Systematic Review

The impact of smartphone app–based interventions on adolescents' dietary intake: a systematic review and evaluation of equity factor reporting in intervention studies

Holly N. Schaafsma [1,2], Heather A. Jantzi [2,3], Jamie A. Seabrook [2,4,5,6,7], Louise W. McEachern [2,3], Shauna M. Burke [2,6,8], Jennifer D. Irwin [8], and Jason A. Gilliland [2,3,5,6,7,8,*]

[1]Health and Rehabilitation Sciences, Faculty of Health Sciences, Western University, London, Ontario, Canada
[2]Children's Health Research Institute, London, Ontario, Canada
[3]Department of Geography, Western University, London, Ontario, Canada
[4]School of Food and Nutritional Sciences, Brescia University College at Western University, London, Ontario, Canada
[5]Department of Pediatrics, Western University, London, Ontario, Canada
[6]Lawson Health Research Institute, London, Ontario, Canada
[7]Department of Epidemiology and Biostatistics, Western University, London, Ontario, Canada
[8]School of Health Studies, Western University, London, Ontario, Canada
*Correspondence: *J.A. Gilliland*, Department of Geography, Western University, 2333 Social Science Centre, 1151 Richmond St, London, ON N6G 2V4, Canada. E-mail: heal@uwo.ca.

Context: *Adolescence is a critical stage for improving nutrition. The popularity of smartphones makes them an ideal platform for administering interventions to adolescents. A systematic review has yet to assess the impact of smartphone app–based interventions exclusively on adolescents' dietary intake. Furthermore, despite the impact of equity factors on dietary intake and the claim for mobile health of increased accessibility, there is minimal research on the reporting of equity factors in the evaluation of smartphone app–based nutrition-intervention research.* ***Objectives:*** *This systematic review examines the effectiveness of smartphone app–based interventions on adolescents' dietary intake and the frequency with which equity factors and statistical analyses specific to equity factors are reported in these intervention studies.* ***Data Sources:*** *Databases (ie, Scopus, CINAHL, EMBASE, MEDLINE, PsycINFO, ERIC, and Cochrane Central Register for Randomized Control Trials) were searched for studies published from January 2008 to October 2022. Smartphone app–based intervention studies that were nutrition focused, evaluated at least 1 dietary intake variable, and included participants with a mean age between 10 and 19 years were included. All geographic locations were included.* ***Data Extraction and Analysis:*** *Study characteristics, intervention results, and reported equity factors were extracted. Because of the heterogeneity of dietary outcomes, findings were reported as a narrative synthesis.* ***Conclusion:*** *In total, 3087 studies were retrieved, 14 of which met the inclusion criteria. Eleven studies reported a statistically significant improvement in at least 1 dietary outcome because of the intervention. Reporting of at least 1 equity factor across articles' Introduction, Methods, Results, and Discussion sections was minimal (n = 5), and statistical analyses specific to equity factors were rare, occurring in only 4 of the 14 included studies. Future interventions should include a measurement of intervention adherence and report the impact of equity factors on the effectiveness and applicability of interventions for equity-deserving groups.*

Key words: app, adolescents, diet, equity, MHealth, smartphone.

https://doi.org/10.1093/nutrit/nuad058

INTRODUCTION

Mobile health and adolescence

Smartphones have become a popular platform for health-related interventions, due to their increased accessibility and ability to provide services to a wider scope of communities at a lower cost in comparison with in-person interventions.[1–3] Specifically, smartphone app–based interventions targeting diet are becoming more prevalent globally,[4,5] and research suggests they may improve dietary (eg, fruit and vegetable) intake and secondary clinical or obesity-related outcomes (eg, weight, blood glucose level) among children and adults.[6,7] Smartphone app–based nutrition interventions are particularly useful for the adolescent population because of this group's frequent use of smartphones.[8–10] The majority of youth 15–24 years old in Canada (97.9%)[10] and teens 13–17 years old in the United States (95%) report owning or having access to a smartphone,[9] and many European countries report that >80% of children 8–16 years old use a smartphone daily.[8] Furthermore, a systematic review of smartphone interventions reported that teens find smartphones to be an acceptable platform on which to view and receive health information.[11]

Adolescence is defined by the World Health Organization as the period of age from 10 to 19 years.[12] This period is an important phase of life for diet quality, because of both physical and social changes.[13–15] Specifically, adolescents have increased calorie and micronutrient needs due to puberty and rapid growth,[13] and poor nutrition can significantly impact their cognitive functioning (eg, academic performance, decision-making),[16] physical health,[17] and mental health.[18] Adolescence also entails prominent social changes, including a growing independence from caregivers regarding food choices.[14,15] Furthermore, the dietary habits formed in adolescence often follow into adulthood, increasing or reducing the risk of developing a chronic disease (eg, cardiovascular disease, diabetes, cancer).[19] Unfortunately, despite the importance of proper nutrition and the formation of healthy eating habits during adolescence, many adolescents worldwide do not meet the global recommendation to consume 5 or more servings of fruits and vegetables per day[20–23] and are exceeding the global recommendation for daily sugar intake (<10% daily energy intake).[24–26] Thus, exploring the effectiveness of smartphone app–based nutrition interventions at improving adolescents' dietary behaviors is warranted.

Previous systematic reviews have examined smartphone app–based nutrition interventions in adults and found significant improvements in nutrition knowledge and dietary intake.[27] However, there is a lack of conclusive evidence on the impact of smartphone app–based interventions on adolescent dietary intake. Existing reviews on youth smartphone app–based interventions have focused solely on weight management apps,[28] are limited in geographic location,[29] or focus exclusively on weight management outcomes as opposed to dietary behaviors.[28] One systematic review that evaluated the impact of general digital-based interventions (eg, email, website, computer games) on adolescent diet and physical activity called for future research to specifically evaluate the effect of smartphone-based interventions on adolescents.[30] Furthermore, to our knowledge, a review has yet to assess the effectiveness of smartphone app–based interventions independent of other intervention components on adolescent dietary intake; previous reviews evaluated the effectiveness of smartphone interventions that included other intervention components simultaneously (eg, in-person counselling or school-based education sessions in addition to a smartphone app).[6,7,27,30]

Equity considerations in mobile health and nutrition interventions

Although proponents of mobile health (mHealth) claim this approach is acceptable for diverse and hard-to-reach communities,[2,3] research has yet to be conducted on how equity is considered and reported in smartphone app–based nutrition intervention research. Equity is defined by the World Health Organization as the "absence of unfair, avoidable, or remediable differences among groups of people, whether those groups are defined socially, economically, demographically, or geographically or by other dimensions of inequality."[31] Although gender and/or sex is often reported by authors to describe their sample characteristics, surprisingly few intervention studies report equity factors such as ethnicity, socioeconomic status (SES), or place of residence, and the reporting of equity-specific analyses on intervention effectiveness is rare.[32] Equity factors are often ignored in the implementation and evaluation of nutrition interventions[33,34] despite the significant impact they have on diet quality,[35–37] which may inadvertently widen the already existing gap in health between the least and most systemically disadvantaged groups.[38] Furthermore, research on mHealth interventions in other health disciplines (eg, chronic disease management) have shown that such interventions are heavily affected by equity factors.[39,40] For example, gender has been shown to influence the use of mHealth platforms by adults, with women being more likely to use health apps and seek health information online than are men.[41] Furthermore, SES factors, such as income, may affect participants' access to a viable internet connection needed to use smartphone apps,[42] and lower educational attainment is associated with a low uptake of digital health interventions.[43] Thus, a review that assesses the frequency of reporting equity factors, including SES, ethnicity, gender and/or sex, and place of residence, and the use of statistical analyses specific to equity factors in smartphone app–based interventions is needed.

This systematic review was conducted to examine (1) the extent to which smartphone app–based nutrition interventions are effective at improving adolescents' dietary intake, and (2) whether equity factors such as SES, ethnicity, gender and/or sex, and place of residence, and statistical analyses specific to these equity factors, are reported in these studies, and if so, how they are reported.

METHODS

Literature search

This systematic review was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-Equity extension guideline[44] and was registered at Open Science Framework (https://doi.org/10.17605/OSF.IO/MD43R). To ensure comprehensiveness of the literature search, 7 databases in the nutrition, medicine, and education disciplines were searched (namely, Scopus, CINAHL, Embase, Medline, PsycINFO, ERIC, and Cochrane Central Register for Randomized Control Trials) in October 2022, using a search strategy of Medical Subject Headings and keywords developed in collaboration with a research librarian at Western University (see Figure S1 in the Supporting Information online). Covidence software[45] was used during the search to manage retrieved articles from the databases and remove duplicates for the screening process. In addition, the references of all included studies were manually screened for eligible studies. One study was found through reference screening and added to the final number of included articles.[46]

Inclusion and exclusion criteria

Inclusion and exclusion criteria were devised on the basis of the Population, Intervention, Control, and Outcome (PICO) research-question framework (Table 1).[47] For the population, the mean age of participants in the included studies must have been between 10 and 19 years, as defined by the World Health Organization's adolescent age range.[12] Adolescents considered healthy and those with a chronic disease (eg, obesity, diabetes, cancer) were included. Smartphone app–based interventions needed to be nutrition focused (eg, nutrition education) but could also target other health behaviors (eg, mental health, physical activity). Control groups could either receive no intervention or a traditional nutrition program (eg, in-person nutrition education). Intervention components had to be delivered through a smartphone app only. However, studies in which the control group received a traditional nutrition program and the intervention group received the traditional program plus a smartphone app intervention were also included, but only findings on group differences, specific to the impact of the smartphone app intervention, are reported in this review. Studies needed to evaluate at least 1 diet-related outcome variable (which could vary across studies), and studies could also evaluate other non-nutrition outcomes (eg, physical activity). All quantitative intervention study designs that evaluated the impact of their intervention were included (eg, randomized control trials, pre-post interventions, cross-over trials), whereas qualitative and nonintervention designs (eg, cross-sectional studies) were excluded. All geographic locations were included. Included studies had to be peer-reviewed published studies and available in English. Posters, conference abstracts, perspective papers, editorials, protocol papers, and dissertations were excluded. Finally, only studies published after January 2008 were included because 2008 is the year the Apple app store officially launched and smartphone apps became available. No inclusion or exclusion criteria specific to equity were used in this review, because the purpose was to evaluate the reporting of equity factors in the included interventions.

Study selection

The title and abstract of each retrieved article were screened independently by 2 reviewers for eligibility (H.N.S. and H.A.J.). The same 2 reviewers independently reviewed the full text. For both title and abstract and full-text screening, conflicts were resolved from

Table 1 **PICOS criteria for inclusion of studies**

Parameter	Inclusion criteria
Population	Adolescents with mean age between 10 and 19 y
Intervention	Delivered solely through smartphone application, included a nutrition component
Comparator	No control group (ie, pre-post intervention), control group receiving no intervention, or control group receiving traditional nutrition education
Outcome	Dietary intake (eg, fruit and vegetable intake, added sugar intake, breakfast consumption)
Study design	Pre-post intervention, randomized controlled trial, or nonrandomized controlled trial

discussion among the 2 reviewers, and when a consensus could not be achieved, a third reviewer adjudicated (J.A.G.).

