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REVIEW

Efficacy of technology-based interventions for obesity prevention in adolescents: a systematic review

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Jyu-Lin Chen[1]
Mary Ellen Wilkosz[2]

[1]Department of Family Health Care Nursing, School of Nursing, University of California, San Francisco, CA, [2]Nursing Department, Sonoma State University, Rohnert Park, CA, USA

Abstract: About one third of adolescents in the USA are overweight and/or obese. Obesity during the adolescent years is associated with many adverse health consequences, including type 2 diabetes, hypertension, hyperlipidemia, and psychosocial problems. Because of substantial advances in technologies and wide acceptance by adolescents, it is now possible to use technology for healthy weight management and prevention of obesity. This systematic review used Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and aimed to evaluate the existing literature reported on the effectiveness of technology-based intervention (web-based, e-learning, and active video games) in preventing obesity in adolescents. The primary aim of this review was to explore if components of specific interventions were associated with a reduction in body mass index. Research articles obtained from CINAHL, Embase, PubMed, PsycInfo, and the Cochrane database from1990 to 2014 were reviewed. A total of 131 published articles were identified, and 14 met the inclusion criteria of a randomized or nonrandomized clinical study with body mass index as primary outcome and/or secondary outcomes of diet/physical activity and/or psychosocial function, tested lifestyle interventions to prevent obesity, used technology, and studied adolescents (aged 12–18 years). The results indicated that six of 14 studies found body mass index and/or body fat decreased at short-term (less than 12 months) follow-up. Six of eleven studies that examined physical activity or physical activity-related outcomes found an improved physical activity outcome (time playing active video games and increase in physical activity time), while five of seven studies which assessed dietary outcomes indicated improvement in dietary behaviors. Five of seven studies suggested an improvement in psychosocial function (reduced depression, improved self-esteem and efficacy, improvement on Behavior Assessment Scale) in adolescents involved in the technology-based intervention. All effective interventions utilized dietary and physical activity strategies as part of intervention components. Because of the variation in duration of intervention (range 10 weeks to 2 years), it is not clear what length of intervention is most effective. Future research should assess the long-term impact of technology-based interventions and evaluate mediators and moderators for weight change in adolescents.

Keywords: technology intervention, obesity, adolescents, web-based, exer-gaming

Introduction

Obesity among adolescents has reached epidemic proportions worldwide.[1] Approximately one third of adolescents in the USA are currently overweight or at risk for becoming overweight.[2] Obesity in adolescence predisposes this age group to obesity in adulthood and is a major risk factor for a number of serious health conditions, including diabetes, hypertension, heart disease, stroke, osteoarthritis, and certain types of cancer.[3–5] Because 80% of obese adolescents will become obese adults,[6] with increased susceptibility to type

Correspondence: Jyu-Lin Chen
University of California, San Francisco, Department of Family Health Care Nursing, 2 Koret Way, Box 0606, San Francisco, CA 94143, USA
Tel +1 415 502 6015
Fax +1 415 753 2161
Email jyu-lin.chen@nursing.ucsf.edu

2 diabetes mellitus and cardiovascular disease,[7–9] management of obesity in adolescents is critical. Many intervention studies have been conducted to address this epidemic health concern.[10–12] As technology has become such an important part of daily life, especially among adolescents, technology-based interventions, including Internet-based weight management tools, social media, apps for smartphones, and active video games, have been developed as methods to prevent obesity in this age group.[13–15]

The most recent research suggests that 78% of adolescents in the USA have cell phones (47% smartphones), 23% have a tablet computer, and 93% have access to a computer and use one at home.[12] Due to the high use of technology among adolescents, there are health promotion opportunities that include tapping into the new media channels integral to youth culture.[13] The use of mobile technologies may offer a practical and reliable means of managing obesity in busy primary care clinics. In the last decade, several interventions using technology to prevent obesity have been tested in schools, in after school programs, and in the clinic setting. Few systematic reviews have been conducted to examine the impact of technology-based interventions on childhood obesity.[16,17] An et al examined the effect of web-based weight management on children and adolescents,[16] and Lu et al explored the effect of health video games on prevention of childhood obesity.[17] The review by An et al explored multiple types of intervention, including home Internet interventions, interventions with parents, and interactive websites.[16] Although their review included weight-related variables (body mass index [BMI], BMI percentile, physical activity, and diet) it included studies testing for multiple other outcomes and included various targeted populations (children, parents) which made comparison of studies difficult. In contrast, Lu et al reviewed studies that focused only on health video games in overweight or obese children.[17] There is a dearth of knowledge on the impact of technology-based interventions, including both web-based and active video games, on weight management and weight-related health behaviors (physical activity, sedentary activity, and diet) in adolescents.

