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A Systematic Review of Interventions to Enhance Healthy Lifestyle Behaviors in Adolescents Delivered via Mobile Phone Text Messaging

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Abstract

Objective: To systematically review healthy lifestyle interventions targeted to adolescents and delivered using text messaging (TM).

Data Source: PubMed, Embase, CINAHL, PsycINFO, and Web of Science databases.

Study Inclusion Criteria: Research articles published during 2011 to 2014; analyses focused on intervention targeting adolescents (10-19 years), with healthy lifestyle behaviors as main variables, delivered via mobile phone-based TM.

Data Extraction: The authors extracted data from 27 of 281 articles using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses method.

Data Synthesis: Adolescent and setting characteristics, study design and rigor, intervention effectiveness, challenges, and risk of bias.

Results: Across studies, 16 (59.3%) of 27 included non-Caucasians. The gender was split for 22 (81.5%) of 27 studies. Thirteen studies were randomized controlled trials. There was heterogeneity among targeted conditions, rigor of methods, and intervention effects. Interventions for monitoring/adherence (n = 8) reported more positive results than those for health behavior change (n = 19). Studies that only included message delivered via TM (n = 14) reported more positive effects than studies integrating multiple intervention components. Interventions delivered using TM presented minimal challenges, but selection and performance bias were observed across studies.

Conclusion: Interventions delivered using TM have the potential, under certain conditions, to improve healthy lifestyle behaviors in adolescents. However, the rigor of studies varies, and established theory and validated measures have been inconsistently incorporated.

Keywords
adolescent health, text messaging, health promotion, intervention studies

Objectives

Text messaging (TM) is a daily activity for adolescents. Approximately 78% of US teens have a cell phone; of those, almost half (47%) own smartphones.[1] Eighty-eight percent of adolescents use TM and more than half text daily. Text messaging is the preferred channel of basic communication with friends.[2] The pervasive nature of TM offers much potential as a strategy for delivering a health intervention to adolescents, owing to its ability to reach this group directly with health promotion messages.

Who are adolescents? The World Health Organization (WHO) defines it as persons aged 10 to 19 years.[3] In 2012, there were 41 844 000 youth aged 10 to 19 years in the United

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States, representing 14% of the total US population.[4] Behavioral patterns established during adolescence help determine young people's current health status and their risk for developing chronic diseases in adulthood.[5] Healthy People 2020 identified an emerging issue in adolescent health—the increased focus on positive youth development interventions for preventing adolescent health-risk behaviors, which include core indicators for healthy development, injury prevention, mental health, sexual health, and substance abuse.[6] These indicators align with the WHO definition of health promotion selected for this systematic review: the process of enabling people to increase control over and to improve their health, moving beyond a focus on individual behavior toward a wide range of social and environmental interventions.[7]

Given the ubiquity of TM among adolescents, it presents a potentially novel and valuable means for delivering health interventions to this group. Text messaging as a communication channel enables researchers to directly reach adolescents in a relatively obtrusive way. Fully understanding the potential and limitations of TM requires spotlighting its role health interventions. Only 1 systematic review has examined the use of TM in interventions for enhancing healthy behaviors in a population that included adolescents.[8] Militello and colleagues[8] extracted data from 7 articles published between 2006 and 2010; these articles were either randomized controlled trials (RCTs) or quasi-experimental studies. Groups receiving text messages experienced greater or increased blood glucose monitoring, energy expenditure, self-reported adherence, and retention rates, as well as less risk for rejection after liver transplantation. Although the sample of articles in the systematic review of Militello and colleagues was small, their results demonstrated the potential of using TM for interventions targeting adolescents.

Our multidisciplinary research team expands previous research by presenting a systematic review of intervention studies published between January 2011 and December 2014 that promoted healthy lifestyle behaviors among adolescents and used TM. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guided this systematic review; PRISMA suggests using the PICO approach to formulate research questions.[9] This systematic review targeted male and female adolescents between ages 10 and 19 years, at high or general risk of a health condition (P), who received a TM intervention (I), or similar adolescents who did not receive the intervention (C) designed to enhance healthy behavior or reduce health risk (O). To more fully understand the spectrum of evidence, this systematic review targeted a broad range of research methods (eg, RCTs, quasi-experimental studies, and observational studies), published in peer-reviewed journals. The research questions were (1) What are characteristics of the adolescent sample and setting targeted for interventions delivered using TM? (2) How effective are interventions delivered using TM in improving healthy lifestyles? (3) How rigorous are the design and methods used in these studies? (4) What are challenges of using TM in interventions? (5) What bias is evident within and across studies?

Methods

Article retrieval and eligibility determination, data extraction, synthesis, and evaluation occurred from December 2014 to July 2015.