Data extraction and quality assessment

The following study characteristics were extracted from the included studies: title, author(s), year, geographic location, study design, study objectives, sample characteristics (ie, sample size, mean age, age range, recruitment location, health status), intervention description (ie, mobile app name, intervention components), time line, evaluation tool, dietary outcome(s), and intervention result(s) (eg, impact on dietary outcome or outcomes [ie, difference in means, confidence intervals, if applicable; *P* values] and impact of intervention adherence, if applicable). Researchers have found that the use of theory to underpin the design of behavior change interventions can influence their effectiveness[48]; therefore, the reporting of a theoretical underpinning in the included studies was also extracted. To assess the quality of included studies, the JBI Checklist for Randomized Controlled Trials was used to evaluate the quality of randomized controlled trials (RCTs), and the JBI Checklist for Quasi-Experimental Studies was used to evaluate non-RCTs and pre-post intervention studies.[49] Because many of the questions between both checklists overlap, the JBI tools allow for quality comparisons to be made between study designs. Two reviewers (H.N.S. and H.A.J.) independently assessed the quality of the studies and resolved any conflicts between themselves; when consensus could not be reached, a third reviewer adjudicated (J.A.G.).

Equity reporting checklist

Information related to the reporting of sex and/or gender, SES, ethnicity, and place of residence and to analyses specific to these equity factors in the included studies was extracted using an equity checklist created by 1 author (H.N.S.), based on previous reviews on the reporting of equity factors in general health and physical activity interventions (Table 2).[50–52] The definitions of these equity factors were based on the PROGRESS framework.[38] The PROGRESS framework, created by Cochrane Methods, identifies the following as equity factors that affect health outcomes: place of residence, race/ethnicity, occupation, gender/sex, religion, education, SES, and social capital.[38]

For this review, any reference to sex (ie, biological) and/or gender (ie, identified) was categorized as sex/gender (S/G). Place of residence was defined as participants' living location (eg, town, region, community). School location was also included as a place of residence in this review because adolescents spend a significant amount of time in their school environment and it can be an important influence on their health.[53] SES, according to the PROGRESS framework, refers to an individual's income.[38] However, for the purpose of this review, *SES-related factors* was used as an umbrella term for any variable related to income, educational attainment, or occupational status, because these factors are often used interchangeably as components of SES in the literature.[54–56] Furthermore, different levels of SES status, including individual, parental/guardian, and family/household were included in this review. The PROGRESS framework encompasses race, ethnicity, culture, and language together in the same category.[38] Therefore, any mention of language or cultural identity–related variables were included in this review under ethnicity in addition to reporting of race or nationality; details on what was reported are specified in the results. Social capital, which refers to community connections resulting in accessibility to services,[38] was not included in this review, because it is heavily interrelated with SES.[38,57] Religion, defined by PROGRESS as a factor that can affect one's access to health services,[38] was outside the scope of this review and not explored.

RESULTS

Study selection

In total, the database search resulted in 6853 studies. After removal of duplicates, 3087 studies remained for title and abstract screening (Figure 1). Of these, 433 were included in the full-text screening. After assessing the eligibility of studies, 14 met the inclusion criteria and were included in this review. One additional article was included after review of reference lists of the 14 studies, and 1 was removed due to poor quality. Of these 14 total studies, 13 unique mobile-app interventions were reviewed. Two studies used the same intervention and sample population but assessed outcomes over a different intervention length.[58,59] Because of the heterogeneity of dietary outcomes examined across the included studies, a meta-analysis could not be completed. For this reason, the findings are synthesized as a narrative summary.

Sample characteristics

The mean age of participants ranged from 10.9[60] to 18.0 years.[61] The total sample size of the studies ranged from 15[62] to 988 adolescents.[63] Most studies recruited participants from secondary schools ($n = 8$).[46,60,63–68] Other recruitment locations included obesity or other health clinics ($n = 2$)[62,69]; a hospital and a school ($n = 2$)[58,59]; secondary schools, post-secondary schools,

Table 2 **Reporting of equity factors checklist**

Reference	Questions				
	1. 1 Introduction: Did authors discuss how SES is relevant to the research question and/or study outcomes?	1.2 Introduction: Did authors discuss how sex/gender is relevant to the research question and/or study outcomes?	1.3 Introduction: Did authors discuss how ethnicity is relevant to the research question and/or study outcomes?	1.4 Introduction: Did authors discuss how place of residence is relevant to the research question and/or study outcomes?	Describe details on section 1 here
	2.1 Methods: Did authors report how SES was considered in the intervention methodology (eg, recruitment, intervention design, statistical analyses)	2.2 Methods: Did authors report how sex/gender was considered in the intervention methodology (eg, recruitment, intervention design, statistical analyses)	2.3 Methods: Did authors report how ethnicity was considered in the intervention methodology (eg, recruitment, intervention design, statistical analyses)?	2.4 Methods: Did authors report how place of residence was considered in the intervention methodology (eg, recruitment, intervention design, statistical analyses)	Describe details on section 2 here
	3.1.2 Results: Did authors report any SES characteristics at baseline?	3.1.2 Results: Did authors report any sex/gender characteristics at baseline?	3.1.3 Results: Did authors report any ethnicity characteristics at baseline?	3.1.4 Results: Did authors report any place of residence characteristics at baseline?	Describe details of section 3.1 here
	3.2.1 Results: Were any statistical analyses reported on intervention results regarding SES?	3.2.2 Results: Were any statistical analyses reported on intervention results regarding sex/gender?	3.2.3 Results: Were any statistical analyses reported on intervention results regarding ethnicity?	3.2.4 Results: Were any statistical analyses reported on intervention results regarding place of residence?	Describe details on section 3.2 here (ie, what type of analyses, findings)
	4.1 Discussion: Was SES discussed regarding the applicability and generalizability of findings?	4.2 Discussion: Was sex/gender discussed regarding the applicability and generalizability of findings?	4.3 Discussion: Was ethnicity discussed regarding the applicability and generalizability of findings?	4.4 Discussion: Was place of residence discussed regarding the applicability and generalizability of findings?	Describe details on section 4 here

Abbreviation: SES, socioeconomic status.

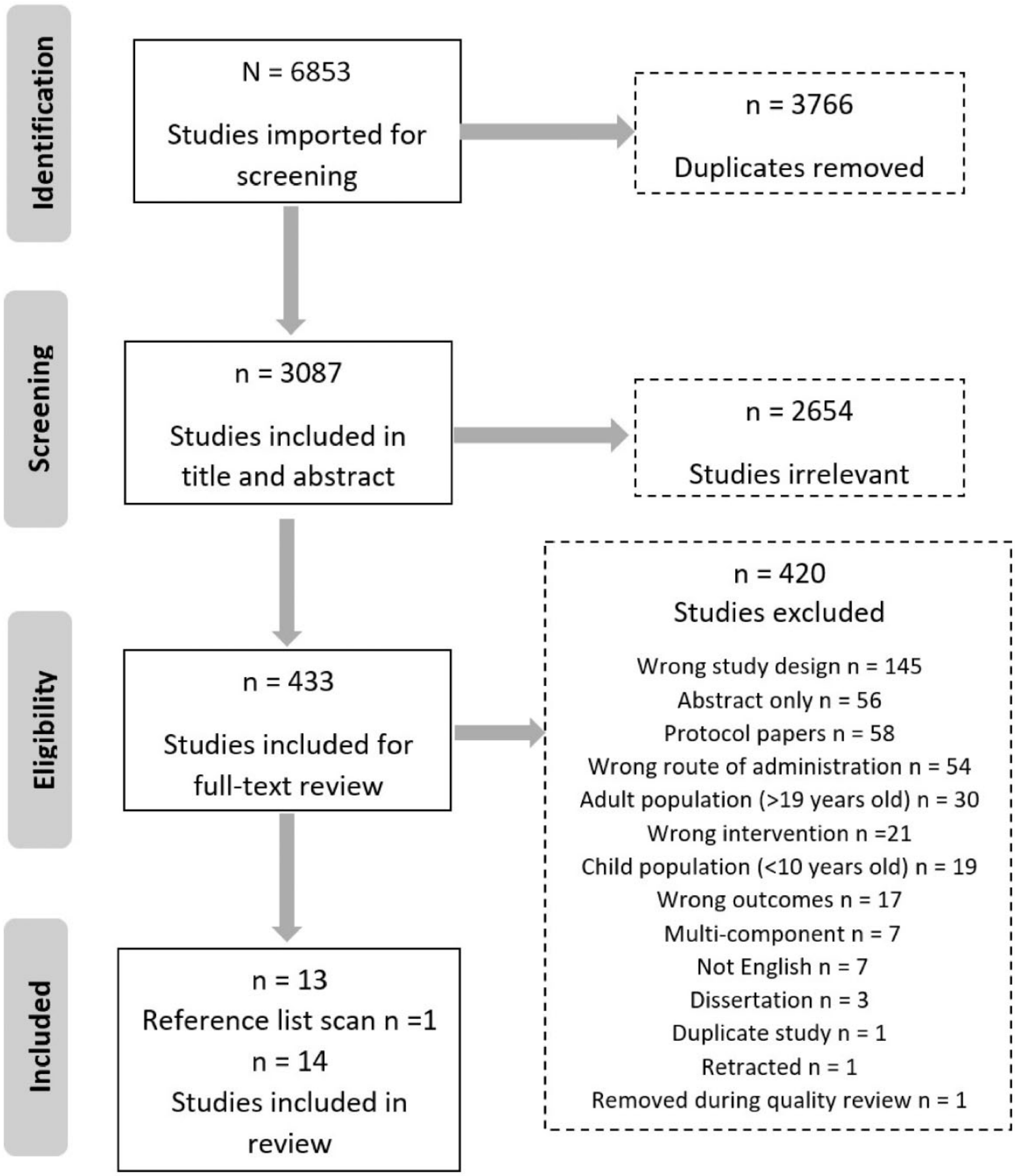

Figure 1 **PRISMA flowchart.**

and other education centers (n = 1)[70]; and sports academies and clubs (n = 1).[61] The majority of studies focused on the general, healthy adolescent population; however, 3 studies focused on adolescents with clinical obesity[58,59,69] and 1 focused on adolescents who survived pediatric cancer but had been off treatment for 2 years.[62]

Study characteristics

Geographic study location ranged substantially, with the majority being from European countries, including Denmark (n = 1),[60] Finland (n = 1),[61] the Netherlands (n = 1),[46] Belgium (n = 1),[63] the United Kingdom (n = 1),[70] Spain (n = 1),[64] and Portugal (n = 1).[66] Others were conducted in the United States (n = 2),[62,65] Thailand (n = 2),[58,59] Singapore (n = 1),[69] Korea (n = 1),[67] and India (n = 1).[68] Studies were published between 2012 and 2021 (almost 50% were published in 2020–2021). Most studies were either RCTs (n = 5)[58,59,61,65,68] or cluster RCTs (n = 1),[46] a pre-post intervention design with (n = 4),[60,63,64,66] or without a control group (n = 2).[62,67] One study, which the authors referred to as a single-cohort study, was included because it involved a 3-month pre-post intervention,[69] and another was a parallel-intervention study.[70] The intervention time line ranged from only 9 days[65] to 6 months, which was the longest intervention.[66]