The purpose of this review is to assist health care providers and researchers in making more informed decisions about which types of technology-based interventions for adolescent obesity prevention are most suitable and achieve sustainable weight reduction, impact on amount of physical activity, a reduction in sedentary activity, improved dietary behaviors, and/or positive psychosocial outcomes. With the advancement of technology and the opportunity to explore the use of technology as an approach to adolescent obesity, it is important to systematically review the methodological rigor of technology-based interventions and their impact on BMI, and to identify types of interventions that work best for prevention of obesity in adolescents. The two specific objectives of this review were to evaluate the existing literature reported on the effectiveness of technology-based interventions in preventing obesity in adolescents and to explore components of these interventions that are associated with significant BMI outcomes.

Methods

Data sources

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines that have been used for other obesity-related systematic reviews.[18] Our search covered all available years from January 1990 to January 2014 in CINAHL, Embase, PubMed, PsycINFO, and the Cochrane Library. The bibliographies of included articles were hand-searched, and promising titles were reviewed in order to locate articles not catalogued in the major databases. If the reviewer was unable to determine if an article pertained to the study by title, then the abstract was reviewed. The search terms used were (Adiposity[mh] OR Body Mass Index[mh] OR Body Weight[mh:noexp] OR Body Weight Changes[mh] OR Obesity[mh] OR Overweight[mh] OR Weight Gain[mh] OR Weight Loss[mh] OR Weight Reduction Program[mh] OR "abdominal fat"[tiab] OR adiposity[tiab] OR bmi[tiab] OR "body mass index"[tiab] OR "body weight"[tiab] OR obese[tiab] OR obesity[tiab] OR overweight[tiab] OR "visceral fat"[tiab] OR "weight loss"[tiab] OR "weight management"[tiab] OR "weight reduction"[tiab]) AND Blogging[mh] OR Cellular Phone[mh] OR Computer-Assisted Instruction[mh] OR Computer Graphics[mh] OR Computer Systems[majr] OR Computers[majr] OR Computers, Handheld[mh] OR Educational Technology[mh] OR Electronic Mail[mh] OR Interactive Tutorial[pt] OR Internet[mh] OR Multimedia[mh] OR Software[mh:noexp] OR Technology[majr:noexp] OR Telecommunications[majr:noexp] OR Telemedicine[mh:noexp] OR Text Messaging[mh] OR User-Computer Interface[mh] OR Videoconferencing[mh] OR Video Games[mh] OR Webcasts as Topic[mh] OR Wireless Technology[mh].

To assure the quality of the study findings reported, we selected papers that used either a randomized controlled trial approach or a quasi-experimental study design. Inclusion criteria consisted of: randomized clinical trials or clinical

trials without randomization or a control group; a primary outcome including BMI or BMI z-score (both self-report and measurement collected using the World Health Organization classification) and one of the health behaviors (diet and physical activity); trials that tested lifestyle/weight management interventions (through physical activity or diet modification using Internet or active video games) intended to prevent obesity or excessive weight gain; trials that tested lifestyle interventions using at least one of the eHealth/mHealth (term used for the practice of medicine and public health supported by mobile devices) intervention components including web (Internet)-based, social media, and mobile communication technology; and participants included adolescents aged from 12–18 years. Papers were excluded if they described primary prevention interventions or if the majority of participants were over 18 years of age and if the articles were published in a language other than English.

Data extraction

This systematic review compares randomized controlled trials and pre-post test (quasi-experimental) studies that utilized technology-based interventions including active video games and the Internet as interventions to decrease BMI or percent body fat. The studies focused primarily on increasing physical activity, decreasing sedentary activity, improving dietary outcomes, and/or improving diet skills (increased fruit and vegetables, decreased sugary drinks and high fat foods) as well as improving psychosocial well-being (weight concerns, self-efficacy, self-esteem, and peer support). This review involves assessing educational, behavioral, and health promotion interventions delivered through technology including web/Internet-based, social media, and mobile communication technology aimed to prevent obesity in adolescents.