Data Sources

The team librarian (S.K.) conducted searches in the PubMed, Embase, CINAHL, PsycINFO, and Web of Science databases using Medical Subject Headings (MeSH), descriptors, and key terms listed in Table 1. Limits to the search were English language, humans, published between 2011 and 2014, and age 10 to 19 years. The search occurred during December 2014 to January 2015. The initial search in these databases yielded 284 articles; 3 duplicates were removed for a total of 281 articles.

Inclusion and Exclusion Criteria

To be eligible for inclusion, articles had to be peer reviewed, describe original research (any type of study design), and focus or include analysis on adolescents between 10 and 19 years. The studies had to evaluate interventions delivered using mobile phone TM and that included a healthy lifestyle behavior as a main or outcome variable (eg, diet and nutrition, medication/medical care adherence, physical activity, smoking and substance abuse, and solar exposure).

Figure 1 illustrates the PRISMA flow chart summarizing article eligibility and selection. Four team members divided and independently reviewed abstracts of the 281 articles to determine eligibility for data extraction. Ascertaining study samples that fit the WHO age range for adolescence (10-19 years) presented challenges. The team first checked the mean age of the participants. If the mean age was between 10 and 19 years, then the article was eligible for further review. If the mean age was not available, then 75% of participants had to be within the WHO adolescent age range. Reviewers scored the abstracts as "yes," "no," and "maybe," noting reasons for exclusion (Figure 1). The articles receiving maybe scores described TM as a data collection method, not as a significant part of intervention delivery; thus, the team reached consensus to eliminate those articles from further review. We also noted that 2 sets of authors[10,11] had reported results from the same RCT; therefore, we included their most recent RCT report[10] in the systematic review. A total of 254 articles were eliminated for reasons listed in Figure 1.

Data Extraction

Data extraction from the selected 27 articles reflected the systematic review questions and PRISMA checklist items. We extracted the following information from each article: authors; study purpose; study design and data collection points; sample size, ethnicity, and age; a brief description of the TM intervention; main or outcome variables and measures; study results; and risk of bias. We assessed the level of evidence for each study using criteria from Cochrane[12] and Dearholt and Dang[13] wherein level 1 evidence was RCTs, level 2 was quasi-experimental

Table 1. Search Strategy for Systematic Review.

Database	Search Terms
PubMed	"Cell Phones"[Mesh] or "Computers, Handheld"[Mesh] or ipad or telemedicine or mhealth or "short message service:" or tablet or tablets or "text messaging" or "text messages" or "media message service" or smartphones or "mobile technology" and "Health Promotion"[Mesh] or "Health Behavior"[Mesh] or "Life Style"[Mesh] or "Weight Reduction Programs"[Mesh] or "Weight Loss"[Mesh] or "Diet, Reducing"[Mesh] or "Sunscreening Agents"[Mesh] or "Sunburn"[Mesh] or "Exercise"[Mesh] or "Diet"[Mesh] or "Skin Neoplasms/prevention and control"[Mesh] or "patient compliance" or "medication adherence" or "smoking cessation" or "tobacco use" or sunscreen
Embase	"mobile phone"/exp or "mobile application"/exp or iphone or ipad or "handheld computers" or "short message service" or tablet or "text messages" or "text messaging" or "media message service" or smartphones or "mobile technology" and "health promotion"/exp or "health promotion" or "health education"/exp or "health education" or "health behavior"/exp or "health behavior" or "alcohol abstinence"/exp or "alcohol abstinence" or "smoking cessation"/exp or "smoking cessation" or "weight reduction"/exp or "weight reduction" or "diet"/exp or "diet" or "sunscreen"/exp or "sunscreen" or "sunburn"/exp or "sunburn" or "skin cancer"/exp or "skin cancer" or "patient compliance"/exp or "patient compliance" or "medication compliance"/exp or "medication compliance" or "dietary compliance"/exp or "dietary compliance"
CINAHL	(MH "Wireless Communications") or (MH "Computers, Hand-Held") or smartphone or iphone or "short message service" or ipad or mhealth or "short message service" or tablet or "text messaging" or "text messages" or "media message service" or "mobile technology" and (MH "Health Promotion") or (MH "Health Education") or (MH "Student Health Education") or (MH "School Health Education") or (MH "Life Style") or (MH "Life Style Changes") or (MH "Life Style, Sedentary") or (MH "Weight Reduction Programs") or (MH "Weight Control") or (MH "Diet") or (MH "Sunscreening Agents") or (MH "Skin Neoplasms") or (MH "Exercise") or (MH "Patient Compliance") or (MH "Medication Compliance") or (MH "Guideline Adherence") or (MH "Smoking Cessation") or (MH "Smoking Cessation Programs") or (MH "Alcoholic Intoxication") or (MH "Alcoholic Beverages") or (MH "Alcoholism")
PsycINFO	(DE "Health Promotion") or (DE "Health Behavior") or (DE "Health Education") or (DE "Drug Abstinence" or DE "Drug Education") or (DE "Alcohol Abuse" or DE "Alcohol Drinking Attitudes" or DE "Alcohol Drinking Patterns" or DE "Alcohol Intoxication" or DE "Alcoholic Beverages" or DE "Alcoholism") or (DE "Smoking Cessation") or (DE "Weight Loss") or (DE "Diets") or (DE "Cancer Screening") or abstinence or sunscreen or sunburn or "skin cancer" or compliance and "cell phones" or smartphones or "mobile phones" or "mobile technology" or handheld or ipad or "text messages" or "text messaging" or "short message service" or mhealth or "media message service" or "wireless"
Web of Science	"health promotion "or "health behavior" or "health education" or drug or alcohol or smoking or tobacco or weight or diet or cancer or sunscreen or sunburn or "skin cancer" or compliance and "cell phones" or smartphone or "mobile phones" or iphone or "mobile technology" or handheld or mobile or "text messages" or "text messaging" or "short message service" or mhealth or "media message service" or wireless