Of the 13 different smartphone app–based interventions, all were intended to improve or influence dietary habits as the primary goal (n = 7),[60,61,63,65,67,68,70] as a combined objective with improving physical activity (n = 3),[46,62,64] as a secondary objective to weight management (n = 3),[58,59,69] or as a significant component of an intervention aimed to improve general health habits (n = 1).[66] In total, 5 of the smartphone apps are publicly available,[61,66,68,69] and the other 7 were either removed from public sites or were never publicly available.[46,58–60,62–64,67,70] One smartphone app intervention did not have a name reported[65]and thus could not be searched on public sites. All smartphone apps included an educational component via the provision of daily tips, education modules, or games related to healthy eating (n = 4),[46,60,64,68] provision of personalized feedback to participants or in-app virtual rewards for meeting diet-related goals based on dietary tracking (n = 4),[61,65,69,70] or both (n = 6).[58,59,62,63,66,67] Six of the smartphone apps used gamification.[46,60,62,63,65,68] The majority of smartphone apps included a daily food record or dietary tracking component as part of the intervention (n = 11).[58–63,65–67,69,70]

A variety of dietary outcomes were measured across studies, with the most common being daily fruit and/or vegetable (FV) intake (n = 7), either servings per day[46,60,62,69,70] or consuming FVs every day[58,59]; sugar consumption (n = 7, including consumption of sugary beverages,[58,59,62] fizzy drinks,[70] or soft drinks[46] (total sugar intake/day),[61] or percentage of daily calories from sugary foods[62]; and total calorie intake per day (n = 4).[61,62,67,69] Multiple studies also explored snack intake (n = 5), including healthy snack ratio,[63] snack consumption portions per day,[46] unhealthy snacks per day (eg, chips, candy)[60], healthy snack choice,[68] and consumption of savory and chocolate snacks.[70] Other studies explored frequency and healthfulness of breakfast,[65] macronutrient consumption,[61,67] fiber consumption,[61,62] and consuming fast foods <3 times per week.[58,59] Diet-quality scores were also used as a dietary outcome (n = 2), including the Mediterranean Diet Quality Index (KIDMED) score,[64] which is based on adherence to the Mediterranean diet,[71] and the Adolescent Lifestyle Profile questionnaire nutrition score,[66] which is based on consumption of FVs and milk, and limiting fat and sugar intake.[72] Dietary outcomes were often evaluated using 3-day or intervention-long food diaries (n = 3),[61,69,70] validated 24-h food frequency questionnaires (n = 3),[46,62,63] 24-h recall conducted by trained reviewers (n = 1),[67] a validated diet quality tool or questionnaire (n = 2),[64,66] a nonvalidated questionnaire (n = 3),[58–60] a photo diet journal (n = 1),[65] or observed food choice (n = 1).[68]

Study quality

The methodological quality of the included studies was variable and broadly attributable to study design because RCTs and nonrandomized controlled interventions often had higher quality ratings than did pre-post interventions (Table S1 in the Supporting Information online).[46,58–70,73] Across both RCT and quasi-experimental studies, lower quality scores were often attributed to the use of self-reported dietary intake data, which lack reliability and often are critiqued but commonly used in nutrition research.[74] Furthermore, participant follow-up was often incomplete, and differences between dropouts and study participants were scarcely reported. Specifically, in RCT studies, blinding of the researchers and/or participants was uncommon, likely due to the difficulties of applying blinding procedures to education-based as opposed to medical treatment interventions.[75] Overall, most studies included the use of appropriate statistical analyses; the four studies given a “no” were due to inadequate sample size or statistical power for the conducted analyses according to their reported sample-size calculation. The study with the lowest quality rating was a pilot study with a sample size of 7 adolescents.[73] This study was deemed poor enough in quality to bias the review’s results and was excluded from the final sample of studies (Table S1 in the Supporting Information online).[46,58–70,73]

Theoretical framework

A theoretical underpinning used in the design of smartphone app–based interventions was reported in half of the studies included in this review (n = 7)[46,62–66,68] (Table S2 in the Supporting Information online).[46,58–70] Of these studies, some reported specific theories (n = 5), including social cognitive theory,[62,65] self-determination theory,[62] narrative transportation theory,[62] self-regulation theory,[46] the health information technology acceptance model,[66] and the dual-process model.[63] Others reported evidence-based theoretical behavior change components as the basis for their nutrition intervention (n = 4), such as social support,[64] implicit learning,[68] intrinsic motivation,[68] self-efficacy,[53] and positive or negative reinforcement.[65]

Dietary intake findings

In total, 11 of the 14 included studies reported a statistically significant positive outcome in at least 1 of their dietary outcome variables (Table 3).[46,58–70] Only 1 of the 7 studies that evaluated FV intake found a statistically significant difference.[60] Ragelienė et al[60] found that participants in the intervention group who used an app that included a FV food diary and games to promote healthy eating had a higher pre-post intervention change in fruit intake compared with the control group, resulting in a significant difference by time and group with a medium effect size ($P = 0.006$; $\eta^2 = 0.064$). There were no significant differences found for vegetable intake in this study.[60]

Only 1 of the 7 studies evaluating sugar intake found significant changes as a result of participating in the smartphone intervention.[70] Jimoh et al[70] found from their 2-phase intervention that participants significantly decreased their self-reported consumption of daily "fizzy" drinks ($P = 0.002$) while recording their food intake on a smartphone app that sent them personalized feedback on their food intake, compared with when the same participants used a paper diary.

Similarly, only 1 of the 4 studies that evaluated caloric intake reported a significant finding.[69] In the study of Chew et al,[69] the pre-post intervention, which targeted adolescents with obesity and included a daily food diary, encouragement of healthier food consumption, and short coaching sessions through a smartphone app, resulted in a 300 mean caloric reduction per day after the 12-week intervention ($P = 0.04$), and a 332 mean caloric reduction per day from baseline to 6-month follow up ($P = 0.02$).

Two studies that evaluated snack choice or snack consumption (n = 5) reported significant results.[68,70] When using the smartphone app, participants in the Jimoh et al[70] 2-phase intervention study reported significantly less chocolate snack consumption occasions per day when using the smartphone app compared with using the paper diary ($P = 0.01$). In the RCT conducted by Kato-Lin et al,[68] in which participants played a smartphone app–based nutrition game once per week for 2 weeks, intervention participants had a significantly higher healthy snack choice score than the control group, resulting in a large effect size ($P = < 0.001$; Cohen's $d = 1.25$).

Both of the studies that evaluated change in diet-quality score showed significant results.[64,66] Benavide et al[64] reported a greater increase in KIDMED score in their intervention group, which used a smartphone app that sent participants personalized healthy eating tips, included a virtual reward system for self-reported goal achievement, and allowed for interaction between app users, resulting in a significant time ($P = 0.001$; $F_1 = 10.27$) and group difference ($P = 0.03$; $F_1 = 4.629$). Similarly, in the Sousa et al study,[66] the intervention used a smartphone app that sent intervention participants' daily challenges to receive virtual rewards, personalized healthy eating messages, and a self-monitoring feature for dietary intake. The researchers found a statistically significant group difference in nutrition scores with a small effect size ($P = 0.03$; $\eta^2 = 0.03$), because the mean score for the smartphone app plus school education group slightly increased, whereas the school-education-only group's score decreased after the intervention.

Smartphone app–based interventions also had a significant impact on a variety of other dietary outcomes. Byrne et al[65] found that when participants received positive and negative feedback from a virtual pet regarding their breakfast intake on a smartphone app, participants had a greater likelihood of consuming breakfast. However, there was no significant difference in the healthfulness of breakfasts consumed between groups.[65] In the Heikkilä et al study,[61] results from the intervention showed that daily grams per kilogram of body weight of protein increased in the education plus app group, which used an app to record their food intake using a photo journal and received personalized feedback on their daily intake, but not in the education-only group, although the increase was clinically negligible. In the short-term study (ie, 2 months) of Likhitweerawong et al,[59] examining the tablet/smartphone-based (OBEST) intervention in adolescents with obesity, a significant increase was noted in intervention participants drinking milk every day after the intervention. On the other hand, in their long-term study, Likhitweerawong et al[58] showed that intervention-group participants were significantly more likely to consume fast food <3 times per week at 6-month follow-up from the start of the intervention than those in the control group. The smartphone app used in the Likhitweerawong et al studies[58,59] included a dietary intake recorder, virtual goal and rewards system, daily healthy eating tips, and messaging from a healthcare provider. The Diet-A smartphone application pre-post intervention implemented by Lee et al,[67] which involved participants recording their dietary intake and then receiving personalized feedback on their disease risk based on their food intake, determined that participants' sodium intake significantly decreased following the intervention; however, participants' calcium intake also significantly decreased.

Intervention adherence

More than half of the studies (n = 11) reported on intervention adherence (Table S2 in the Supporting Information online),[46,58–70] such as the percentage of intervention participants who engaged with the app, app logins per week, or app food-diary

Table 3 **Summary of key study findings by intervention length (N = 14)**

Reference	Intervention length	Sample size (N)	Age range (mean), y	Sex/gender (%)	Design	Evaluation Tool	Outcome	Key findings (mean or %)	App features
Sousa et al. (2020)[66]	6 mo	204	12–16 (12.4)	42.2 M, 57.8 F	Pre-post with control	ALP questionnaire	ALP nutrition score	IG: 0.02 increase[a] CG: 0.07 decrease	Personalization; dietary tracking; participant interaction
Benavides et al. (2021)[64]	14 wk	301	NR (12.8)	54.2 M, 45.8 F	Pre-post with control	KIDMED score	KIDMED score	IG: 0.90 increase[c] CG: 0.20 increase	Personalization; virtual rewards; participant interaction
Chew et al. (2021)[69]	3 mo, 6-mo follow-up	21 at 3 mo 20 at 6 mo	10–17 (13.8)	58 M, 42 F	Pre-post	V, 3-d record	Calories/d	300-kcal decrease 3 m[b] 332-kcal decrease 6 m[b]	Dietary tracking and feedback
							Veg servings/d	NS	
Rageliené et al. (2022)[60]	3 mo	118	9–13 (10.9)	45.8 M, 54.2 F	Pre-post with control	NV, questionnaire	Fruit servings/d	IG: 0.62 increase[c] CG: 0.04 increase	Dietary tracking; gamification
							Veg servings/d	NS	
							Unhealthy Snacks/d	NS	
Lee et al. (2017)[67]	3 mo	33	16–18 (17.2)	27.3 M, 72.7 F	Pre-post	V, 24-h recall	Sodium mg/d	807 mg/d decrease[b]	Dietary tracking and feedback; personalization
							Calcium mg/d	145 mg/d decrease[b]	
							Iron mg/d	NS	
							Calories/d	NS	
							CHO g/d	NS	
							PRO g/d	NS	
							Fat g/d	NS	
							Saturated fat g/d	NS	
Likhitweerawong et al. (2021)[58]	8 wk, 6-month follow-up	70	10–15 (13.0)	68.5 M, 31.5 F	RCT	NV, questionnaire	Fast food <3/wk	IG: 85% of participants[a] CG: 57% of participants	Virtual rewards; dietary tracking and feedback
							SSB <3/wk	NS	
							Snack <3/wk	NS	
							FV every day	NS	
							Milk every day	NS	
							3 meals/d	NS	
Likhitweerawong et al. (2020)[59]	8 wk	70	10–15 (13.0)	68.5 M, 31.5 F	RCT	NV, Questionnaire	Milk every day	IG: 45% of participants to 66% of participants[b]	Virtual rewards; dietary tracking and feedback
							Fast food <3/wk	NS	
							SSB <3/wk	NS	
							Snack <3/wk	NS	
							FV every day	NS	
							3 meals/d	NS	
	8 wk	15	12–17 (14.8)	60 M, 40 F	Pre-post	V, FFQ	FV servings/d	NS	
							Calories/d	NS	