Outcome variables

The initial search generated a total of 1,175 papers from all the search databases. To obtain rigorous scientific evidence, only randomized controlled trials and pre-post test studies were selected for this systematic review in terms of key outcomes and interventions used. One reviewer screened the study title and abstract as the first screening stage and narrowed the articles to 131 papers. Two reviewers then reviewed the abstract and narrowed the search from 131 articles to 32 articles by eliminating duplicate papers based on the same research. Articles that were nonintervention studies, such as review papers, and cross-sectional studies were also excluded. The primary outcome was reduction of BMI in adolescents with the use of technology. Studies that did not target obesity, were not technology-based, and not conducted in adolescents were excluded. Based on the inclusion criteria, two reviewers examined the full papers and identified 14 studies that met the inclusion criteria[13,21–33] (see Figure 1).

The 14 studies reviewed used a variety of outcome measures, including weight-related measures (ie, BMI, BMI z-score) which were the primary outcomes reviewed in this paper, as well as several secondary outcomes including percentage of body fat, physical activity level, physical fitness, dietary intake, and psychosocial variables (ie, self-esteem, self-competence). In this review, the effects of the interventions were evaluated in terms of weight-related measurements, specifically BMI and BMI z-score, as they were used in the studies included in the review.

Intervention components

Detailed examination of the following components of effective interventions was conducted: behavior change targets, method used to effect weight changes, frequency of contact, and duration of the intervention. The effectiveness of the intervention was determined by reviewing the results of the study and reporting the study findings.

Assessment of methodological rigor

We adapted the methodological rigor assessment for the included articles from those in use by the Cochrane Effective Practice and Organization of Care Review Group and recent systematic reviews.[19,20] The nine criteria were scored objectively using published data and reflect potential bias (see Table 1). Studies were rated independently by two reviewers. Disagreements were discussed until consensus was reached. Disagreement between reviewers was due to confusion in meaning of "intent to treat", and once clarified, consensus was reached. Each item was rated as "yes" (1), "no" (0), or "not applicable". A total methodological quality score (ranging from 0 to 9) was calculated by summing up all "yes" items. Studies were rated as having good methodological quality if they met at least 80% of the criteria (seven of nine items or five of six items).

Results

Effectiveness of technology-based intervention in preventing adolescent obesity

BMI/percentage body fat

Six studies (42.8%) found a significant decrease in BMI or percentage body fat after the intervention.[13,23,25,27,28,33]