studies, and level 3 included observational studies. We did not assess level 4 evidence because the requisite opinion of the respected authorities and/or nationally recognized expert committees/consensus panels based on scientific evidence was not an eligibility criterion for the systematic review. Four team members divided and independently extracted data from articles that differed from than those assigned for the initial abstract review. The data extraction template was posted in a secure cloud storage service. This strategy allowed team members to continuously add data to the template and query other team members for additional review of complex articles or information entered into the template. The team met monthly throughout the data extraction period to discuss the most recent data additions and approve updates. Additionally, the 2 lead authors (L.J.L. and S.R.) split articles from junior authors (C.A. and R.M.) to confirm their extracted information. Data extraction occurred from January 2015 through June 2015.

Data Synthesis

Synthesis occurred during July 2015. To determine sample and setting characteristics, the team synthesized information pertaining to gender, age, ethnicity, and geographic location for the sample in each article. To determine design and methodological rigor, the team noted the type of research design for each study. One team member compiled instruments or measures of each study's main variables and secondary variables and reliability/validity estimations. Another team member reviewed each article to determine whether the intervention was based on the established theories or conceptual frameworks that explain health behavior. To determine the effectiveness of TM as an intervention, 2 team members evaluated the results reported in each study related to the primary outcome variable(s). Tests of statistical significance were primarily used to determine the effectiveness of the intervention reported in each study. Text messaging challenges were based on the information provided by the authors in each article. The team reached consensus for the risk of bias in individual studies and across studies using Cochrane's Collaboration's tool for assessing bias.[14] This tool includes the domains of selection bias (random sequence generation and allocation concealment), performance bias (blinding of participants and personnel), detection bias (blinding of outcome assessment), attrition bias (incomplete outcome data), reporting bias (selective reporting), and other sources of bias. The team further reviewed bias in individual studies using the "risk of bias" assessment tool.[14] We used the