(continued)

Table 3 **Continued**

Reference	Intervention length	Sample size (N)	Age range (mean), y	Sex/gender (%)	Design	Evaluation Tool	Outcome	Key findings (mean or %)	App features
Fuemmeler et al. (2020)[62]							Total fat g/d	NS	Gamification; dietary tracking and feedback
							Fiber g/d	NS	
							FV fiber g/d	NS	
							Kcal from sweet foods	NS	
							Sugary beverages g/d	NS	
Heikkilä et al. (2019)[61]	5-week intervention, 17-week follow-up	79	16–20 (18.0)	56 M, 44 F	RCT	NR, food diary	PRO g/kg/d	IG: 0.1 increase[a] 17 wk CG: No change 17 wk	Dietary tracking (photo) and feedback
							PRO g/d	NS	
							% total energy	NS	
							CHO g/kg/d	NS	
							CHO g/d	NS	
							% total energy	NS	
							Fat g/kg/d	NS	
							Fat g/d	NS	
							% total energy	NS	
							Saturated fat g/d	NS	
							MUFA g/d	NS	
							PUFA g/d	NS	
							Calories/d	NS	
							Fiber g/d	NS	
							Sugar g/d	NS	
Jimoh et al. (2018)[70]	4-wk paper diary; 4-wk app diary	30	16–19 (17.0)	32.4 M, 67.6 F	2-Phase parallel	NR, Food diary	Chocolate snacks/d	Mean difference NR[a]	Dietary tracking and feedback
							Savory snacks/d	NS	
							Fizzy drinks/d	Mean difference NR[a]	
							Cereals/d	NS	
							Fruit occasions/d	NS	
							Veg occasions/d	NS	
Spook et al. (2016)[46]	4 wk	231	15–21 (17.3)	37.2 M, 62.8 F	Cluster RCT	V, FFQ	Fruit servings/d	NS	Gamification
							Veg servings/d	NS	
							Snack portions/d	NS	
							Soft drinks/d	NS	
De Cock et al. (2018)[63]	4 wk	988	14–16 (14.9)	59.4 M, 40.6 F	Pre-post with control	V, FFQ	Healthy snack ratio	NS	Gamification; dietary tracking and feedback; virtual rewards

(continued)

Table 3 **Continued**

Reference	Interventio-n length	Sample size (N)	Age range (mean), y	Sex/gender (%)	Design	Evaluation Tool	Outcome	Key findings (mean or %)	App features
Kato-Lin et al. (2020)[68]	2 wk	58	10–11 (NR)	56.7 M, 43.3 F	RCT	Observation	Good food (ie, snack) choice	IG: 2.48[a] CG: 1.10	Gamification
Bryne et al. (2011)[65]	9 d	39	12–14 (13.1)	56.4 M, 43.6 F	RCT	NR, photo journal	No. of breakfasts/9 d	Pos/Neg group: 0.52[a] Pos only group: 0.27 Control: 0.20	Gamification; dietary tracking (photo) and feedback
							Healthfulness of breakfast	NS	

[a]Significant by group.
[b]Significant by time.
[c]Significant by group and time.
Abbreviations: ALP, Adolescent Lifestyle Profile; CG, control group; CHO, carbohydrate; F, female; FFQ, Food Frequency Questionnaire; FV, fruit and vegetables; IG, intervention group; M, Male; MUFA, monounsaturated fatty acid; Neg, negative; NR, not reported; NS, not significant; NV, not validated; Pos, positive; PRO, protein; PUFA, polyunsaturated fatty acid; RCT, randomized controlled trial; V, validated; Veg, vegetables.

completion.[46,58,59,61–66,69,70] Of these studies, many reported poor engagement with the app intervention (n = 6),[46,59,62,63,69,70] whereas only 1 study reported good participant engagement.[61] Three studies explored whether adherence to the app affected the intervention results.[46,62,63] De Cock et al[63] found that there were no differences in healthy snack ratio after the intervention among their control group, low-app-use group, and high-app-use group. Spook et al[46] found their intervention did not affect participants' dietary intake; however, once they analyzed their results by self-reported app use, there was a significant decrease in snack consumption among active app users in comparison with the control group ($P = 0.01$). Similarly, despite the intervention in the Fuemmeler et al study[62] not significantly affecting participants' diet, once analyzed by app use, the researchers determined that non-app users' mean grams of sugary beverage intake per day increased after the intervention, whereas that of the app users did not, resulting in a significant group and time interaction ($P = 0.038$). However, they also found that the percentage of daily calories from sweet foods significantly increased in the app-user group but not in the non–app-user group, resulting in a significant group and time interaction ($P = 0.049$).[62]

Reporting of equity factors

In total, authors of 5 of the 14 studies reported the consideration of at least 1 equity factor throughout the Introduction, Methods, Results, and Discussion sections of their article,[46,59,60,63,70] and 3 authors reported all 4 equity factors at least once in their study[58,59,65] (Table 4)[46,58–70]. The most commonly reported equity factor was S/G, predominantly in the Results section, when describing participants' baseline characteristics, which occurred in all 14 studies. SES-related factors were the second most frequently reported equity factor across studies. Examples of SES-related factors that were reported in the Results sections included median household income,[62,65,69] parental education level,[69] mother's education level,[62] parental employment,[60] participants' technical vs vocational education status,[46,63] and participants' General Certificate of Secondary Education educational attainment score.[70] SES-related factors were also frequently discussed in the Introduction section in reference to SES or economic factors being an important influence or predictor of dietary choice[60] or obesity risk,[46,58] or referring to lower SES groups as at-risk groups that should be targeted for health promotion initiatives.[70]

Ethnicity was reported less often and was frequently described in the baseline Results and the Discussion sections. Two studies, using the same intervention, reported ethnicity in the Methods section, as ethnicity was part of their inclusion criteria, with all participants having to be of Thai ethnicity.[58,59] For baseline results, only 4 studies reported participants' ethnicity. One study reported that 87% (13/16) of their study participants were White and did not report the ethnicity of the other participants.[62] A different study reported that 84% of their sample was Caucasian, and the rest identified as biracial, of mixed race, or "other", without specifying their race or ethnicity.[65] One study categorized their participants as either Dutch or non-Dutch,[46] while another study reported the ethnicity of their participants as Chinese, Malay, Indian, or "other."[69] Place of residence was sparsely reported across studies, and what was reported varied considerably. For example, in the Introduction section of 2 studies, mention of the school and community,[60] and the general physical environment,[58] were reported as contributing factors in relation to adolescent obesity. In the Methods section, Likhitweerawong et al[58,59] reported all participants had to live in the same province as an inclusion criterion. De Cock et al[63] enrolled participants from selected cities with comparable socio-economic characteristics, population density, and size to minimize differences between the intervention and control groups. Ragelienė et al[60] noted that although their participants were recruited from various schools, public schools in Central Denmark are similar in terms of class sizes and socioeconomic characteristics. The Results section of 1 study simply reported that the school where participants were enrolled was in a northeastern US agricultural community,[65] whereas a different study specifically reported the percentage of participants enrolled from different school districts.[66]

A commonality across the reporting of equity factors in the Discussion section of reviewed articles was that authors reported the need for their research to be explored in more demographically, socioeconomically, and culturally diverse sample populations.[60,62,65] Other studies reported equity factors specific to their intervention findings. For example, Chew et al[69] suggested that because the majority of participants in their study were from lower-income situations, had lower levels of educational attainment, and belonged to a racial or ethnic minority group, that their intervention may be useful for reaching equity-deserving groups. Similarly, Spook et al[46] reported they included a range of interactive game components to increase intervention engagement with low-SES youth, who have been shown in previous research to be less engaged with health interventions. Likhitweerawong et al[59] reported a limitation of their study is that they did not include SES as a confounding variable. De Cock et al[63] suggested that different app strategies may be needed to improve snacking habits of teens depending on sex, such as more explorative-style

Table 4 **Reporting of equity factors summary table (N = 14)**

Reference	Introduction				Methods				Results: characteristics				Results: analyses				Discussion			
	1.1 SES	1.2 S/G	1.3 ETH	1.4 POR	2.1 SES	2.2 S/G	2.3 ETH	2.4 POR	3.1.1 SES	3.1.2 S/G	3.1.3 ETH	3.1.4 POR	3.2.1 SES	3.2.2 S/G	3.2.3 ETH	3.2.4 POR	4.1 SES	4.2 S/G	4.3 ETH	4.4 POR
Benavides et al (2021)[64]		X								X								X		
Bryne et al (2012)[65]									X	X	X	X					X		X	
Chew et al (2021)[69]									X	X	X						X		X	
De Cock et al (2017)[63]		X			X	X		X	X	X			X	X				X		
Fuemmeler et al (2020)[62]									X	X	X								X	
Heikkilä et al (2019)[61]										X								X		
Jimoh et al (2018)[70]	X				X				X	X			X	X			X	X		
Kato-Lin et al (2020)[68]					X					X										
Lee et al (2017)[67]						X				X										
Likhitweerawong et al (2021)[58]	X			X			X	X		X							X			
Likhitweerawong et al (2020)[59]							X	X		X							X			
Rageliené et al (2021)[60]	X	X		X				X	X	X									X	
Sousa et al (2019)[66]						X		X		X		X		X		X		X		X
Spook et al (2016)[46]	X		X				X		X	X	X		X	X	X		X			

Abbreviations: ETH, ethnicity; POR, place of residence; SES, socioeconomic status; S/G, sex/gender.

games for girls and more competitive-style games for boys. Sousa et al[66] called for research to focus on the cultural and social influences of school environments on mHealth interventions.