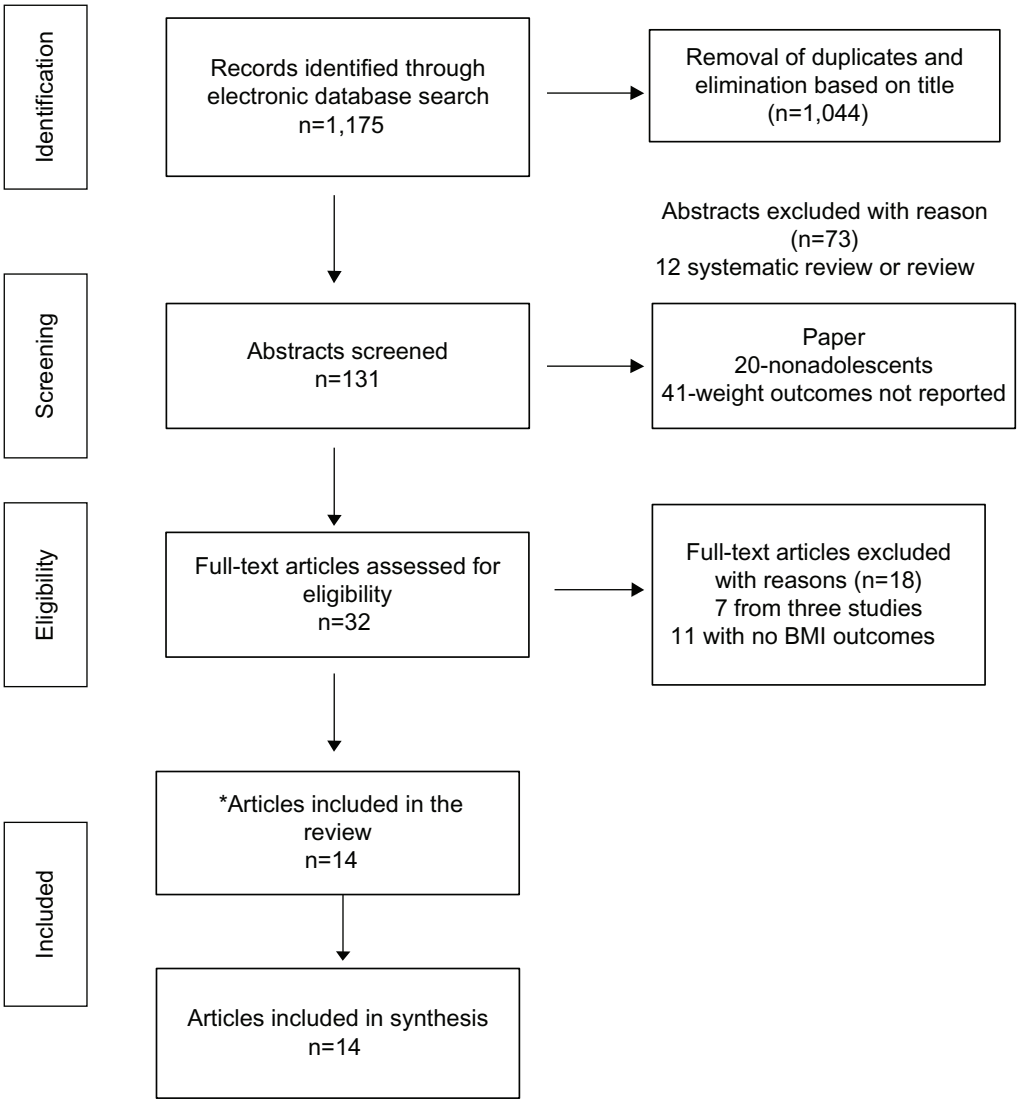

Figure 1 Preferred reporting items for systematic reviews and meta-analyses flow diagram for articles identified, screened eligible, and included in this paper.
Note: *Systematic reviews.
Abbreviation: BMI, body mass index.

Four Internet-based intervention studies[23,25,27,33] and two active video game-based interventions[13,34] reported that adolescents in the intervention group had significantly reduced BMI and/or percentage body fat immediately after the intervention or up to 9 months post intervention. Short-term effects of technology-based interventions were found (less than 12 months of follow-up) in all six studies, while one study (by Williamson et al)[33] found no beneficial effect on BMI at assessment 2 years post baseline (see Table 2 for study description).

Physical activity, sedentary activity time, and dietary behavior

Six of the eleven studies that examined physical activity or physical activity-related outcomes found improved physical activity outcomes (four Internet-based interventions and two active video gaming interventions).[13,21,23,26,28,35] Two of three studies that assessed the impact of technology-based interventions on reducing sedentary activity time found a significant decrease in sedentary behaviors (all active video game interventions).[13,28] For dietary behavior, five of eleven studies assessed dietary outcomes indicating improvement in dietary behaviors (ie, increased fruit/vegetable intake, decreased sugary drinks and snacking) in adolescents in the intervention groups (four Internet-based interventions and one active video game intervention).[13,22–24,33] For instance, a study by Chen et al[22] on tailored web-based interventions for Chinese-American adolescents (aged 12–15 years) found a significant decrease in sedentary activity associated

Table 1 Methodological rigor of included studies

Reference	Randomization	Blinding	Inclusion/exclusion criteria clearly described	Intent-to-treat analysis used	Adequate sample size calculations shown	Adequate control group*	Standard measures described	Comparison of baseline parameters of completers versus noncompleters	80% retention rate**	MR score
Adamo et al[21]	1	0	1	1	0	1	1	1	1	7/9
Chen et al[22]	1	0	1	1	1	1	1	1	1	8/9
Christison and Khan[13]	N/A	N/A	1	0	0	N/A	1	1	1	4/6
Doyle et al[23]	1	0	1	1	1	1	1	1	1	8/9
Ezendam et al[24]	1	0	1	1	0	1	1	1	1	7/9
Hung et al[25]	N/A	N/A	1	0	0	N/A	1	1	1	4/6
Jago et al[26]	1	0	1	1	0	1	1	1	1	6/9
Jones et al[27]	1	1 assessor	1	1	0	1	1	1	1	8/9
Maddison et al[28]	1	0	1	1	1	1	1	1	1	8/9
Nguyen et al[29]	1	0	1	1	0	1	1	1	0	6/9
Owens et al[30]	N/A	N/A	1	1	0	N/A	1	0	0	3/6
Staiano et al[31]	1	0	1	1	0	1	1	1	0	6/9
Wagener et al[32]	1	0	1	1	0	1	1	0	1	6/9
Williamson et al[33]	1	0	1	1	1	1	1	1	0	7/9