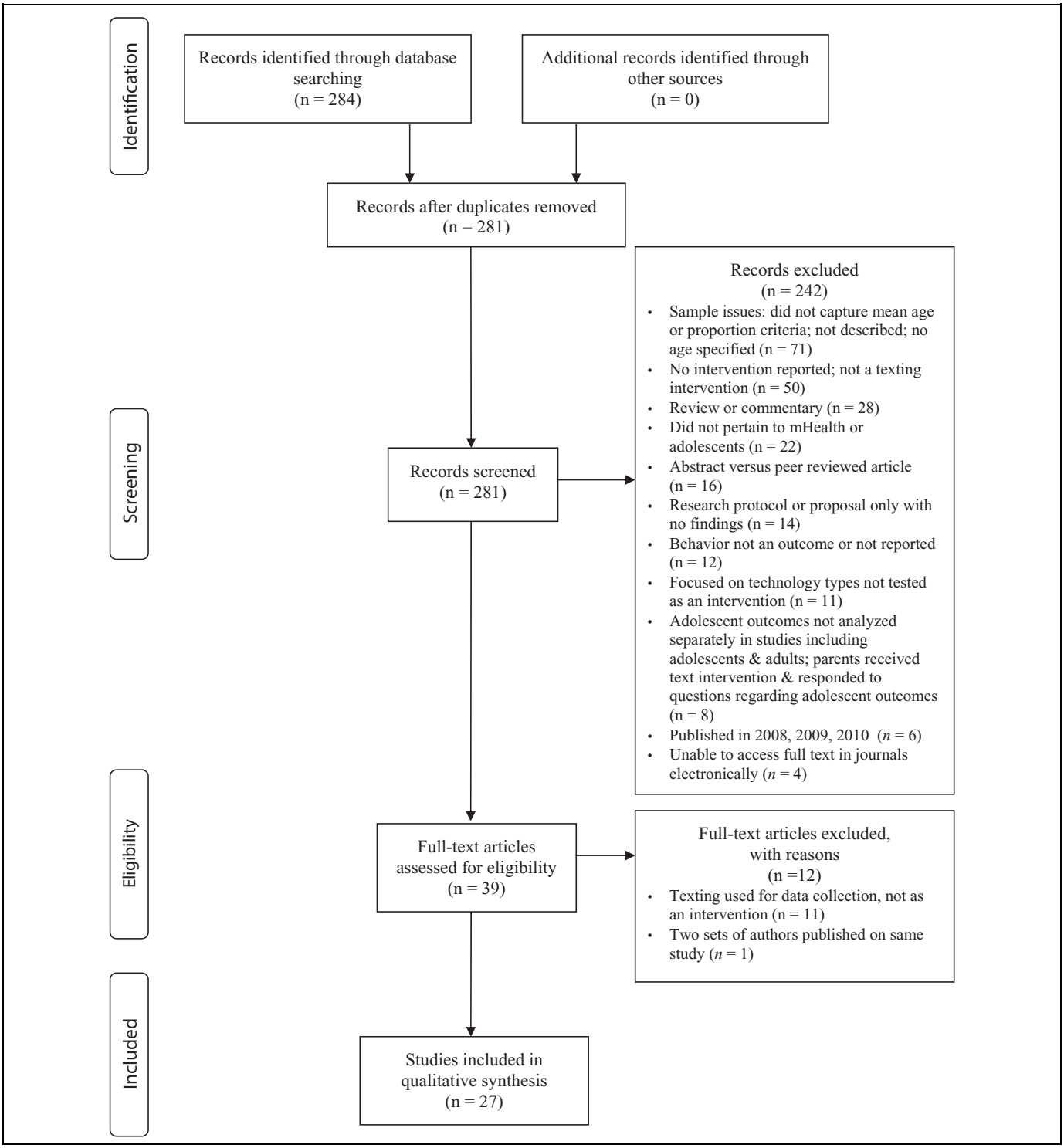

Figure 1. PRISMA flow chart.

Amico's recommendation of maximum 30% to 40% attrition in either study arm as a further indicator of attrition bias.[15]

Results

Table 2 presents the summary highlights of each of the 27 studies. Below, we state the synthesis of the results.

Sample and Setting Characteristics

The grand mean age for the adolescents represented in the samples reporting mean age was 16.09 years. The majority of studies (n = 22; 81.5%) included males and females; however, 3 (11%) studies had a sample comprised solely of females,[10,17,19] 1 (3.7%) had an all-male sample,[28] and 2

Table 2. Results From Final Sample of Articles.[a]

