for Nonrandomized Studies of Interventions (ROBINS-I) tool.[26,29] Studies were assessed according to the following domains: bias because of confounding, bias in selection of study participants, bias in classification of interventions, bias because of deviations from intended interventions, bias because of missing data, bias in measurement of outcomes, and bias in selection of the reported result. Each study was assigned an overall risk of bias judgement (low, moderate, serious, and critical risk).

Quality Assessment

A summary of the intervention effect and a measure of quality for all outcomes were produced using the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach.[30] The GRADE approach considers 5 domains (study limitations, consistency of effect, imprecision, indirectness, and publication bias) to assess the quality of the body of evidence for each outcome. The evidence was downgraded from "high quality" by one level for serious (or by two levels for very serious) limitations, depending on assessments for risk of bias, indirectness of evidence, serious inconsistency, imprecision of effect estimates, or potential publication bias.

RESULTS

Results of the Search

A database search produced 29 301 records and hand searching revealed another 168 records. After removal of 9132 duplicates, 20 337 records were screened at the title-abstract stage, which identified 680 records for full-text review. Of these, 51 studies (146 articles) met our inclusion criteria for nondigital interventions and 23 were included in the meta-analysis. We excluded 407 records at the full-text review stage for reasons including wrong intervention type, wrong study design, wrong comparator, wrong patient population or wrong outcomes (Supplemental File). Figure 2 shows the study breakdown across exclusion reasons.

Description of Included Studies

Of the 51 included studies, 37 were RCTs,[31–67] 4 were nonrandomized controlled trials,[68–71] and 10 were quasi-experimental studies.[72–81]

Forty-four studies were conducted in HIC, including two studies that were multicenter (Australia, Belgium, Cyprus, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, New Zealand, Norway, Switzerland, Sweden, Spain, United Kingdom, and United States), and 7 in LMIC (Brazil, Ecuador, Lebanon, China, Mexico, and Iran).

Most studies were conducted in school settings, with the exception of 7 studies that were conducted in the community[33,38,49,66,69] or participant's homes.[37,40] Intervention duration ranged from 8 weeks to 4 years. Sixteen studies conducted interventions that ran for 18 months or longer (up to 7 years), whereas another 17 studies implemented interventions that spanned one school year (typically 8-12 months). The remaining studies ($n = 17$) implemented interventions for a duration of <6 months, and 1 study was unclear in its duration[48] (see Table 2 for characteristics of included studies).

All interventions employed a behavioral modification component including classroom education (ie, didactic, peer-to-peer, or exercise activities), family and community engagement and counseling (ie, newsletters and other media) to promote the benefits of physical activity, the risk of sedentary behavior, and excessive screen use. Some interventions also included other components, such as school and home environment modifications (ie, greater access to healthy foods in the cafeteria, improved physical activity spaces and equipment at school, and implementation of school wellness policies).[32,43,49,51,55,57–60,80] None of the studies disaggregated outcome data based on discrete behavioral and environmental components, providing a limited ability to analyze and understand the specific component effects on outcomes in this age group.

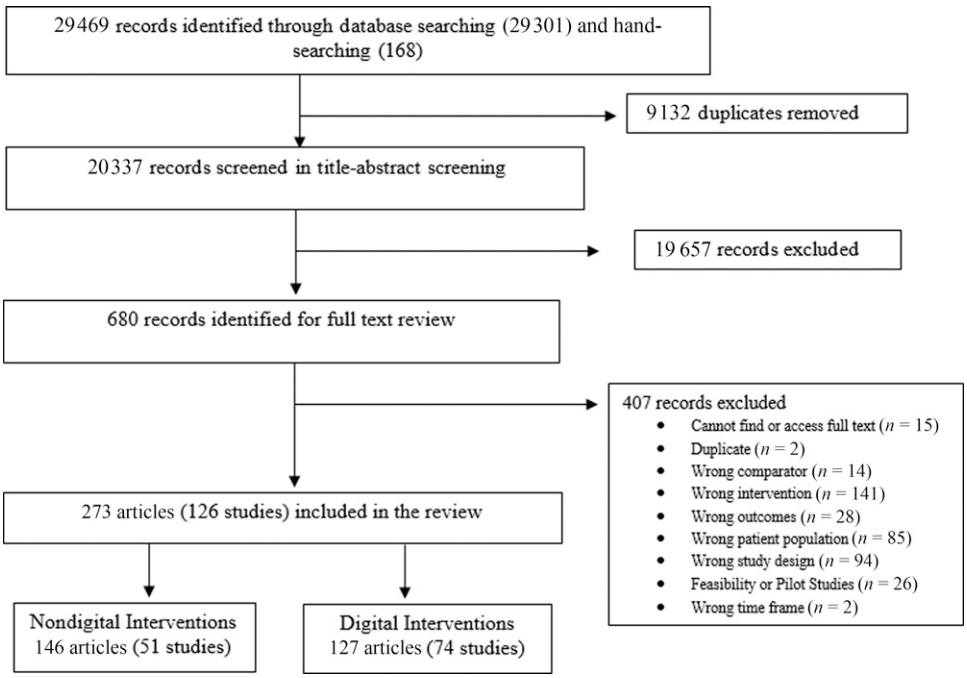

FIGURE 2
PRISMA diagram.