Reporting of statistical analyses specific to equity factors

Four studies conducted analyses related to their interventions specific to reported equity factors. Three studies explored variation in intervention adherence and uptake by comparing equity-related baseline characteristics of high- vs low-adherence participants.[46,63,70] De Cock et al[63] explored how gender and the education sector influenced app use and found no significant differences for gender but that those with high use of the app were more likely to be enrolled in general-level education compared with technical or vocational education. Jimoh et al[70] conducted a similar analysis to determine if food-record completion varied by reported sex and/or the educational attainment scores of the adolescent participants and found no significant differences in completion rates. Similarly, Spook et al[46] compared baseline reported characteristics (ie, gender, ethnicity, and education sector) between active and nonactive users in the intervention group and found no significant differences. Variation in intervention effectiveness in relation to equity factors was explored in 2 studies. To analyze how sex affected the relationship between sensitivity to reward and healthy snack intake in adolescents, De Cock et al[63] used a multilevel impact analysis and found that in boys, healthy snack intake increased with higher sensitivity to reward ($b = 1.38$; standard error, 0.59; $P < 0.05$), whereas in girls, there was an opposite effect ($b = -1.90$; standard error, 0.94; $P < 0.05$). Sousa et al[66] conducted a repeated measures analysis to determine the impact of gender and school district on intervention results and a univariate analysis to determine if gender or school district were predictors of effectiveness in their intervention group only in adolescents. Sousa et al[66] found that gender did not have a significant effect in either analyses, but they determined there was a significantly larger variation in mean nutrition scores between the intervention and control groups in 1 school district (ie, place of residence), suggesting the intervention may have had a greater impact in 1 school district than in the other 2.

DISCUSSION

Impact of smartphone app–based interventions on dietary intake

Overall, this review provides evidence that smartphone app–based dietary interventions can positively influence dietary outcomes in adolescents: 11 of the 14 intervention studies found a significant improvement in at least 1 dietary intake outcome. However, many of the studies evaluated multiple dietary-outcome variables, which makes it difficult to specify the extent to which smartphone app–based interventions affect specific dietary outcomes. In total, 12 of the 63 dietary outcome variables evaluated across the 14 studies in this review showed a statistically significant improvement. The most common dietary outcomes explored were FV intake, sugar intake, and total daily caloric intake. This is similar to previous systematic reviews evaluating either all ages or general electronic health (eHealth) interventions in adolescents,[7,76] and these dietary behaviors are commonly targeted in adolescent nutrition interventions.[77] Regarding the impact of smartphone app–based interventions on specific dietary intake outcomes, 1 study found a significant improvement in fruit, but not vegetable, intake.[60] The significant increase in fruit, but not vegetable intake has been found in previous nutrition intervention studies[78] and may be related to adolescents regularly consuming more servings of fruits than vegetables.[79,80] One study, whose main objective was weight management, reported a mean reduction of 300 calories at both time points in the study of adolescents with obesity, which holds substantive clinical significance in comparison with the other findings.[69] In their meta-analysis, Villinger et al[7] found that smartphone app–based interventions in a predominantly adult population had a significant impact on FV intake, but not on calorie intake, and Champion et al,[76] in their meta-analysis on eHealth school-based interventions in youth, also found that overall the interventions increased FV intake. Considering only 1 of the 7 studies exploring FV intake and 1 of the 4 studies exploring caloric intake in this review reported a significant outcome, smartphone app interventions may only have a small influence on FV and caloric intake in adolescents overall. One study in this review found a significant decrease in "fizzy drink" consumption.[70] This is a promising finding because sugar-sweetened beverage intake is a priority nutrition concern for adolescents; they consume it regularly worldwide[81,82] and it is associated with obesity, dental caries, and potential insulin resistance.[83] In regard to snack intake, 2 of the 5 studies reported significant findings. One reported a decrease in unhealthy snack consumption,[70] and the other reported an increase in adolescents choosing the healthy snack option.[68] These findings differ from that of the Champion et al[76] meta-analysis, which found that school-based general eHealth interventions (eg, web-based, email, text messaging) did not decrease the consumption of sugar-sweetened beverages or high-energy snacks among adolescents.

Smartphone app–based interventions may be more effective at decreasing consumption of sugar-sweetened beverages and high-energy snacks in comparison with other eHealth interventions; however, it still is a mild influence: only 1 of 7 studies exploring sugar intake and 2 of the 5 exploring snack intake reported significant beneficial changes in this review.

Smartphone app–based interventions also have a positive impact on diet-quality indices among adolescents. Both studies in this review that evaluated diet-quality scores reported significant positive changes because of their intervention.[64,66] Although the score changes were small and may lack clinical significance, the results are promising. Similarly, Scarry et al[4] reported that diet-quality improved in 60% of studies (n = 6 of 10) included in their systematic review of mobile interventions on adult diet quality.

App components varied across studies, with either diet education and healthy eating messaging, diet tracking, or both as the primary mechanisms used to promote dietary behavior change. Similarities in app components across studies that reported significant findings include the use of personalized healthy eating tips and recommendations (n = 5),[58,59,64,66,67] goal setting and virtual rewards systems (n = 4),[58,59,64,66] gamification (n = 3),[60,65,68] and providing personalized feedback based on reported dietary intake (n = 2).[61,70] Similarly, tailored messages, reward systems, and gamification were found to be components of effective interventions in the Schoeppe et al[6] systematic review of apps for diet, physical activity, and sedentary behavior in predominantly adults, showing the potential benefit of these app features for health promotion interventions. However, because of the variation in app components used across studies and the variation of dietary outcomes evaluated in this review, conclusions on the effectiveness between individual smartphone app features on adolescents' dietary outcomes cannot be drawn. Dietary tracking or logging was used in 11 of the 13 different smartphone apps.[58–63,65–67,69,70] Although dietary tracking or food logging is prevalent in dietary smartphone apps,[84] there is concern about how this may affect disordered eating, because engaging with smartphone diet tracking has been found to be associated with maladaptive[85] and disordered[86] eating behaviors among youth. Furthermore, extra consideration is warranted when using diet tracking in an adolescent population, because disordered eating behaviors and diagnoses often emerge in adolescence,[87,88] and adolescents who engage in dieting are at an increased risk for disordered eating behaviors in adulthood.[89]

Numerous studies reported varied compliance and intervention adherence, with 6 studies reporting poor compliance,[46,59,62,63,69,70] and 1 study reporting good compliance.[61] How authors evaluated compliance varied across studies, making it difficult to compare their findings. Length of intervention across studies reporting poor compliance ranged from 4 weeks[46,63] to 3 months.[69] Five of the 6 studies that reported poor compliance required participants to record their daily food intake, either as a food diary[59,69,70] or as part of the intervention's smartphone game.[62,63] It is possible that the burden of manually recording their daily food intake may be a contributor to poor intervention compliance in adolescents, because dietary recording for interventions, even on a mobile device, has been reported as burdensome for adults in previous research.[90] Comparatively, Heikkilä et al,[61] who reported good intervention compliance with their 5-week intervention, also included a daily food diary, but they used a photograph method that allowed participants to take photos of their meals as opposed to manually inputting them into the app, which may have alleviated some of the participant burden. Three studies included an evaluation of how participant adherence influenced intervention outcomes,[46,62,63] of which 2 determined adherence to the smartphone intervention significantly influenced the effectiveness of their intervention on dietary outcomes.[46,62] The Schoeppe et al[6] review of app interventions found a similar finding in that all 3 of their included studies that evaluated app adherence reported that more app use was related to greater improvements in physical activity and healthy eating. Furthermore, González et al[91] concluded in their secondary analysis of intervention participants' results that greater adherence to their smartphone intervention improved dietary outcomes compared with intervention participants who did not engage with the app. This provides evidence that participant adherence, or dose of intervention, may greatly contribute to the effectiveness of smartphone app–based interventions. Thus, intervention adherence, using app analytics such as frequency of app interaction, should be reported and considered in future smartphone app–based nutrition interventions when evaluating impact on dietary intake. Future interventions should also consider using app components that may improve adherence. A scoping review on participant engagement with smartphone app interventions reported that personalized content and feedback, data visualization, push notifications, educational material, self-monitoring features, and goal setting capabilities are app components associated with increased participant engagement.[92]

Possible mediating factors of intervention effectiveness

Two of the studies with nonsignificant findings were located in a similar geographic location (ie, Belgium and the Netherlands).[46,63] The World Health Organization European Region report indicates that Belgium has one of the highest rates of adolescents consuming FVs daily but also higher rates of sweets consumption compared with other European countries.[79] Considering this, differences in outcomes could be related to dietary or cultural differences, and it is possible that smartphone app–based interventions may be more effective at changing dietary intake in countries outside central-western Europe.

Variation in intervention length may have also influenced intervention effectiveness. For example, all of the studies that reported only nonsignificant dietary outcome findings contained interventions that were $\leq$8 weeks in duration,[46,62,63] whereas all of the interventions that were $\geq$12 weeks long were associated with a significant positive finding in at least 1 of their dietary intake outcomes.[60,64,66,67,69] Thus, it is plausible that smartphone app–based interventions may need to be implemented over a longer period than 8 weeks, with 12 weeks being a preferred duration for intervention effectiveness. This is consistent with a previous review of nutrition and physical activity interventions in postsecondary students.[93]

Only 7 of the 12 smartphone apps were theoretically informed, according to the authors' reporting.[46,62–66,68] Similarly, in their literature review on mobile apps for adolescent health promotion, Dute et al[94] found 5 of the 12 included apps clearly reported a theoretical underpinning. This lack of theory is less than ideal, because researchers have found that the use of theory in health promotion interventions can improve an intervention's effectiveness,[48] and being theoretically based is a component for an effective nutrition intervention.[95] However, in this review, intervention results did not meaningfully vary by the reported use of theory. Of the 7 studies that reported a theoretical underpinning, 4 found at least 1 significant result[64–66,68] and the other 3 studies reported only nonsignificant results.[46,62,63] This is a similar finding to those of Milne-Ives et al [96] in their systematic review on behavior-change mobile app interventions in predominantly adults. Those authors reported use of a theory did not appear to change intervention effectiveness. There also did not appear to be any unique differences between the type and quantity of theories reported by authors in the included studies that were effective vs not; however, because only 7 studies in this review reported the use of theory, conclusions cannot be drawn on which behavior-change theories or techniques are most effective at influencing smartphone app–based nutrition interventions in adolescents.