Authors/Purpose	Design and Sample	Intervention (Comparison/Control)	Main Outcomes	Main Findings
Branson et al[16] Examine effects of TM appointment reminders to improve mental health treatment attendance	Quasi-experiment, posttest only; measurement: at 3 months 48 patients (female, n = 24) in outpatient child mental clinic for low-income ethnic minority youth in New York City; (40% African-American, 46% Latino, 14% multiracial/other) Mean age: 15.1 (±1.5) years	IG (n = 24): received TM reminders for time/date of next appointment CG (n = 24): historical control group from the same clinic and time period; received no reminder TM	Treatment attendance Self-reported satisfaction with intervention Presence of psychiatric disorder Reminder outcomes	Attendance rates higher for IG than CG; after controlling for demographic and mental health factors, this difference remained significant ($P = .02$) IG received TM reminders before 88% (226/257) of sessions Most (82%-100%) participants reported satisfaction with TM reminders
Brown et al[17] Evaluate TM for delivering a health promotion intervention to adolescent, minority mothers	Qualitative interviews; measurement: 1 interview/month × 6 months 5 females attending a supplemental nutrition program in a Midwestern US state (3 African American and 2 Latino) Mean age: 18.2 (±0.84) years	IG: received essentials for postpartum care information by TM weekly × first 6 months postpartum; educational content in the form of text and/or pictures	Intervention evaluation Intervention impact	4 themes identified: social support, gaining information to overcome barriers, parenting validation, fit and benefits of using mobile phone for intervention Positive impact: all mothers provided breast milk to their children; 100% adherence to childhood immunization; all infants met well-baby care guidelines by 6 months
Carroll et al[18] Assess feasibility and acceptability of a mobile phone glucose monitoring system for adolescents with diabetes and their parents	Single-participant experiment; measurements: at 3 and 6 months 39 patients (female, n = 19) seen in an Indiana adolescent diabetes clinic Age range: 13-19 years	IG: received a Glucophone smartphone × 6 months to enable testing/reporting blood glucose levels and interaction (via TM and voice call) with a nurse practitioner	System usability and satisfaction	TM helped participants remember to check their blood sugar
Chandra et al[19] Evaluate acceptability and feasibility of TM for promoting positive mental health and as a helpline among adolescent females	Single-participant experiment; measurements: at 1 month and 1 month after study conclusion 40 females living in urban India Mean age: 16.8 (±1.68) years	IG: received 1 TM/day × 1 month regarding positive mental health or helpline information; participants could call/text back with question or concerns	TM intervention perceptions	62% liked receiving the TM 50% said the TM made them feel happy 8% faced family objections about TM 62% preferred helpline TM over mood-lifting TM
Cornelius et al[20] Examine a HIV prevention intervention delivered via mobile phones to adolescents	Single-participant experiment; measurements: at baseline, 7, and 19 weeks 40 African Americans (female; n = 21) recruited from community organizations and schools in a southeastern US state Mean age: 15.4 (±1.7) years	IG: attended weekly in-person meetings × 7 weeks then received daily multimedia TM to serve as "boosters" × 3 months	TM evaluation HIV-related knowledge and attitudes	HIV knowledge increased after in-person meetings; no change from completion of meetings to conclusion of TM No change in attitudes toward condoms after meetings or TM Increased confidence in avoiding HIV after receiving TM No change in HIV-risk behaviors overtime Participants reliably responded to TM 97% said number of TM was "just right"
Dewar et al[10] Evaluate impact of a school-based multicomponent program (NEAT girls) on adolescent girls' PA and sedentary behaviors	RCT; measurements: at baseline and 12 months 357 girls attending 12 secondary schools in low-income communities in Australia (ethnicity not reported) Mean age 13.2 (±.50) years	IG (n = 178; 6 schools): received enhanced PA sessions, interactive seminars, student handbooks, nutrition workshops, pedometers, parent newsletters; TM to encourage PA, healthy eating, and decreased sedentary behavior. CG (n = 179; 6 schools): wait-list CG	PA Sedentary behaviors Social cognitive mediators	No group by time interactions for PA or social cognitive mediators Greater reductions in recreational computer use ($P = .02$) and sedentary activity ($P = .04$) in IG than CG

(continued)

Table 2. (continued)

Authors/Purpose	Design and Sample	Intervention (Comparison/Control)	Main Outcomes	Main Findings
Fabbrocini et al[21] Evaluate adherence to therapy in acne patients using mobile phones and TM	RCT; measurement: at baseline and after 12 weeks 160 patients (female, n = 87) enrolled from outpatient acne service (ethnicity not reported) Mean age: 19.5 years (IG); 18.5 years (CG)	IG (n = 80): received 2 TM addressing acne × 2/day × 12 weeks CG (n = 80): did not receive TM	Adherence QOL Satisfaction with TM	Greater increases in adherence to treatment ($P < .0001$) and improvement in QOL ($P < .0001$) in IG than CG 95% of participants were "very much" or "quite" satisfied with TM
Haug et al[22] Test efficacy of an individually tailored TM intervention for smoking cessation in youth	RCT; measurements: at baseline and at 6 months 755 students (female, n = 392) attending schools in Switzerland who were smokers at baseline Mean age 18.2 (±2.3) years	IG (n = 372; 90 classes): received online assessment of individual smoking behavior, weekly TM assessment of smoking-related target behaviors, 2 weekly tailored TM, and integrated quit day preparation and relapse-prevention program CG (n = 383; 88 classes): did not receive the intervention	Smoking behavior change	No significant difference in 7-day abstinence rates, stage of change, or quit attempts Decreased mean number cigarettes smoked/day greater in IG than CG ($P = .002$)
Haug et al[23] Test appropriateness and effectiveness of an individually tailored TM intervention to reduce problem drinking in vocational school students	Single-participant experiment; measurements: at baseline and at 12 weeks 477 students (female, n = 111) attending 7 schools in Switzerland; 72% reported ≥1 instances of RSOD in the past 30 days Mean age: 18 (±2.4) years	IG: received 1-2 tailored TM/week; TM tailored for age, gender, number of standard drinks per week, and RSOD	RSOD behavior change	Decreased percentage had RSOD within the last month from baseline for at least 1 RSOD occasion ($P <.001$) and >2 RSOD occasions ($P = .01$) Decreased number of drinks in a typical week ($P = .002$), percentage with 1+ alcohol-related problems in the last 3 months ($P = .009$) and maximum number of drinks on a single occasion ($P = .08$)
Herbert et al[24] Investigate adolescents' use of a diabetes TM program and determine whether certain groups more likely respond to TM	Single-participant experiment; measurements: at baseline and at 6 weeks 23 adolescents (female, n = 11) with diabetes from a mid-Atlantic US state (78% white) Mean age: 15.13 (±1.14) years	IG: received 2 TM/day for majority of intervention; TM included information/tips and a request to respond to a specific question; TM topics included blood glucose monitoring, nutrition, PA, and sleep/mood	TM evaluation Glucose monitoring	Participants responded to 78% of TM; most to nutrition TM, least to blood glucose TM Correlation between females and overall TM response rate and number personal TM sent/day ($P < .05$) Trend for participants with lower blood glucose to respond to more TM ($P = .08$)
Hingle et al[25] Evaluate a skin cancer prevention TM intervention among adolescents	Single-participant experiment; measurements: at baseline and at 12 weeks 113 adolescents (female, n = 60) from 3 Arizona middle schools who had completed a sun safety education program 2 weeks prior to enrollment (ethnicity not reported) Age range: 11-14 years	IG: received 3 TM/week × 13 weeks; TM addressed skin cancer risk, sun protection benefits, and beliefs inconsistent with public health recommendation	Sun-safety behavior, knowledge, and attitudes	Increased self-reported use of sunscreen ($P = .001$), hats ($P = .02$), and sunglasses ($P = .02$) Greater consideration of sun avoidance during peak hours ($P = .02$) Increase overall skin cancer knowledge ($P = .03$)
Huang et al[26]	RCT; measurements: at baseline and 4 months	IG (n = 18): received Web and TM information (tailored TM and queries)	Weight/BMI PA	IG demonstrated greater, but not statistically significant, change in