Notes: *Control group was reflective of study group in number, age, sex, ethnicity; **80% of participants completed the intervention.
Abbreviations: N/A, not available; MR, methodological rigor.

with improved physical activity and fruit/vegetable intake at 6 months post intervention. Maddison et al[28] examined an active video game upgrade package in adolescents aged 10–14 years and found that youth in the intervention group increased the time playing active video games while decreasing the time in nonactive video games (see Table 3).

Other psychosocial outcomes

Seven studies assessed the impact of technology-based interventions on psychosocial outcomes (ie, self-efficacy, weight concern, peer support, and self-competence).[13,22,25–27,29,31,32] Five of the seven studies suggested improvement in psychosocial function in adolescents using the technology-based interventions.[13,22,25,27,31,32] For example, Wagener et al[32] found that adolescents in an exer-gaming program had improved self-perceived psychological adjustment and competence to exercise after the intervention, and Jones et al[27] found that adolescents in their intervention group reported fewer weight and body shape concerns (see Table 3).

Components of effective interventions

Seven Internet-based interventions and seven active video game-based interventions were included in this systematic review. Six of 14 studies (four Internet-based and two active video game-based interventions) found that BMI and/or body fat decreased.[13,23,25,27,28,33] All effective interventions utilized dietary and physical activity strategies as part of the intervention components. Six Internet-based interventions required weekly logins whereas active video game interventions recommended daily use. Based on the results, it is recommended that the intervention intensity that was based weekly has the potential to decrease obesity (see Table 4 for significant BMI outcomes with intervention components).

Discussion

The present systematic review investigates the potential impact of recent technological innovations (such as the Internet or active video games) for adolescents and the effect of these technology-based interventions on weight-related outcomes. Based on our review of 14 clinical intervention studies, there is no clear evidence that technology-based interventions decrease obesity in adolescents. We found that slightly less than half of the studies reviewed in this paper supported the use of technology in reducing unhealthy weight in adolescents. All effective interventions included improving physical activity and healthy eating habit as key components. However, each of these interventions only had a short-term impact on weight management. This is

Table 2 Study description

Reference	Study design	Sample characteristics	Intervention/control/components
Adamo et al[21]	RCT	Overweight and/or obese, aged 12–17 years Total n=30 Canada	Interactive video game cycling versus stationary cycling to music PA
Chen et al[22]	RCT	Normal weight, overweight or obese Chinese-American 12–15 years n=54 USA	Tailored web-based versus general health web-based information Diet/PA/SB
Christison and Khan[13]	Prospective Observational	Overweight or obese 8–16 years n=48 USA	10 weekly 2-hour sessions. Nutrition and behavior education Active video game (one hour ×10 weeks) Diet/PA
Reference	**Study design**	**Sample characteristics**	**Intervention/control**
Doyle et al[23]	RCT	Overweight or obese 12–18 years n=80 USA	16-week Internet program versus usual care handouts Diet/PA
Reference	**Study design**	**Sample characteristics**	**Intervention/control**
Hung et al[25]	Quasi-experimental (pre and post)	BMI >25 12–14 years n=37 Taiwan	WEP was integrated with a weight-loss student group held at school for 14 weeks Diet/PA
Jago et al[26]	RCT	Boys: no weight criteria 10–14 years n=473 USA	Boy scouts fit for life (20 minutes weekly contact + Internet) versus mirror image F/V PA
Jones et al[27]	RCT By school	n=105 Mean age 15.1 (SD =1) years USA	SB2-BED versus wait list control 16 week Internet-based healthy weight maintenance program with mentor program Diet/PA/SB
Maddison et al[28]	RCT	n=322 Age 10–14 years	Active video game upgrade package info on PA, healthy eating, and weight loss/ inactive video game Diet/PA
Nguyen et al[29]	RCT Blinded	n=151 13–16 years	Loozit group program, a two-phase behavioral lifestyle intervention with or without additional therapeutic contact Diet/PA/SB