The mean age of participants ranged from 5.0 to 18 years of age. Approximately one-half of the studies (n = 23) reported a mean age <10 years, 11 studies included both school-aged children and adolescents, and the remaining studies reporting mean ages between 11 and 18 years.

Risk of Bias

The majority of nondigital based RCTs (28 of 37) were high risk of bias, six had some concerns,[31,32,43,52,66,67] and three were of low risk.[48,51,53] Randomization was considered adequate in 24 trials. A common reason for downgrading study quality was concerns with risk of bias due to deviations from the intended interventions, involving allocation concealment blinding processes, and outcome assessment. Allocation concealment was unclear in most studies (26 of 37). Blinding of participants and personnel was considered poor or unclear, with only four trials blinding participants,[48,51–53] 9 trials blinding personnel,[31–33,46,48,51–54] and 7 trials blinding outcome assessment.[32,48,51–53,59,67] Other reasons for downgrading study quality included attrition bias, disclosed funding and conflicts of interest. Attrition bias was considered high risk in 6 trials, with loss to follow-up ranging from 22%[44,56] to 32%.[60] The majority of studies disclosed funding, except for three studies,[35,38,47] whereas 9 studies did not declare their conflicts of interest.[34,35,53,55,58,60,62,63,78]

Of the nonrandomized controlled trials and QES, the majority of studies (9 of 14) were judged as having a moderate risk of bias because of poor adjustment of confounding variables, missing outcome data, subjective outcome assessments, and selected reported results. Three studies had an overall low risk of bias,[69,70,76] whereas two studies had serious risk.[74,78]

Effect of the Interventions

Eighteen studies were included in the RCT meta-analyses for nondigital based interventions,[31,32,36–38,40,43,47–53,56,57,60,62,68] whereas 5 studies were included in QES meta-analyses.[68,70,71,73,81]

When compared with control groups, nondigital interventions probably results in a slight reduction of TV-specific screen time (minutes per day) (mean difference [MD], −12.46; 95% confidence interval [CI], −20.82 to −4.10; participants = 6097; studies = 6; I^2 = 59%; P = .004; moderate quality of evidence). Additionally, nondigital interventions may result in a reduction in screen time (all media types) (minutes per day) (MD −11.45; 95% CI, −19.18 to −3.73; participants = 7070; studies = 9; I^2= 38%; P = .004; low quality of evidence) (Figs 3 and 4).

TABLE 2 Characteristics of Included Studies (Nondigital Based Interventions for Screen Time and Sedentary Behaviors)

Source	Country, World Bank Region[a]	Study Design[b]	Participants (Sample Size, Age Range, Description)	Intervention		Reported Outcomes[c]
				Duration, Frequency	Description	
Andrade et al (32)	Ecuador, LAC	cRCT	*N* =1440, grades 8–9; mean age 12.8 (SD 0.8) y; 62.4% female	2 mo, every 2 wk	Classroom education on physical activity and screen time behavior; school environment modifications and parental workshops (ACTIVITAL)	ST
Aragon Neely et al (33)[d]	USA, NA	RCT	*N* = 439; 2–12 y; median age 5.0 y	4 mo	Play Nicely video or handout 'Pulling the Plug on TV violence'	ST, PA
Bickham et al (72)[d]	USA, NA	QES	*N* = 529; grades 6–8 living in rural school district	3-4 mo (1 semester)	Peer-to-peer education about health effects of excessive screen media use (Take the Challenge)	ST, PA
Breslin et al (73)	Ireland, ECA	QES	*N* = 416; 8–9 y; primary school children from lower socioeconomic backgrounds	12 wk, weekly	Education and activities on effects of physical activity on health and nutrition (Sport for LIFE)	ST, PA, SB
Colin-Ramirez et al (34)[d]	Mexico, LAC	RCT	*N* = 619; 8–10 y; mean age 9.4 (SD 0.7) primary school students from low SES; ∼48% female	1 y, weekly	Education on physical activity and sedentary behavior; exercise breaks and physical activity classes (RESCATE)	ST
Cong et al (74)[d]	USA, NA	QES	*N* = 416; 5–9 y; Hispanic children from low-income backgrounds	22 mo	Education and exercise activities to reduce TV and video game screen time and increase physical activity (Transformacion Para Salud)	ST
Contento et al (35)[d]	USA, NA	cRCT	*N* = 1136; inner city seventh grade students; mean age 12 y	8-10 wk	Education on healthy food and activity choices and agency (C3 Intervention)	ST
Cronholm et al (70)	Sweden, ECA	CBA	*N* = 228; mean age 14.8y; 59% boys	7 y	Increase in physical activity curriculum	ST, PA
Duncan et al (36)	New Zealand, EAP	cRCT	*N* = 675; primary school students; 7–10 y	1 y	Education to promote physical activity and healthy eating (Healthy Homework)	ST, PA, SB