Reporting of equity factors

Overall, the frequency of reporting equity factors across the 14 included studies was limited: only 4 of the 14 articles reported at least 1 equity factor in the Background, Methods, Results, and Discussion sections. S/G and SES-related factors were the most commonly reported equity factors. When race or ethnicity was reported, researchers often categorized participants as belonging to either a single ethnicity or to an "Other" category that was not specified. Although this practice is still common in health research, it not only provides insufficient understanding of the ethnicity and cultural background of the participants in the study, it also disregards the nuanced differences in the ways these groups have been historically and systemically oppressed.[97] Therefore, it is advised that when researchers collect information on ethnicity, they should aim for inclusivity by providing comprehensive categories for participants to choose from,[98] and when reporting ethnicity, it is advised that researchers report all ethnicities in their sample, specifying which ethnicities are included under "Other," if listed as a category, unless the sample size is so small that it could potentially identify participants,[98] which may have been the case for some studies included in this review. Place of residence was scarcely reported across studies in this review. This is worrisome because an adolescent's food environment, particularly their accessibility to healthy or unhealthy foods, could influence the effectiveness of a smartphone app–based intervention; researchers have found that adolescents' food-purchasing and dietary choices are significantly related to both their household and school neighborhood food environments.[99,100] Despite many studies reporting equity factors at baseline or in the Discussion section of articles, only 4 studies conducted statistical analyses specific to equity factors, and of these, only 2 explored the impact of equity factors on intervention effectiveness. This review's findings are similar to those of Vargas-Garcia et al[101] in their systematic review of interventions to reduce sugar-sweetened beverage consumption at all ages, in which they found that all of their included studies (N = 40) reported gender at baseline, but fewer studies reported income and ethnicity, no studies reported other PROGRESS equity factors (including place of residence), and only 3 studies conducted analyses specific to equity factors. Similarly, a systematic review of general physical activity interventions among all ages found that despite many articles measuring PROGRESS equity factors, few reported analyses specific to equity factors.[102] The lack of analyses to assess the differential impact of equity factors on intervention effectiveness is not surprising, because there is debate in the literature about the credibility of subgroup analyses when conducted poorly and without premeditation.[103] There are also specific guidelines a researcher should follow when conducting subgroup analyses, including a sufficient sample size, which may deter researchers from attempting it.[104]

Because of the limited analyses conducted, conclusions about the differential impact of equity factors on smartphone app–based intervention effectiveness cannot be made and are also notably outside the scope of this review. However, it is interesting to note that 1 study did find that intervention effectiveness varied by gender in regard to higher sensitivity to rewards promoting healthy snack intake in male adolescents but not females.[63] The authors posited that this may be due to female adolescents eating more healthfully at baseline, and that they possibly enjoy the more reflective and exploratory components of the app, as opposed to the competitive components.[63] Atwood et al,[102] in their review of equity reporting in physical activity interventions, also found that some studies showed that gender influenced intervention effectiveness. Another study in this review found that school district had a significant impact on the nutrition score differences between the intervention and control groups.[66] It is possible that the school districts varied by average household income, ethnic makeup, local food environments, or school food programs (eg, free healthy school lunches), resulting in this difference. This review provides preliminary evidence that equity factors including S/G and place of residence could influence smartphone app–based nutrition interventions' effectiveness, and thus their influence should be considered in future interventions.

In addition, the authors of many studies in this review recognized the lack of a demographically, socioeconomically, and culturally diverse sample and called for future research to investigate intervention impacts in more diverse populations. The inclusion of more diverse populations in intervention studies can improve external validity while providing a greater understanding of intervention effectiveness in equity-seeking groups.[105] Alternatively, research conducted on specific demographic groups who are traditionally underrepresented in medical research can also provide beneficial evidence for the effectiveness of interventions in diverse populations.[106] Therefore, these strategies should be considered for future smartphone app–based interventions targeting adolescents.

Findings of this review should be taken in context of the various limitations of the studies included. A significant limitation of many included articles is lack of statistical power from an inadequate sample size: more than half of the articles had a sample size of ≤60 participants. Inadequate statistical power and limited to no justification of sample size are common concerns in nutrition research.[107] Another factor that should be considered when evaluating this review is that the majority of included studies evaluated more than 1 dietary outcome, with many evaluating 6 or more.[58,59,61,62,67,70] This type of multiple hypothesis testing without correcting for multiple comparisons is a common statistical error and may inflate the likelihood of finding a statistically significant result.[107,108] Lack of validated outcome measures for dietary intake was also common; many studies used nonvalidated questionnaires to assess dietary intake. Furthermore, almost all the studies relied on self-reported dietary intake data, either through questionnaires, 24-h recalls, or food diaries, which are often biased and prone to underreporting, potentially affecting the validity of findings.[74]

This review also has its own limitations. First, only peer-reviewed studies that were available in English were included in this review and grey literature was excluded, which may have resulted in important findings being missed. Risk of bias across studies, based on publication bias or selective reporting bias, was not formally assessed in this review but may have resulted in a risk of bias across included studies. Only the frequency of authors reporting equity-related factors and analyses was observed, and it is possible that equity may have been a consideration in the planning of the intervention but was not reported, and thus was missed in this review. Furthermore, it is also possible that authors reported equity-related factors and analyses for purposes outside of equity consideration. Authors' intentions were not noted in this review, because the purpose was to assess the frequency of reporting equity-related factors, not the intention for doing so.

CONCLUSION

Because multicomponent programs were excluded, this review provides evidence that smartphone app–based nutrition interventions, independent of other intervention methods, can affect adolescents' dietary intake. Personalized healthy-eating education messages, virtual reward systems, and gamification may be useful methods to improve the effectiveness of smartphone app–based interventions on adolescents' dietary intake. Future interventions should consider including adherence to interventions through app analytics, because app adherence will likely influence the intervention's impact on dietary behavior. Future research should also consider exploring intervention participants' experience with the app intervention and possible barriers to app adherence to better understand participants' rationale for poor intervention uptake. A time line of ≥12 weeks is preferred to ≤8 weeks for effectiveness when implementing a smartphone app–based nutrition intervention in adolescents, and this should be considered in future mHealth intervention research. Furthermore, the use of validated dietary outcome measurements is essential to improve the quality of current research on this topic. This review highlights a critical lack of reporting of equity factors in smartphone app–based nutrition interventions, while also drawing attention to the potential differential impact of these equity factors on intervention effectiveness. Thus, researchers should consider the importance of equity in their interventions, report equity factors and how these may influence their intervention, and conduct appropriate statistical analyses with adequate statistical power to determine the differential impact of equity factors on intervention adherence and effectiveness.

Acknowledgments

Author contributions. All authors made significant contributions to this manuscript, including the study design and methods. H.N.S. and H.A.J. created the initial search terms, completed the literature search, screened titles, abstracts, and full texts, and assessed the quality of included studies. J.A.G., J.A.S., and L.W.M. contributed to the revision of the search terms and literature search strategy; J.A.G. supervised the project and adjudicated in any disagreements related to study inclusion or exclusion and quality assessment. H.N.S. extracted and synthesized the data. J.A.G., J.A.S., L.W.M., S.M.B., and J.D.I. all made contributions to the data synthesis. H.N.S. drafted the original manuscript. J.A.G., H.A.J., J.A.S., L.W.M., S.M.B., and J.D.I. critically reviewed and revised the manuscript at various stages for both intellectual content and writing quality. All authors have approved the final version to be published.

Funding. This work was supported by the Canadian Institutes of Health Research (CIHR) through project grant 399384, and through trainee support from the Children's Health Foundation (CHF) provided through the Children's Health Research Institute (CHRI).

The funders did not have any role in the conception, design, performance, or approval of this work, and the views expressed in this work are the authors and are not necessarily those of CIHR, CHF, or CHRI.

Declaration of interest. The authors have no relevant interests to declare.

Supporting Information

The following Supporting Information is available through the online version of this article at the publisher's website.

Figure S1 **MEDLINE search and keywords**

Table S1 **JBI quality assessment (N = 15)**

Table S2 **Extended study characteristic summary table (N = 14)**

Table S3 **PRISMA-E checklist**

REFERENCES

1. World Health Organization. *International Telecommunication Union. Mobile Technologies for Oral Health: An Implementation Guide*. World Health Organization. Published 2021. Available at: https://apps.who.int/iris/handle/10665/345255. Accessed September 2022.
2. Tate EB, Spruijt-Metz D, O'Reilly G, et al. mHealth approaches to child obesity prevention: successes, unique challenges, and next directions. *Transl Behav Med*. 2013;3:406–415. doi:10.1007/s13142-013-0222-3.
3. Bastawrous A, Armstrong MJ. Mobile health use in low- and high-income countries: an overview of the peer-reviewed literature. *J R Soc Med*. 2013;106:130–142. doi:10.1177/0141076812472620.
4. Scarry A, Rice J, O'Connor EM, et al. Usage of mobile applications or mobile health technology to improve diet quality in adults. *Nutrients* 2022;14:2437. doi:10.3390/nu14122437.
5. Müller AM, Alley S, Schoeppe S, et al. The effectiveness of e-& mHealth interventions to promote physical activity and healthy diets in developing countries: a systematic review. *Int J Behav Nutr Phys Act*. 2016;13:109. doi:10.1186/s12966-016-0434-2.
6. Schoeppe S, Alley S, Van Lippevelde W, et al. Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: a systematic review. *Int J Behav Nutr Phys Act*. 2016;13:127. doi:10.1186/s12966-016-0454-y.
7. Villinger K, Wahl DR, Boeing H, et al. The effectiveness of app-based mobile interventions on nutrition behaviours and nutrition-related health outcomes: a systematic review and meta-analysis. *Obes Rev*. 2019;20:1465–1484. doi:10.1111/obr.12903.
8. Smahel D, MacHackova H, Mascheroni G, et al. EU Kids Online 2020: Survey results from 19 countries. Published 2020. Available at: https://doi.org/10.21953/lse.47fdeqj01ofo. Accessed October 10, 2022.
9. Pew Research Center: Internet, Science & Tech. Teens, Social Media & Technology 2018. Published May 31, 2018. Available at: https://www.pewresearch.org/internet/2018/05/31/teens-social-media-technology-2018/. Accessed October 10, 2022.
10. Government of Canada, Statistics Canada. Table 22-10-0115-01 Smartphone use and smartphone habits by gender and age group, inactive. Ottawa, Canada. Published June 2021. Available at: https://doi.org/10.25318/2210011501-eng. Accessed October 10, 2022.
11. Keating SR, McCurry MK. Systematic review of text messaging as an intervention for adolescent obesity. *J Am Assoc Nurse Pract*. 2015;27:714–720. doi:10.1002/2327-6924.12264.
12. World Health Organization. Adolescent health. Updated 2023. Available at: https://www.who.int/health-topics/adolescent-health#tab=tab_1. Accessed October 10, 2022.
13. Das JK, Salam RA, Thornburg KL, et al. Nutrition in adolescents: physiology, metabolism, and nutritional needs. *Ann N Y Acad Sci*. 2017;1393:21–33. doi:10.1111/nyas.13330.
14. Neufeld LM, Andrade EB, Ballonoff Suleiman A, et al. Food choice in transition: adolescent autonomy, agency, and the food environment. *Lancet*. 2022;399:185–197. doi:10.1016/S0140-6736(21)01687-1.
15. Keown A, Nelson R. Independent decision making of adolescents regarding food choice. *Int J Consum Stud*. 2018;42:469–477. doi:10.1111/ijcs.12446.
16. Cohen JFW, Gorski MT, Gruber SA, et al. The effect of healthy dietary consumption on executive cognitive functioning in children and adolescents: a systematic review. *Br J Nutr*. 2016;116:989–1000. doi:10.1017/S0007114516002877.
17. Wahl R. Nutrition in the adolescent. *Pediatr Ann*. 1999;28:107–111. doi:10.3928/0090-4481-19990201-07.
18. O'Neil A, Quirk SE, Housden S, et al. Relationship between diet and mental health in children and adolescents: a systematic review. *Am J Public Health*. 2014;104:e31–e42. doi:10.2105/AJPH.2014.302110.
19. World Health Organization. Diet, nutrition and prevention of chronic diseases: report of a joint WHO/FAO expert consultation. 2003. Available at: https://apps.who.int/iris/handle/10665/42665. Accessed October 2022.