Intervention duration/ follow-up	Retention rate (%)*	Outcomes	Results
Twice weekly (60 minutes) for 10 weeks Follow-up right after the intervention	86.1%	Body composition Metabolic profile PA and diet behavior	No difference in all outcomes between groups, except for some exercise behaviors Minutes spent at vigorous intensity and distance pedaled were higher in the music group
Once a week for 8 weeks Follow-up at 6 months post intervention	93%	Body composition BP PA and diet behavior Knowledge/self-efficacy	1. No difference in body composition 2. Intervention group significantly decreased waist-to-hip ratio and DBP, increased PA, vegetable/fruit intake and knowledge
Once weekly for 10 weeks Follow-up assessment done immediately after the intervention	83%	Body composition PA and diet behavior Psychological	Significantly reduced BMI and BMI z-score Significantly reduced television time and soda consumption while increased PA time and eating at the table Significantly improved global self-worth and behavioral conduct
Intervention duration/ follow-up	**Retention rate (%)**	**Outcomes**	**Results**
16-week program Follow-up at 4 months post intervention	82.5%	Body composition PA and diet behavior	BMI z-score was reduced significantly in the intervention compared with the control from baseline to post intervention but not at 4-month follow-up Intervention group reported using more eating and PA-related skills more often post intervention and at follow-up
Intervention duration/ follow-up	**Study completion rate (%)**	**Outcomes**	**Results**
Regular classes (weekly), exercise course (weekly) and individual counseling (2–3/6 months) After intervention	97.3%	Body composition Physical fitness Self-esteem and self-efficacy	BMI, waist circumference, and triceps skinfold was reduced Improve fitness Improved self-esteem and self-efficacy
9-week troop and Internet program log onto the study website at least twice a week after intervention and 6 month after	90.4%	Body composition PA Self-efficacy and preference	No difference in body composition between groups Spring intervention group had increased light PA by 12 minutes
SB2-BED 16-week Internet-facilitated, semistructured program versus wait list control 9-month follow-up for height, weight, completion of self-report questionnaire and semistructured interview	83% (17% had no ending data)	BMI Binge eating behaviors Dietary fat and sugar intake Depression Adherence	Reduction in BMI for intervention ↓ binge eating behaviors and weight and shape concerns No change in dietary fat and sugar intake No change in depression Those that did not complete were more likely white, reported depressed, had more weight and shape concerns
Assigned to active video game or no change (sedentary) video games Assessments at baseline, 12, and 24 weeks	100%	BMI Body composition PA Cardiorespiratory fitness Video game play Food snacking	BMI intervention no change, BMI in control ↑ ↓ body fat in intervention Time playing active video games ↑ with ↓ in time playing no active video games
7-week group session (parents and adolescent separately) on diet and PA (phase 1) followed by quarterly adolescent only sessions (phase 2) with telephone or email coaching for intervention group	88%	BMI Self-reported psychosocial and lifestyle changes	Additional therapeutic contact had no impact on outcomes

(*Continued*)

Table 2 (*Continued*)

Reference	Study design	Sample characteristics	Intervention/control
Owens et al[30]	Pre and post	8 families n=21 subjects 10±1.6 years	4 families loaned Wii Fit™ exercise modules without instruction or suggestions for use (intervention) and 4 families not Control group loaned device after 3 months PA
Staiano et al[31]	RCT	Overweight and obese African-American adolescents 15–19 years n=54	20-week exercise game (video game that requires gross motor activity) three groups: competitive exer game, cooperative exer game, or control PA
Wagener et al[32]	RCT	n=40 12–18 years	Supervised 10-week group dance-based exer game exercise or waitlist control group PA
Williamson et al[33]	RCT	n=57 (40 parent and adolescent dyads) 11–15 years 13.2 years average age	Interactive behavioral Internet program/ control condition Diet/PA

Note: Wii Fit™; Nintendo, Kyoto, Japan.
Abbreviations: BD2, Student Bodies 2; BMI, body mass index; WEP, weight loss E-learning program; PA, physical activity; RCT, randomized controlled trial; SD, standard deviation; F/V, fruit and vegetable; SB, sedentary behavior; BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure.