TABLE 2 Continued

Source	Country, World Bank Region[a]	Study Design[b]	Participants (Sample Size, Age Range, Description)	Intervention		Reported Outcomes[c]
				Duration, Frequency	Description	
Epstein et al (37)	USA, NA	RCT	$N = 70$; 4–7 y; ≥75th BMI percentile for age and sex; participate in at least 14 h of RV viewing and computer game per week	2 y	TV monitoring device recorded number of minutes of use at the home; education on alternatives to sedentary behaviors; tailored monthly newsletter for parents	ST, PA
Escobar-Chaves et al (38)	USA, NA	RCT	$N = 202$; 6–9 y; children from large, urban multiethnic population	6 mo, biweekly	2-h workshop and 6 bimonthly newsletters to reduce screen time/TV use	ST
Filho et al 2019 (39)[d]	Brazil, LAC	cRCT	$N = 1272$; grades 7–9 students from full-time schools in neighborhoods of socially vulnerable areas; 11–18 y	4 mo, weekly	Education on excessive screen time and opportunities for increased physical activity at school; health promotion posters and flyers (Fortaleça sua Saúde)	ST, PA
Foster et al (60)	USA, NA	cRCT	$N = 1349$; grades 4–6 students from schools where 50% of the students are eligible for free or reduced-price meals; mean age 11 y	2 y	Nutrition education; nutrition policy and social marketing at school; parent outreach and involvement (School Nutrition Policy Initiative)	ST, SB
Fulkerson et al (40)	USA, NA	RCT	$N = 160$; 8–12 y with BMI >50th percentile for age	1 y, monthly	Education for student and parent on nutrition and physical activity (HomePlus)	ST
Gentile et al (41)[d]	USA, NA	RCT	$N = 1323$; grades 3–5 students; mean age 9.6 y; 53% female	8 mo	Paid and unpaid advertising and media promotion, and education on limiting screen time use, increasing physical activity, and improving nutrition (Switch what you Do, View, and Chew)	ST, PA
Gholamian et al (75)[d]	Iran, MENA	QES	$N = 120$; adolescent girls with internet addiction from high schools of	2 mo	2-d education session for students; 1 session for parents about	ST

TABLE 2 Continued

Source	Country, World Bank Region[a]	Study Design[b]	Participants (Sample Size, Age Range, Description)	Intervention		Reported Outcomes[c]
				Duration, Frequency	Description	
			same social and economic situation; 16–17 y		excessive internet use and related health effects	
Habib-Mourad et al (42)[d]	Lebanon, MENA	cRCT	$N = 2276$; grades 4–5; 9–11 y	3 mo, weekly	Education and interactive activities on decreasing sedentary behavior, increasing physical activity, and increasing healthy food consumption (Health-E-PALS)	PA, SB
Harrison et al (76)[d]	Ireland, ECA	QES	$N = 312$; students from schools in areas of social disadvantage; mean age 10.2 (SD 0.7) y	16 wk, weekly	Education on increasing physical activity and reducing screen time with personal workbooks to record leisure time/screen time use (Switch off -Get Active)	ST, PA
Jones et al (43)	USA, NA	cRCT	$N = 718$; girls in the sixth grade enrolled in 2 semesters of physical education; mean age 11.6 (SD 0.4)	18 mo	Health curriculum and peer-based behavioral journalism, physical education program and improvement of school food service (IMPACT)	ST, PA, SB
Kipping et al (31)	United Kingdom, ECA	cRCT	$N = 2221$; grades 4–6; 8–11 y	6-7 mo	Education on nutrition and reduced screen time use with homework activities; newsletters sent to parents (AFLY5)	ST, PA, SB
Knebel et al (44)[d]	Brazil, LAC	cRCT	$N = 999$; grades 7–9	10 mo	Education on health eating, physical activity, and screen time use; school environment modifications; teacher training (Movimente)	ST
Kobel et al (45)[d]	Germany, ECA	cRCT	$N = 1943$; grades 1–2; 48.8% female; mean age 7.1 (SD 0.6)	1 y, mixed	Education and alternative recreational activities for physical activity and reduced	ST, PA