20. Acar Tek N, Yildiran H, Akbulut G, et al. Evaluation of dietary quality of adolescents using Healthy Eating Index. *Nutr Res Pract*. 2011;5:322–328. doi:10.4162/nrp.2011.5.4.322.
21. Darfour-Oduro SA, Buchner DM, Andrade JE, et al. A comparative study of fruit and vegetable consumption and physical activity among adolescents in 49 low-and-middle-income countries. *Sci Rep*. 2018;8:1623. doi:10.1038/s41598-018-19956-0.
22. Rosi A, Paolella G, Biasini B et al.; SINU Working Group on Nutritional Surveillance in Adolescents. Dietary habits of adolescents living in North America, Europe or Oceania: a review on fruit, vegetable and legume consumption, sodium intake, and adherence to the Mediterranean Diet. *Nutr Metab Cardiovasc Dis*. 2019;29:544–560. doi:10.1016/j.numecd.2019.03.003.
23. Kupka R, Siekmans K, Beal T. The diets of children: overview of available data for children and adolescents. *Glob Food Sec*. 2020;27:100442. doi:10.1016/j.gfs.2020.100442.
24. Amoutzopoulos B, Steer T, Roberts C, et al. Free and added sugar consumption and adherence to guidelines: the UK national diet and nutrition survey (2014/15–2015/16). *Nutrients*. 2020;12:393. doi:10.3390/nu12020393.
25. Ruiz E, Rodriguez P, Valero T, et al. Dietary intake of individual (free and intrinsic) sugars and food sources in the Spanish population: findings from the ANIBES study. *Nutrients*. 2017;9:275. doi:10.3390/nu9030275.
26. Bailey RL, Fulgoni VL, Cowan AE, et al. Sources of added sugars in young children, adolescents, and adults with low and high intakes of added sugars. *Nutrients*. 2018;10:102. doi:10.3390/nu10010102.
27. Paramastri R, Pratama SA, Ho DKN, et al. Use of mobile applications to improve nutrition behaviour: a systematic review. *Comput Methods Programs Biomed*. 2020;192:105459. doi:10.1016/j.cmpb.2020.105459.
28. Langarizadeh M, Sadeghi M, As'habi A, et al. Mobile apps for weight management in children and adolescents; an updated systematic review. *Patient Educ Couns*. 2021;104:2181–2188. doi:10.1016/j.pec.2021.01.035.
29. Reddy P, Dukhi N, Sewpaul R, et al. Mobile health interventions addressing childhood and adolescent obesity in sub-Saharan Africa and Europe: current landscape and potential for future research. *Front Public Health*. 2021;9:604439. doi:10.3389/fpubh.2021.604439.
30. Rose T, Barker M, Maria Jacob C, et al. A systematic review of digital interventions for improving the diet and physical activity behaviors of adolescents. *J Adolesc Health*. 2017;61:669–677. doi:10.1016/j.jadohealth.2017.05.024.
31. World Health Organization. Health equity. Updated 2023. Accessed October 10, 2022. Available at: https://www.who.int/health-topics/health-equity.
32. Petkovic J, Jull J, Yoganathan M, et al. Reporting of health equity considerations in cluster and individually randomized trials. *Trials* 2020;21:308. doi:10.1186/s13063-020-4223-5.
33. Kumanyika SK. A framework for increasing equity impact in obesity prevention. *Am J Public Health*. 2019;109:1350–1357. doi:10.2105/AJPH.2019.305221.
34. McGill R, Anwar E, Orton L, et al. Are interventions to promote healthy eating equally effective for all? Systematic review of socioeconomic inequalities in impact. *BMC Public Health*. 2015;15:457. doi:10.1186/s12889-015-1781-7.
35. Shatenstein B, Ghadirian P. Influences on diet, health behaviours and their outcome in select ethnocultural and religious groups. *Nutrition*. 1998;14:223–230. doi:10.1016/S0899-9007(97)00425-5.
36. Alkerwi A, Vernier C, Sauvageot N, et al. Demographic and socioeconomic disparity in nutrition: application of a novel correlated component regression approach. *BMJ Open*. 2015;5: E 006814. doi:10.1136/bmjopen-2014-006814.
37. Olstad DL, Campbell NRC, Raine KD. Diet quality in Canada: policy solutions for equity. *CMAJ*. 2019;191:E100–E102. doi:10.1503/cmaj.180938.
38. O'Neill J, Tabish H, Welch V, et al. Applying an equity lens to interventions: using PROGRESS ensures consideration of socially stratifying factors to illuminate inequities in health. *J Clin Epidemiol*. 2014;67:56–64. doi:10.1016/j.jclinepi.2013.08.005.
39. Mayberry LS, Lyles CR, Oldenburg B, et al. mHealth interventions for disadvantaged and vulnerable people with type 2 diabetes. *Curr Diab Rep*. 2019;19:148. doi:10.1007/s11892-019-1280-9.
40. Nittas V, Ameli V, Little M, et al. Exploring the equity impact of mobile health-based human immunodeficiency virus interventions: a systematic review of reviews and evidence synthesis. *Digit Health*. 2020;6:205520762094236. doi:10.1177/2055207620942360.
41. Escoffery C. Gender similarities and differences for e-Health behaviors among U.S. adults. *Telemed J E Health*. 2018;24:335–343. doi:10.1089/tmj.2017.0136.
42. Bol N, Helberger N, Weert JCM. Differences in mobile health app use: a source of new digital inequalities? *Inf Soc*. 2018;34:183–193. doi:10.1080/01972243.2018.1438550.
43. Azzopardi-Muscat N, Sørensen K. Towards an equitable digital public health era: promoting equity through a health literacy perspective. *Eur J Public Health*. 2019;29:13–17. doi:10.1093/eurpub/ckz166.
44. Welch V, Petticrew M, Tugwell P, et al.; PRISMA-Equity Bellagio Group. PRISMA-Equity 2012 Extension: reporting guidelines for systematic reviews with a focus on health equity. *PLoS Med*. 2012;9:e1001333. doi:10.1371/journal.pmed.1001333.
45. Covidence. Covidence - Better systematic review management. Available at: https://www.covidence.org/. Accessed October 10, 2022.
46. Spook J, Paulussen T, Kok G, et al. Evaluation of a serious self-regulation game intervention for overweight-related behaviors ("Balance It"): a pilot study. *J Med Internet Res*. 2016;18:e225. doi:10.2196/jmir.4964.
47. Defining your question: PICO and PS | NCCMT. Available at: https://www.nccmt.ca/knowledge-repositories/search/138. Accessed July 24, 2022.
48. Noar SM, Benac CN, Harris MS. Does tailoring matter? Meta-analytic review of tailored print health behavior change interventions. *Psychol Bull*. 2007;133:673–693. doi:10.1037/0033-2909.133.4.673
49. Critical Appraisal Tools | JBI. Available at: https://jbi.global/critical-appraisal-tools.Accessed October 20, 2022.
50. Schlund A, Reimers AK, Bucksch J, et al. Do intervention studies to promote physical activity and reduce sedentary behavior in children and adolescents take sex/gender into account? A systematic review. *J Phys Act Health*. 2021;18:461–468. doi:10.1123/jpah.2020-0666.
51. Welch V, Doull M, Yoganathan M, et al. Reporting of sex and gender in randomized controlled trials in Canada: a cross-sectional methods study. *Res Integr Peer Rev*. 2017;2:15. doi:10.1186/s41073-017-0039-6.
52. Love RE, Adams J, Sluijs E v. Equity effects of children's physical activity interventions: a systematic scoping review. *Int J Behav Nutr Phys Act*. 2017;134:14. doi:10.1186/s12966-017-0586-8.
53. Harrison F, Jones AP. A framework for understanding school based physical environmental influences on childhood obesity. *Health Place*. 2012;18:639–648. doi:10.1016/j.healthplace.2011.12.009.
54. Geyer S, Hemström O, Peter R, et al. Education, income, and occupational class cannot be used interchangeably in social epidemiology. Empirical evidence against a common practice. *J Epidemiol Community Health*. 2006;60:804–810. doi:10.1136/jech.2005.041319.
55. Broer M, Bai Y, Fonseca F. A review of the literature on socioeconomic status and educational achievement. In: Hegarty S, Rutkowski L, eds. *Socioeconomic Inequality and Educational Outcomes. IEA Research for Education*. Vol. 5. Switzerland: Springer, Cham; 2019:7–17. doi:10.1007/978-3-030-11991-1.
56. Seabrook JA, Avison WR. Socioeconomic status and cumulative disadvantage processes across the life course: implications for health outcomes. *Can Rev Sociol*. 2012;49:50–68. doi:10.1111/j.1755-618x.2011.01280.x
57. Uphoff EP, Pickett KE, Cabieses B, et al. A systematic review of the relationships between social capital and socioeconomic inequalities in health: a contribution to understanding the psychosocial pathway of health inequalities. *Int J Equity Health*. 2013;12:54. doi:10.1186/1475-9276-12-54.
58. Likhitweerawong N, Boonchooduang N, Kittisakmontri K, et al. Effectiveness of mobile application on changing weight, healthy eating habits, and quality of life in children and adolescents with obesity: a randomized controlled trial. *BMC Pediatr*. 2021;21:1–9. doi:10.1186/s12887-021-02980-x.
59. Likhitweerawong N, Boonchooduang N, Kittisakmontri K, et al. Short-term outcomes of tablet/smartphone-based (OBEST) application among obese Thai school-aged children and adolescents: a randomized controlled trial. *Obesity Medicine*. 2020;20:100287. doi:10.1016/j.obmed.2020.100287.
60. Ragelienė T, Aschemann-Witzel J, Grønhøj A. Efficacy of a smartphone application-based intervention for encouraging children's healthy eating in Denmark. *Health Promot Int*. 2022;37:1–19. doi:10.1093/heapro/daab081.
61. Heikkilä M, Lehtovirta M, Autio O, et al. The impact of nutrition education intervention with and without a mobile phone application on nutrition knowledge among young endurance athletes. *Nutrients*. 2019;11:2249. doi:10.3390/nu11092249.
62. Fuemmeler BF, Holzwarth E, Sheng Y, et al. Mila Blooms: a mobile phone application and behavioral intervention for promoting physical activity and a healthy diet among adolescent survivors of childhood cancer. *Games Health J*. 2020;9:279–289. doi:10.1089/g4h.2019.0060.
63. De Cock N, Van Lippevelde W, Vangeel J, et al. Feasibility and impact study of a reward-based mobile application to improve adolescents' snacking habits. *Public Health Nutr*. 2018;21:2329–2344. doi:10.1017/S1368980018000678.
64. Benavides C, Benítez-Andrades JA, Marqués-Sánchez P, et al. eHealth intervention to improve health habits in the adolescent population: mixed methods study. *JMIR Mhealth Uhealth*. 2021;9:e20217. doi:10.2196/20217.
65. Byrne S, Gay G, Pollack JP, et al. Caring for mobile phone-based virtual pets can influence youth eating behaviors. *J Child Media*. 2012;6:83–99. doi:10.1080/17482798.2011.633410.
66. Sousa P, Martinho R, Reis CI, et al. Controlled trial of an mHealth intervention to promote healthy behaviours in adolescence (TeenPower): effectiveness analysis. *J Adv Nurs*. 2020;76:1057–1068. doi:10.1111/jan.14301.
67. Lee JE, Song S, Ahn JS, et al. Use of a mobile application for self-monitoring dietary intake: feasibility test and an intervention study. *Nutrients*. 2017;9:748. doi:10.3390/nu9070748.
68. Kato-Lin YC, Kumar UB, Sri Prakash B, et al. Impact of pediatric mobile game play on healthy eating behavior: randomized controlled trial. *JMIR Mhealth Uhealth*. 2020;8:e15717. doi:10.2196/15717
69. Chew CSE, Davis C, Lim JKE, et al. Use of a mobile lifestyle intervention app as an early intervention for adolescents with obesity: single-cohort study. *J Med Internet Res*. 2021;23:e20520. doi:10.2196/20520.