consistent with other obesity prevention interventions in children that are either home-based or school-based.[36–38] Because of the variation in duration of intervention (ranging from 10 weeks to 2 years) and dose (daily to weekly), the literature to date does not provide enough evidence on the optimal dose or duration of the most effective intervention for prevention of obesity in adolescents, although the trend pointed toward dosing a minimum of one hour/weekly for 10–16 weeks for best results. This is consistent with a systematic review done for obesity prevention in a primary care setting.[39]

In comparing the various modalities of technology and their delivery (Internet versus active video games), there is no clear evidence that one format is more effective than another. Depending on the age of the participants, different modalities might be more attractive than others. For example, a younger adolescent might prefer exer-games and interacting with peers, while an older adolescent might prefer a smartphone app or Internet-based program for weight management that could be used privately.

The literature currently available is also insufficient to examine the impact of technology-based obesity prevention interventions on weight-health related outcomes such as physical activity, sedentary activity, dietary behaviors, or psychosocial outcomes. In eleven studies that examined the impact of technology-based obesity prevention on physical activity and dietary behaviors, only six reported positive improvement in these outcomes. Even fewer studies examined the impact of interventions on sedentary behaviors and psychosocial outcomes. Therefore, it is challenging to determine the effect of technology-based intervention on weight-related health behaviors, and we do not know whether improvement of these behaviors led to decreased weight among adolescents. One plausible reason for this lack of evidence might be the wide range of ages encompassed by these studies. Participants in the various studies ranged in age from 10–19 years. These years encompass later childhood (9–12 years), early adolescence (13–14 years), and late adolescence (15–17 years) as well as young adulthood (18–19 years). The developmental differences and the prevalence of using technology among these age groups may impact any potential trend seen in the data. Depending on the age group being investigated, interest in technology and use may vary.

Intervention duration/ follow-up	Study completion rate (%)	Outcomes	Results
Randomized family given Wii Fit to use in home for 3 months then control families given Wii Fit for 3 months	100% No mention of withdrawals	Body composition Daily PA Balance Muscular fitness Aerobic fitness Flexibility Wii Fit use	No significant change in daily physical activity, muscular fitness, flexibility, balance, or body composition
20-week exer game (video game that requires gross motor activity) Baseline, 10-week and 20-week data collection	72%	BMI Peer support Self-efficacy Self esteem	Cooperative lost the most weight, ↑ self-efficacy No difference in weight gain with competitive and control Both competitive and cooperative had increased peer support
Exer gaming in group setting (dance game). Adolescents came to 10-week group-based exer game exercise program	97.5%	BMI Perceived competence scale Behavior Assessment Scale Parent Rating Scale for Adolescents	No difference in pre/post-test BMI Improved self-perceived psychological adjustment and competence to exercise
Counselors were educated on culturally relevant dietary and physical activity issues, and they incorporated this information into the face-to-face and Internet counseling sessions Two-year intervention	70%	BMI, body weight, body composition Weight loss behaviors	Adolescents in the behavioral treatment lost more body fat immediately after the intervention but no difference was found at 2 years follow up

This review suggests that both active video games and Internet-based interventions including diet and physical components have the potential to decrease obesity in adolescence, especially Internet-based interventions. Because of the variation in duration of intervention (10 weeks to 2 years), it is not clear what length of intervention is most effective. Only one study included long-term follow-up data (more than 12 months after the intervention), and the intervention did not support long-term efficacy with regard to healthy weight management.[33]

Our review indicates that several interventions provide short-term improvements in BMI but none that seem to be sustainable. Sustained weight loss is an ongoing struggle, regardless of the sample being studied or the interventions used, and is no different in this population. Very few interventions seem to specifically focus on lifelong lifestyle modifications. Many of the interventions that were investigated either provided the participants with the necessary equipment (ie, loaning Wii Fit, allowing temporary upgrades to active video games) or were activities that were set up for a limited time period at school (GameBike or Dance-Dance Revolution). After the intervention, participants no longer had access to these exercise opportunities, so likely reverted back to the prestudy lifestyle habits that lead to their overweight or obesity. Technology-based intervention for weight management needs to be developed in such a way that it incorporates resources that will continue to be available in order to see sustainability.