TABLE 2 Continued

Source	Country, World Bank Region[a]	Study Design[b]	Participants (Sample Size, Age Range, Description)	Intervention		Reported Outcomes[c]
				Duration, Frequency	Description	
					screen time use (Join the Healthy Boat)	
Lindenberg et al (46)[d]	Germany, ECA	cRCT	$N = 2430$; students at risk for internet use disorder (CIUS≥20); 12–18 y	1 y	Education focused on internet use disorder and related behaviors and mental health (PROTECT)	ST
Llargues et al (47)	Spain, ECA	cRCT	$N = 426$; 5–6 y; primary school children	2 y	Education of healthy dietary habits and physical activity	ST, PA
Lloyd et al (48)	United Kingdom, ECA	cRCT	$N = 1324$; 9–10 y; students from state-run primary and junior schools	Unclear duration, daily	Education on healthy lifestyle behaviors; creation of supportive environments and personal goal setting with parental support (Healthy Lifestyles Program)	PA, SB
Morgan et al (66)[d]	Australia, EAP	RCT	$N = 115$ fathers (29–53 y) and 153 daughters (4–12 y); mean age 7.7 (SD 1.8)	2 mo	Education on physical activity, socio-emotional wellbeing, and engagement in activities (DADEE program)	ST, PA
Novotny et al (49)	USA, NA	cRCT	N=4333; 2–8 y	2 y	Increased access to healthy foods and environments for safe play; strengthened school wellness policies; social marketing and training (Children's Healthy Living Program)	ST, PA
Neumark-Sztainer et al (61)[d]	USA, NA	cRCT	$N = 356$ girls; mean age 15.9 (SD 1.2); 75% were racial/ ethnic minorities	9 mo, 2 cohorts, weekly	Physical education, individual counseling, parent outreach and lunch get-togethers (New Moves)	ST, PA, SB
Nyberg et al (50)	Sweden, ECA	cRCT	$N = 378$; 6-y old students living in disadvantaged areas	6 mo	Education and motivational interviewing on physical activity, reducing screen time and healthy eating (Healthy School Start)	ST, PA, SB

TABLE 2 Continued

Source	Country, World Bank Region[a]	Study Design[b]	Participants (Sample Size, Age Range, Description)	Intervention		Reported Outcomes[c]
				Duration, Frequency	Description	
Pardo et al (77)[d]	Spain, ECA	QES	$N = 682$; 12–15 y	3 y, daily	Education and extracurricular activities on reducing screen time and sweetened beverage consumption, and increasing physical activity (Sigue la Huella (Follow the Footstep))	ST, SB
Puder et al (51)	Switzerland, ECA	cRCT	$N = 652$; predominately migrant children; mean age 5.2 (SD 0.6)	9.5 mo, mixed	Physical activity sessions and environmental changes, parental education, teacher training and healthy food promotion (Ballabeina)	ST, PA
Racine et al (78)[d]	USA, NA	QES	$N = 1027$; 8–13 y; 60% female	12 wk, weekly	Physical activities and education on healthy lifestyle behaviors, nutrition and staying active	ST, PA
Robinson (53)	USA, NA	RCT	$N = 198$; grades 3–4; 8–10 y; mean age 8.9 y	1 y	Education on self-monitoring and self-reporting of screen time use	ST, PA, SB
Robinson et al (52)	USA, NA	RCT	$N = 284$; 8–10 y African American girls from low-income areas; with BMI ≥25th percentile for age and/or at least 1 overweight parent or guardian	2 y	Afterschool dance intervention offered 5 d/wk (Stanford GEMS)	ST, PA
Sahota et al (54)[d]	United Kingdom, ECA	cRCT	$N = 636$ children; 7–11 y; mean age 8.4 y (SD 0.63)	1 y	Active program promoting lifestyle education, modification of school meals, school action plans (APPLES)	PA, SB
Salmon et al (55)[d]	Australia, EAP	cRCT	$N = 311$; grade 5 students from primary schools from low socioeconomic areas; 10.6 y	9 mo	Behavior modification and functional movement intervention, in addition to physical activity classes (Switch-Play)	ST, PA