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Table 2. (continued)

Authors/Purpose	Design and Sample	Intervention (Comparison/Control)	Main Outcomes	Main Findings
Compare a tailored versus generic weight management intervention among adolescent survivors of childhood leukemia	38 overweight survivors (female, n = 23) off therapy for 2+ years recruited from a clinical trial (89.5% Hispanic, 2% black) Mean age: 13 years (range 10-16)	and weekly (1 month) to biweekly (2-4 months) counseling-based intervention CG (n = 17): received printed materials; biweekly phone call	Dietary intake Depression	weight across study period compared to CG ($P = .06$) and no difference in changes in BMI, PA, or daily calories consumed IG reported reduced negative mood over time compared to CG ($P = .01$)
Huang et al[27] Evaluate improved generic, Internet, and mobile phone-delivered intervention on disease management, self-efficacy, and communication	RCT; measurements: at baseline, 2 months, and 8 months 81 patients (female, n = 44) with inflammatory bowel disease, cystic fibrosis, diabetes seen at tertiary care pediatric center (49% Hispanic, 9% black, 1% native American) Mean age: 17 years (range 12-20)	IG (n = 38): received access to a Web site for disease management, communication skills, and lifestyle tips + tailored TM CG (n = 37): received monthly email messages on general health issues	Disease self-management Health-related self-efficacy	Group × time interaction for disease self-management ($P = .02$) and self-efficacy ($P = .02$); IG reported increased self-management and self-efficacy, but CG remained constant
Juzang et al[28] Evaluate a TM HIV prevention program among young adults	Quasi-experiment; measurements: at baseline, 3, and 6 months 60 young black men in Philadelphia Median age: 17 years (CG); 19 years (IG)	IG (n = 20): received HIV prevention TM CG (n = 19): received nutrition TM Both groups: TM designed to increase positive outcome expectancies, norms, self-efficacy and intentions for condom use; received TM × 3/week × 12 weeks	Sexual health knowledge, awareness, and risk-prevention behavior	Greater condom norms and sexual health awareness in CG than in IG at all time points (no *P* values given) No changes in condom use intention
Lana et al[29] Assess impact of a Web-based intervention supplemented with TM to reduce TCBR	RCT; measurements: at baseline and 9 months 2001 adolescents (female, n = 1081) attending Spanish and Mexican schools Age range: 12-16 years	IG 1 (n = 177): received access to Web site with information about the main cancer-risk behaviors IG 2 (n = 244): the same as IG 1 + weekly TM to encourage adherence CG (n = 316): not specified	Weight BMI (kg/m^2) Diet behavior: TCBR (smoking, unhealthy diet, alcohol use, obesity, sedentary lifestyle, and sun exposure)	TCBR scores reduced in all groups with a significant drop in IG 1 and IG 2, but not CG (no *P* values reported) IG 2 intervention increased the probability of improving posttest TCBR score and giving up at least 2 risky behaviors
Lau et al[30] Evaluate Internet and TM intervention for promoting PA among adolescents	Quasi-experiment; measurements: at baseline and 8 weeks 78 Chinese school children (female, n = 51) in Hong Kong Mean age: IG, 12.29 (±0.87) years; CG, 13.26 (±1.14) years	IG (n = 38): received Internet- and stages of change-based PA program × 2/week and daily TM on weekdays 5 TM types: motivational, informational, behavioral skills, reinforcement of PA benefits, and solutions for PA barriers CG (n = 40): no intervention	PA level over the last 7 days SMR	No time × condition interactions for PA or SMR; significant increases in PA ($P = .05$) and SMR ($P = .01$) in IG but not in CG Positive correlation between number of TM read and SMR ($P < .01$)
Love-Osborne et al[31] Evaluate feasibility of adding a health educator to school-based health center teams to deliver preventive services for overweight adolescents (TM used to reinforce goals between visits)	RCT; measurements: at baseline and 9 months 165 adolescents (female, n = 86) with BMI ≥85% recruited from 2 centers (88.5% Hispanic) Mean age: 15.7 (±1.5) years	IG (n = 77): received MI with goal-setting plus 2 TM/week (1 individualized goal-related and 1 reminder to turn in log) CG (n = 72): no intervention	Self-monitoring: of weight and lifestyle behaviors BMI (both groups) Cardiovascular fitness (IG)	Greater proportion of CG decreased or maintained a stable BMI than IG ($P = .025$); greater proportion of CG decreased BMI Z-score by 0.1 or more than CG ($P = .02$) Sports participation higher in CG than IG ($P = .02$)
MacDonell et al[32] Assess feasibility of using ecological momentary assessment via TM on personal cell phones to measure medication adherence	Single-participant experiment; measurement: at 14 days 16 African-Americans (female, n = 7) with asthma enrolled from a large, urban hospital, and university student health center	IG: received TM daily to prompt a response about asthma medications/symptoms; sent event-based TM when they experienced asthma symptoms or took asthma rescue/controller medications	Asthma control Medication adherence Asthma symptoms Rescue medication use	Adherence to controller medication from 0 to 14 days during the TM trial (M = 8.69 ± 5.39) Asthma-related symptoms or limitations reported 28.1% of trial days but use of rescue medications 18.8% of days