70. Jimoh F, Lund EK, Harvey LJ, et al. Comparing diet and exercise monitoring using smartphone app and paper diary: a two-phase intervention study. *JMIR Mhealth Uhealth*. 2018;6:e17. doi:10.2196/mhealth.7702.
71. Štefan L, Prosoli R, Juranko D, et al. The reliability of the Mediterranean diet quality index (KIDMED) questionnaire. *Nutrients*. 2017;9:419. doi:10.3390/nu9040419.
72. Pérez-Fortis A, Ulla Díez SM, Padilla JL. Psychometric properties of the Spanish version of the Health-Promoting Lifestyle Profile II. *Res Nurs Health*. 2012;35:301–313. doi:10.1002/nur.21470.
73. Villasana MV, Pires IM, Sá J, et al. Promotion of healthy lifestyles to teenagers with mobile devices: a case study in Portugal. *Healthcare (Basel)*. 2020;8:315. doi:10.3390/healthcare8030315.
74. Ravelli MN, Schoeller DA. Traditional self-reported dietary instruments are prone to inaccuracies and new approaches are needed. *Front Nutr*. 2020;7:90. doi:10.3389/fnut.2020.00090.
75. Friedberg JP, Lipsitz SR, Natarajan S. Challenges and recommendations for blinding in behavioral interventions illustrated using a case study of a behavioral intervention to lower blood pressure. *Patient Educ Couns*. 2010;78:5–11. doi:10.1016/j.pec.2009.04.009.
76. Champion KE, Parmenter B, McGowan C, et al. Effectiveness of school-based eHealth interventions to prevent multiple lifestyle risk behaviours among adolescents: a systematic review and meta-analysis. *Lancet Digit Health*. 2019;1:206–221. doi:10.1016/S2589-7500(19)30088-3.
77. Hsu MSH, Rouf A, Allman-Farinelli M. Effectiveness and behavioral mechanisms of social media interventions for positive nutrition behaviors in adolescents: a systematic review. *J Adolesc Health*. 2018;63:531–545. doi:10.1016/j.jadohealth.2018.06.009.
78. Evans CE, Christian MS, Cleghorn CL, et al. Systematic review and meta-analysis of school-based interventions to improve daily fruit and vegetable intake in children aged 5 to 12 y. *Am J Clin Nutr*. 2012;96:889–901. doi:10.3945/ajcn.111.030270.
79. Inchley J, Currie D, Jewell J, et al. *Adolescent obesity and related behaviours: Trends and inequalities in the WHO European Region, 2002–2014: Observations from the Health Behaviour in School-Aged Children (HBSC) WHO Collaborative Cross-National Study*. World Health Organization. Regional Office for Europe; 2017. Available at: https://apps.who.int/iris/handle/10665/329417. Accessed October 10, 2022.
80. Lange SJ. Percentage of adolescents meeting federal fruit and vegetable intake recommendations - youth risk behavior surveillance system, United States, 2017. *Morb Mortal Wkly Rep*. 2021;70:69–74. doi:10.15585/mmwr.mm7003a1.
81. Rosinger A, Herrick K, Gahche J, et al. Sugar-sweetened beverage consumption among U.S. youth, 2011-2014. *NCHS Data Brief.* 2017;(271):1–8.
82. Yang L, Bovet P, Liu Y, et al. Consumption of carbonated soft drinks among young adolescents aged 12 to 15 years in 53 low- and middle-income countries. *Am J Public Health*. 2017;107:1095–1100. doi:10.2105/AJPH.2017.303762.
83. Bleich SN, Vercammen KA. The negative impact of sugar-sweetened beverages on children's health: an update of the literature. *BMC Obes*. 2018;5:6. doi:10.1186/s40608-017-0178-9.
84. Tonkin E, Brimblecombe J, Wycherley TP. Characteristics of smartphone applications for nutrition improvement in community settings: a scoping review. *Adv Nutr*. 2017;8:308–322. doi:10.3945/an.116.013748.
85. Honary M, Bell BT, Clinch S, et al. Understanding the role of healthy eating and fitness mobile apps in the formation of maladaptive eating and exercise behaviors in young people. *JMIR Mhealth Uhealth*. 2019;7: E 14239. doi:10.2196/14239.
86. Simpson CC, Mazzeo SE. Calorie counting and fitness tracking technology: associations with eating disorder symptomatology. *Eat Behav*. 2017;26:89–92. doi:10.1016/j.eatbeh.2017.02.002.
87. Kessler RC, Berglund PA, Chiu WT, et al. The prevalence and correlates of binge eating disorder in the World Health Organization World Mental Health Surveys. *Biol Psychiatry*. 2013;73:904–914. doi:10.1016/j.biopsych.2012.11.020.
88. Micali N, Hagberg KW, Petersen I, et al. The incidence of eating disorders in the UK in 2000-2009: findings from the general practice research database. *BMJ Open*. 2013;3: E 002646. doi:10.1136/bmjopen-2013-002646.
89. Neumark-Sztainer D, Wall M, Larson NI, et al. Dieting and disordered eating behaviors from adolescence to young adulthood: findings from a 10-year longitudinal study. *J Am Diet Assoc*. 2011;111:1004–1011. doi:10.1016/j.jada.2011.04.012.
90. Turner-McGrievy GM, Dunn CG, Wilcox S, et al. Defining adherence to mobile dietary self-monitoring and assessing tracking over time: tracking at least two eating occasions per day is best marker of adherence within two different mobile health randomized weight loss interventions. *J Acad Nutr Diet*. 2019;119:1516–1524. doi:10.1016/j.jand.2019.03.012.
91. González ODJ, Tugault-Lafleur CN, Buckler EJ, et al. The Aim2Be mHealth intervention for children with overweight or obesity and their parents: person-centered analyses to uncover digital phenotypes. *J Med Internet Res*. 2022;24:e35285. doi:10.2196/35285.
92. Oakley-Girvan I, Yunis R, Longmire M, et al. What works best to engage participants in mobile app interventions and e-Health: a scoping review. *Telemed J E Health*. 2022;28:768–780. doi:10.1089/tmj.2021.0176.
93. Plotnikoff RC, Costigan SA, Williams RL, et al. Effectiveness of interventions targeting physical activity, nutrition and healthy weight for university and college students: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2015;12:45. doi:10.1186/s12966-015-0203-7.
94. Dute DJ, Bemelmans WJE, Breda J. Using mobile apps to promote a healthy lifestyle among adolescents and students: a review of the theoretical basis and lessons learned. *JMIR mHealth uHealth*. 2016;4:e39. doi:10.2196/mhealth.3559.
95. Sahay TB, Ashbury FD, Roberts M, et al. Effective components for nutrition interventions: a review and application of the literature. *Health Promot Pract*. 2006;7:418–427. doi:10.1177/1524839905278626.
96. Milne-Ives M, Lam C, De Cock C, et al. Mobile apps for health behavior change in physical activity, diet, drug and alcohol use, and mental health: systematic review. *JMIR Mhealth Uhealth*. 2020;8:e17046. doi:10.2196/17046.
97. Gee GC, Ford CL. Structural racism and health inequities. *Du Bois Rev*. 2011;8:115–132. doi:10.1017/S1742058X11000130.
98. Flanagin A, Frey T, Christiansen SL; AMA Manual of Style Committee. Updated guidance on the reporting of race and ethnicity in medical and science journals. *JAMA* 2021;326:621–627. doi:10.1001/jama.2021.13304
99. Sadler RC, Clark AF, Wilk P, et al. Using GPS and activity tracking to reveal the influence of adolescents' food environment exposure on junk food purchasing. *Can J Public Health*. 2016;107:eS14–eS20. doi:10.17269/CJPH.107.5346.
100. Engler-Stringer R, Le H, Gerrard A, et al. The community and consumer food environment and children's diet: a systematic review. *BMC Public Health*. 2014;14:522. doi:10.1186/1471-2458-14-522.
101. Vargas-Garcia E j, Evans C e l, Prestwich A, et al. Interventions to reduce consumption of sugar-sweetened beverages or increase water intake: evidence from a systematic review and meta-analysis. *Obes Rev*. 2017;18:1350–1363. doi:10.1111/obr.12580.
102. Attwood S, van Sluijs E, Sutton S. Exploring equity in primary-care-based physical activity interventions using PROGRESS-Plus: a systematic review and evidence synthesis. *Int J Behav Nutr Phys Act*. 2016;13:1–16. doi:10.1186/s12966-016-0384-8.
103. Inglis G, Archibald D, Doi L, et al. Credibility of subgroup analyses by socioeconomic status in public health intervention evaluations: an underappreciated problem? *SSM Popul Health*. 2018;6:245–251. doi:10.1016/j.ssmph.2018.09.010.
104. Sun X, Briel M, Busse JW, et al. Credibility of claims of subgroup effects in randomised controlled trials: systematic review. *BMJ*. 2012;344:e1553. doi:10.1136/bmj.e1553.
105. Kennedy-Martin T, Curtis S, Faries D, et al. A literature review on the representativeness of randomized controlled trial samples and implications for the external validity of trial results. *Trials*. 2015;16:495. doi:10.1186/s13063-015-1023-4.
106. Enyioha C, Hall M, Voisin C, et al. Effectiveness of mobile phone and web-based interventions for diabetes and obesity among African American and Hispanic adults in the United States: systematic review. *JMIR Public Health Surveill*. 2022;8: E 25890. doi:10.2196/25890
107. Schaafsma H, Laasanen H, Twynstra J, et al. A review of statistical reporting in dietetics research (2010–2019): how is a Canadian journal doing? *Can J Diet Pract Res*. 2021;82:59–67. doi:10.3148/cjdpr-2021-005.
108. Groenwold RHH, Goeman JJ, Cessie SL, et al. Multiple testing: when is many too much? *Eur J Endocrinol*. 2021;184:E11–E14. doi:10.1530/EJE-20-1375.