TABLE 2 Continued

Source	Country, World Bank Region[a]	Study Design[b]	Participants (Sample Size, Age Range, Description)	Intervention		Reported Outcomes[c]
				Duration, Frequency	Description	
Salmon et al (64)[d]	Australia, EAP	cRCT	*N* = 293 children; 7–9 y, mean age 8.0 (SD 1.3)	18 mo	Education and environmental changes including signage, physical activity equipment (Transform Us!)	ST
Salway et al (65)[d]	United Kingdom, ECA	cRCT	*N* = 1558 girls, 13–14 y	5 mo	Peer-led intervention to promote physical activity (PLAN-A)	ST, PA, SB
Schmidt et al (71)	Norway, ECA	nRCT	*N* = 813; 13–15 y	7 mo	Teacher-led activities to promote healthy lifestyles (Active and Healthy Kids Program)	PA, ST
Sevil et al (81)	Spain, ECA	QES	*N* = 225; 12–14 y; mean age 13.06 ± 0.61; 52.9% girls	One school year	A multicomponent intervention with curricular (ie, tutorial action plan, interdisciplinary project, and school break) and extracurricular (ie, family involvement, institutional and noncurricular activities, and dissemination of health information and events) actions to promote adolescents' healthy lifestyles	ST, PA, SB
Simon et al (62)	France, ECA	RCT	*N* = 954; 11–12 y; mean age 11.7 (SD 0.6) y	4 y, weekly	Education on physical activity and sedentary behavior; new opportunities for physical activity during school/after-school hours (ICAPS)	ST, PA
Spruijt-Metz et al (63)[d]	USA, NA	cRCT	*N* = 459; middle school girls; 75% Latina; mean age 12.5 y	5-7 d, daily	Education and activities on physical activity and sedentary behavior (Get Moving!)	ST, PA
Tarro et al (56)	Spain, ECA	cRCT	*N* = 702; children and adolescents from primary and high schools in disadvantaged	9 mo	Peer-led education and social marketing health-promoting activities to promote physical	ST, PA

TABLE 2 Continued

Source	Country, World Bank Region[a]	Study Design[b]	Participants (Sample Size, Age Range, Description)	Intervention		Reported Outcomes[c]
				Duration, Frequency	Description	
			neighborhoods; 9–11 y		activity, healthy eating and reduce screen time (EYTO-Kids project)	
Van Kann et al (79)[d]	Netherlands, ECA	QES	$N = 791$; grades 6–7; 8–11 y	1 y, daily	School environment modifications including increased recess, new equipment, and opportunities for physical activity (Active Living Project)	PA, SB
Van Lippevelde et al (57)	Germany, Belgium, Greece, Hungry and Norway, ECA	cRCT	$N = 3325$; 10–12 y; mean age 11.2 y	2 mo, weekly	Education on increased awareness about sedentary behaviors; goal setting and home environment modifications (UP4FUN)	ST, SB
Van Nassau et al (68)	Netherlands, ECA	nRCT	$N = 2088$; 12–14 y	20 mo	Education on physical activity and other healthy lifestyle behaviors (DOiT)	ST, PA
van Stralen et al (80)[d]	Netherlands, ECA	QES	$N = 600$; grades 6–7; 8–12 y; mean age 9.8 (SD 0.7 y); 51% girls; 13% Dutch ethnicity; 35% overweight	20 mo	Increased sports participation; personal workbooks for children and parents; parental information about developing supportive home environments (JUMP-in)	ST, PA
Veldman et al (67)[d]	Australia, EAP	cRCT	$N = 60$; 5–10 y; mean age 7.7 SD 1.8, 50% girls	6 mo	Promotion of physical activity through team sport activities and academic enrichment	PA, SB
Verbestel et al (69)[d]	Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, and Sweden, ECA	nRCT	$N = 9184$; 2–9.9 y	2 y	Education on healthy lifestyle behaviors including decreased daily screen time use and increasing daily physical activity (IDEFICS)	PA, SB

TABLE 2 Continued

Source	Country, World Bank Region[a]	Study Design[b]	Participants (Sample Size, Age Range, Description)	Intervention		Reported Outcomes[c]
				Duration, Frequency	Description	
Wang et al (58)[d]	USA, NA	RCT	*N* = 450; grades 5–8 African American adolescents in public schools in low socioeconomic urban areas; 9–14 y	18 mo	School and community environment enrichment and modifications; family support to reduce sedentary behavior and increase other healthy behaviors (HEALTH-KIDS)	PA, ST
Xu et al (59)[d]	China, EAP	cRCT	*N* = 1182; grade 4 students; mean age 10.2 (SD 0.5)	1 y (2 school semesters), mixed	Education on healthy behaviors; school environment promotion; family involvement and fun programs/ events for students (CLICK-Obesity)	ST

[a] World Bank regions: EAP, East Asia Pacific; ECA, Europe & Central Asia; LAC, Latin America & Caribbean; MENA, Middle East & North Africa; NA, North America; SA, South Asia; SSA, Sub-Saharan Africa.
[b] CBA, controlled before-after; cRCT, cluster randomized controlled trial; nRCT, nonrandomized controlled trial; QES, quasi-experimental study; RCT, randomized controlled trial.
[c] PA, physical activity; SB, sedentary behavior; ST, screen time.
[d] Studies were excluded from analysis for reasons including, unclear sample sizes at follow-up or post-intervention, lack of disaggregation of data between intervention and control groups, no outcomes of interest.