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Table 2. (continued)

Authors/Purpose	Design and Sample	Intervention (Comparison/Control)	Main Outcomes	Main Findings
	Mean age: 19.75 (±1.77) years			Responded to 78.5% of all time-based TM with a relevant response
Mulvaney et al[33] Improve diabetes adherence using individually tailored TM	Quasi-experiment; measurement: at baseline and at 3 months 28 adolescents (female, n = 15) with diabetes enrolled through a diabetes clinic (6% African American, 1% Hispanic and Pacific Islander) Mean age: IG, 15.9 (±2.9) years; CG, 15.8 (±2.7) years	IG (n = 23): received TM tailored to participants reported top 3 barriers to adherence; 8-12 unrepeated TM/week CG (n not stated): historical controls from the same clinic; matched with IG on age, gender, and HgbA1c values	Glycemic control System usability and satisfaction	Interaction between group × time ($P < .01$) for HgbA1c; values in IG were unchanged but increased in CG. High system usability and satisfaction
Nguyen et al[34] Evaluate the effectiveness of additional therapeutic contact as an adjunct to an extended weight-loss maintenance intervention	Randomized trial (no control group); measurement: at baseline, 12, and 24 months 161 overweight and obese adolescents (gender not reported) seen in New Zealand community health centers (ethnicity not reported) Age range: 13-16 years	IG 1 (n = 78): received Loozit program including 7 × 75-minute weekly group sessions; maintenance of 5 × 60-minute quarterly adolescent booster group sessions IG 2 (n = 79): received Loozit + additional contact every 2 weeks (overall 14 telephone coaching sessions and 32 TM and/or email messages)	Baseline to 24-month changes in BMI *Z*-scores and waist:height ratio Psychosocial well-being Dietary intake PA	No statistically significant group effects or group-by-time interactions for primary outcomes and very few for secondary outcomes From baseline to 24 months, reductions in BMI and triglycerides in IG 2 ($P < .05$)
Rhee et al[35] Develop and evaluate a comprehensive Mobile phone-based Asthma Self-Management Aid for Adolescents (mASMAA)	Descriptive study with focus groups component; measurement: at 2 weeks Adolescents with asthma and their parents (16 dyads; female, n = 6) recruited from emergency department and primary care clinics in a university medical center (40% black, 7% Asian) Mean age: 15 (±1.5) years	Intervention (2 weeks); received TM at a time chosen by each adolescent based on preference and medication schedule; adolescents encouraged to initiate asthma-related TM at least × 2/day	Asthma symptoms Asthma control level Activity level Frequency of rescue and other medication use and asthma control	60% of adolescents experienced uncontrolled asthma for 2+ days during study Each adolescent on average submitted 19 self-initiated TM (range 3-38) regarding symptoms (69%), activity (48%), and medication (10%) or 2 or more categories (29%) Intervention increased awareness of symptoms and triggers, improved asthma self-management, and medication adherence
Seid et al[36] Evaluate an intervention that integrates MI, problem-solving skills training, and TM for adolescents with asthma	RCT; measurements: at baseline, 1, and 3 months 29 adolescents (gender not described) with moderate and severe asthma) enrolled from an Ohio hospital (76.9% African American) Mean age: 15.76 (±1.67) years	IG (n = 12): received 2 brief in person sessions 1 week apart (asthma education, MI, problem-solving skills training) and 1 month of tailored TM CG (n = 14): received asthma education but no tailored TM	Manipulation Mechanism of effect Efficacy (asthma symptoms, QOL)	All participants found intervention appealing and acceptable At 1 and 3 months, motivation, intentions, asthma symptoms, and barriers had clinically meaningful Cohen's *d* medium to large effect sizes (0.5-0.96)
Shi et al[37] Test TM smoking behavior intervention to increase self-reported smoking abstinence and reduce daily cigarette consumption among adolescents	RCT (cluster randomization of 6 schools); measurements: at baseline and at 12 weeks 179 Chinese adolescent smokers (female, n = 8) attending 6 vocational high schools Age range: 16-19 years	IG (n = 76): received daily tailored TM, interactive communication, and adjuvant online support CG (n = 46): received a self-help pamphlet	Smoking cognitions, attitudes, and behaviors	Attitude toward disadvantages of smoking and mean reduction of cigarettes/day higher in IG ($P < .01$) Intervention effectively inhibited cigarette ($P < .01$) and nicotine dependence ($P = .04$) psychologically Difference in number of TM sent to investigator not significant