The goal of this review was to determine ways in which health care providers and researchers can make more informed decisions about which types of technology-based interventions for adolescent obesity are most suitable and achieve sustainable weight reduction, impact the amount of physical activity, reduce sedentary activity, improve dietary behaviors, and/or positive psychosocial outcomes. Although we found no clear evidence of an effect of technology-based intervention for prevention of obesity in adolescents, the use of developmentally appropriate technology has the potential to assist health care providers in dealing with the obesity epidemic, especially when interventions focus on both physical activity and healthy dietary behaviors. Future research should include rigorous evaluation of cost-effectiveness as well as the mediating and

Table 3 Outcome measured by study: arrows indicate significant increase or decrease on the outcomes

Reference	BMI	Other metabolic index	Physical activity	Sedentary behavior	Diet	Self-efficacy	Knowledge	Psychosocial
Adamo et al[21]	No difference	No effect	↑ vigorous PA time in control group	N/A	No effect	N/A	N/A	
Chen et al[22]	No difference	↓ waist-hip ratio and DBP	↑ PA	N/A	↑ F/V	No effect	↑	
Christison and Khan[13]	↓ BMI and BMI z-score	N/A	↑ PA time	↓ television time	↓ soda ↑ eat at table	N/A	N/A	↑ global self-worth
Doyle et al[23]	↓ BMI z-score	N/A	↑ PA skill	N/A	↑ diet skill	N/A	N/A	N/A
Ezendam et al[24]	No difference	N/A	↓ step counts at 4 months follow-up but not at 2 years	N/A	↓ sugary drink and snack ↑ F/V	N/A	N/A	N/A
Hung et al[25]	↓ BMI and triceps skinfold	N/A	↑ fitness			↑ S-E		↑ self-esteem
Jago et al[26]	No difference	N/A	↑ light PA time	N/A	N/A	No effect	N/A	N/A
Jones et al[27]	↓ BMI	N/A	N/A	N/A	No effect	N/A	N/A	↓ weight concern No change in depression
Maddison et al[28]	↓ no change in BMI body fat	N/A	↑ time in active video game	↓ time in inactive game	No effect	N/A	N/A	N/A
Nguyen et al[29]	No difference	N/A	No effect	No effect	No effect	N/A	N/A	No effect
Owens et al[30]	No difference	N/A	No effect	N/A	N/A	N/A	N/A	N/A
Staiano et al[31]	No difference	N/A	N/A	N/A	N/A	N/A	N/A	↑ peer support and self-efficacy
Wagener et al[32]	No difference	N/A	N/A	N/A	N/A	N/A	N/A	↑ psychosocial adjustment and competence
Williamson et al[33]	↓ body fat at 6 months post intervention No difference after 2 years	N/A	No difference	N/A	↓ fatty foods	N/A	N/A	N/A

Note: ↑↓ indicate significant increase and decrease, respectively.
Abbreviations: BMI, body mass index; PA, physical activity; N/A, not available; DBP, diastolic blood pressure; F/V, fruit and vegetable; S-E, self-efficacy.

Table 4 Significant BMI outcome (decreased BMI or percent body fat)

Reference	Intervention type	Intervention components	Intervention duration	Intervention intensity	Follow-up time	Study type
Christison and Khan[13]	Active video game	Diet and PA	10 weeks	Weekly	10 weeks after baseline	Pre-post
Doyle et al[23]	Internet	Diet and PA	16 weeks	Weekly	4 months post intervention	RCT
Jones et al[27]	Internet	Diet, PA, and SB	16 weeks	Weekly	9 months	RCT
Hung et al[25]	Internet	Diet and PA	14 weeks	Weekly	14 weeks	Pre-post
Madison et al[28]	Active video game	Diet and PA	12 weeks	60 minutes most days of the week	24 weeks	RCT
Williamson et al[33]	Internet	Diet and PA	1 year	52 sessions, weekly	6 months (decreased BMI) and 2 years (no difference)	RCT

Abbreviations: BMI, body mass index; PA, physical activity; RCT, randomized controlled trial; SB, sedentary behavior.

moderating factors associated with effective technology-based interventions, and should also include more long-term follow-up. In addition, assessment of weight-related health outcomes, such as physical activity, sedentary activity, dietary behaviors, self-efficacy, and quality of life, should be included in future research.

Disclosure

The authors report no conflicts of interest in this work.

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