However, these interventions may make little to no difference on reducing screen time specific to computer gaming or video gaming (minutes per day) given the high uncertainty of the evidence (MD, −3.51; 95% CI, −9.02 to 2.01; participants = 5365; studies = 5; I^2 = 56%; *P* = .21; very low quality of evidence). With regards to sedentary behavior, nondigital interventions probably result in a slight reduction of sedentary time (minutes per day) as compared with controls (MD, −3.86; 95% CI, −6.30 to −1.41; participants = 8920; studies = 8; I^2 = 0%; *P* = .002; moderate quality of evidence) (Figs 5 and 6).

The effects of nondigital interventions on MVPA (minutes per day) as compared with control groups may make little to no difference on increasing MVPA (MD, −0.07; 95% CI, −1.83 to 1.69; participants = 5540; studies = 6; I^2 = 31%; *P* = .94; low quality of evidence). Two RCTs reported accelerometer data for weekdays and weekends (counts per minute or steps per day).[52,69] However, both studies found nonsignificant differences between intervention and control groups at follow-up, after adjustment (Fig 7).

With regards to QES, nondigital interventions may make little to no difference on reducing screen time of all media types (minutes per day) (MD, −26.76; 95% CI, −67.31 to 13.79; participants = 1984; studies = 3; I^2 = 97%; *P* = .20; very low quality of evidence) or sedentary behavior (minutes per day) (MD, −9.65; 95% CI, −41.05 to 21.75; participants = 1010; studies = 3; I^2 = 90%; *P* = .60; very low quality of evidence), given the high uncertainty of the evidence (Supplemental Information).

DISCUSSION

This review provides a comprehensive appraisal of 51 studies conducted in 24 countries, evaluating nondigital interventions aimed at minimizing screen time and sedentary behavior in healthy children and adolescents of normal BMI. This review analyzed over 16 000 children and adolescents and included 19 new trials, conducted in the last 5 years.[17,31,36,39,40,44–46,

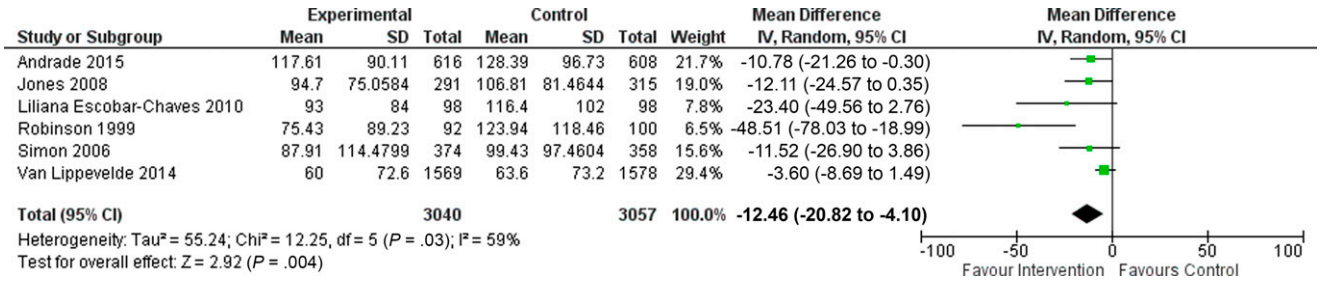

FIGURE 3
Forest plot of screen time (author-defined TV; minutes per day).

[48–50,56,65–67,69–71,81] Our review suggests that nondigital interventions indeed resulted in a small, but significant reduction in sedentary behavior. This review also indicates that nondigital interventions were most successful at reducing TV screen time compared with other forms of screen time, such as computer and gaming. Although there are many previous reviews that evaluated both single and multicomponent interventions in a variety of populations, including overweight and obese participants, it was important that this review focus solely on healthy children and adolescents, to provide greater insight into the possible effectiveness and potential of these interventions in public health prevention initiatives.

Previous systematic reviews[16–23] found similar results, whereby screen time from all media types was reduced by 10 to 20 minutes per day in intervention groups when compared with control groups. However, these meta-analyses varied in their inclusion criteria of participants (ie, exclusively overweight and obese populations) and in some cases, both preschool and adult populations. For example, van Grieken et al[19] reported adolescent screen time use was reduced by a mean of −17.95 minutes per day (95% CI, −26.61 to −9.28) in a pooled analysis of 13 studies including overweight and obese adolescents. Likewise, Wahi et al[20] found in a pooled analysis of 9 studies in children (aged 3.9 to 11.7 years), intervention groups reduced screen time by a mean of −0.90 hours per week (95% CI, −3.47 to 1.66), however these results were not significant ($P = .49$). Albeit in the long-term, this small reduction does equate to some improvement in public health.

Interestingly, most interventions recruited young children, under the age of 13 years; perhaps as an effort to prevent excessive screen time and social media use in their later years, and to instill positive habits and long-term behavior change. Furthermore, a common observation of this review and previous systematic reviews is that a majority of the nondigital interventions targeting sedentary behavior and screen time are multicomponent and are often delivered through schools. Although this makes it difficult to evaluate the true effect of the screen time or sedentary behavior components, this observation suggests that addressing behavioral change in school-aged children and adolescents are most effective when

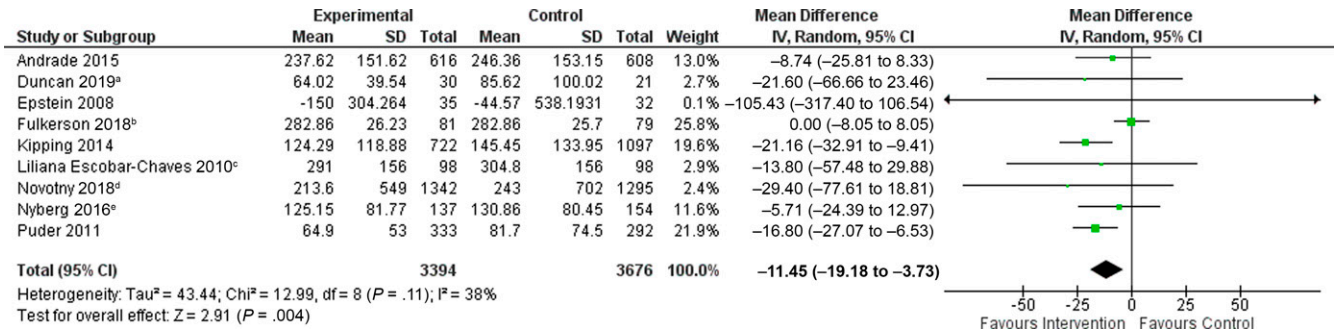

FIGURE 4
Forest plot of screen time all media (author defined; minutes per day). [a]Reported as hours per day, converted to minutes per day. [b]Reported as hours per week, converted to minutes per day. [c]Reported as hours per day, converted to minutes per day. [d]Reported as hours per day, converted to minutes per day. [e]Unpublished data, requested from author.

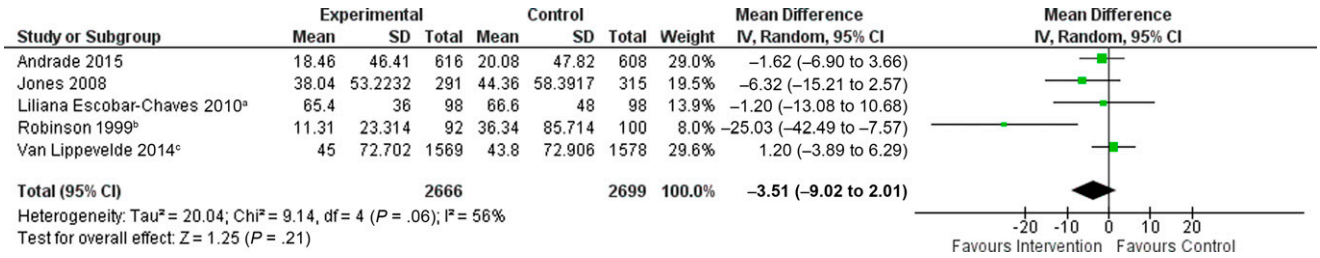

FIGURE 5

Forest plot of screen time (author defined computer gaming or video games; minutes per day). [a]Reported as hours per day, converted to minutes per day. [b]Reported as hours per week, converted to minutes per day. [c]Reported as hours per day, converted to minutes per day.

used as a comprehensive and multifaceted strategy rather than a singular-component intervention. Similarly, school-based interventions alone may not be enough to counteract the trend of increasing screen time and sedentary behavior.

Although we included the largest number of studies to-date in a systematic review on screen time and sedentary behavior in SACA, most studies were conducted in HIC. It is possible that this finding is attributed to the stark inequality in digital connectivity in SACA living in LMIC. In the recent COVID-19 report, The International Telecommunication Union and United Nations Children's Fund (UNICEF) highlight that 1.2 billion children and adolescents (aged 3-17 years) do not have internet access at home, and primarily reside in South Asia, West, East, Central, or Southern Africa.[83] Likewise, disparities exist between HIC and LMIC in mobile phone ownership, although this gap is closing among youth. Physical inactivity, however, remains consistent across world regions.[11] Thus, as the world becomes more connected, we expect preventive interventions, policies, and programs to become more prevalent.

Unfortunately, this review and meta-analysis present similar gaps in the evidence and methodology as a previous scoping exercise of existing systematic reviews conducted by the authors. An overwhelming majority of interventions were implemented in high-income settings and the heterogeneity of available data because of diverse interventions, a lack of standardization of screen time metrics, vague and diverse methodologies, and use of subjective tools such as self-reported screen use limit the findings of this review. Thus, generalizability of these findings proves difficult. Furthermore, some of the findings of this review should be interpreted with caution, considering the quality of the evidence. Despite a robust number of studies included, very few were rated as high-quality. Moreover, although many studies reported a randomized-controlled design, the majority of included RCTs lacked description and/or implementation of more robust methods. Consistent with existing literature, the risk of bias in some areas was notable across the majority of studies; the most common risks of bias among included studies were failure to blind participants and personnel, attrition bias, and selective reporting. This limits and introduces a level of

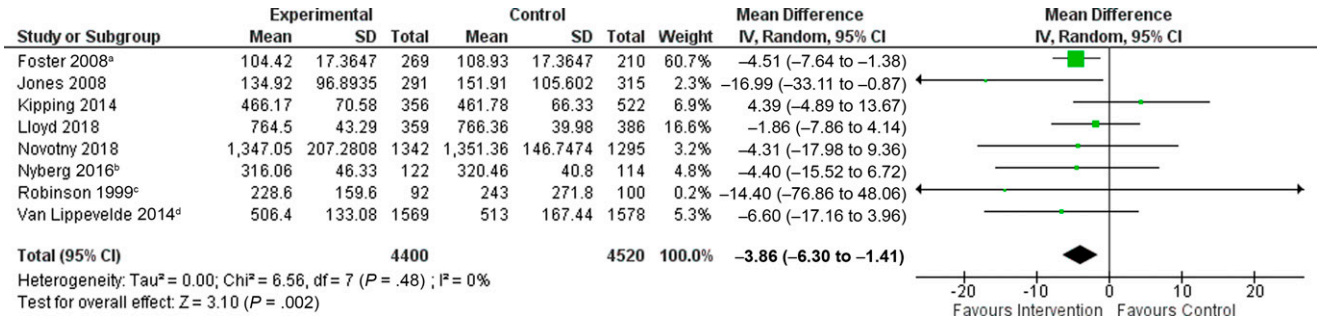

FIGURE 6

Forest plot of sedentary behavior (author-defined; minutes per day). [a]Reported as hours per week, converted to minutes per day. [b]Unpublished data, requested from author. [c]Reported as hours per day, converted to minutes per day. [d]Reported as hours per day, converted to minutes per day.

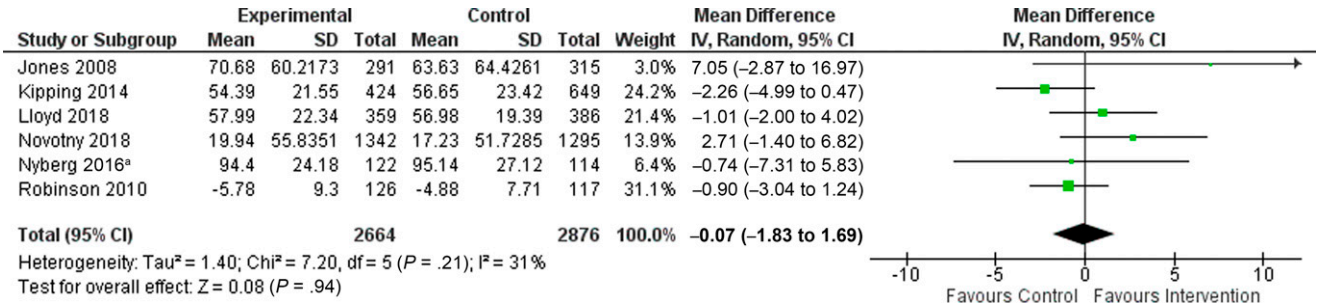

FIGURE 7

Forest plot of moderate-to-vigorous physical activity (minutes per day). [a]Unpublished data, requested from author.

uncertainty regarding the efficacy of these types of interventions.

Implications for Policy, Recommendations and Research

With the rise of digital technologies, the proliferation of technology and connectivity have led to increased sedentary behaviors and poorer lifestyle behaviors in this age group. We know that increasingly poor lifestyle behaviors among youth and adolescents are no longer population health issues relegated to high-income settings. Thus, utilizing nondigital interventions to promote universal health, including physical activity and minimizing screen time are critical for long-term gains in human health and development. Future research should examine screen time as a proportion of sedentary time, as well as use standardized and objective measures of screen use and sedentary time. Policies and programs which reduce sedentary time and excessive screen use will be critical, especially in the post-COVID 19 reality.

ABBREVIATIONS

BMI: body mass index
CI: confidence interval
COVID-19: coronavirus disease 2019
HIC: high-income countries
LMIC: low- and middle-income countries
MD: mean difference
MVPA: moderate-to-vigorous physical activity
SACA: school-aged children and adolescents

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