(continued)

Table 2. (continued)

Authors/Purpose	Design and Sample	Intervention (Comparison/Control)	Main Outcomes	Main Findings
				No difference between groups in self-reported 7- and 30-day tobacco abstinence
Shrier et al[38] Evaluate the MOMENT intervention for marijuana use cessation among adolescents	Single-participant experiment; measurements: at baseline, 2 weeks, and 17 weeks 27 patients (female, n = 19) in 2 adolescent clinics in a Northeastern US city (44% black, 37% Hispanic) Median age: 19 years (range, 15-24)	IG (n = 16): received 2 brief motivational enhancement therapy sessions; 2 weeks of mobile reports with TM supporting self-efficacy and coping strategies	Marijuana use and desire	TM-motivated nonuse of marijuana were interesting, motivating, and helpful Average use events/day declined over the study Desire to use during and after a triggering context decreased from baseline to 3-month follow-up ($P < .0001$ and $P = .03$, respectively) Nonsignificant change in motivational scale scores
Skov-Ettrup et al[39] Compare 2 versions of an Internet- and TM-based smoking cessation intervention	RCT; measurement: at baseline and at 12 months 2030 newly registered users of xhale.dk (female, n = 1204; ethnicity not reported) Mean age: IG, 19.4 (±3.1) years; CG, 19.5 (±3.2) years	IG 1 (untailored intervention; n = 371): received TM about smoking cessation sent once daily × 5 weeks; weekly TM × next 3 weeks IG 2 (tailored intervention; n = 383): received weekly TM 4 weeks before quit date and daily TM 1 to 3 days before quit date; then 2 tailored TM/day × 4 weeks; then 4 to 5 TM/wk × 4 weeks	Smoking cessation perceptions and behavior	79.8% chose to receive supporting TM No significant difference between IG 1 and IG 2 in changes in self-efficacy and beliefs about smoking from baseline to 12-month follow-up
Ting et al[40] Investigate the effects of TM reminders on adherence to clinic visits and the use of HCQ among adolescents with lupus	RCT; measurement: at baseline and at 14 months 70 patients (female, n = 65) in a lupus registry with childhood-onset systemic lupus erythematosus with unlimited access to TM (36% black) Mean age: 18.6 (±2.5) years	All participants received visit adherence intervention: TM reminder sent 7, 3, and 1 day(s) prior to appointment IG 1: received printed information about HCQ benefits and side effects IG 2: received printed information + a standardized daily TM reminder regarding HCQ intake	Clinical visit and medication adherence	19% of patients were nonadherent to clinic visits at baseline; among them, there was improved visit adherence during the TM intervention ($P = .01$) After IG 1 had been concluded, adherence rates declined ($P = .02$), but rates remained higher compared to baseline ($P = .005$) Medication adherence poor in more than two-thirds of cohort based on HCQ blood levels, self-reports, and pharmacy refill data
Whittaker et al[41] Test mobile delivery of a depression prevention intervention for adolescents	RCT; measurement: at baseline and at 12 months 855 students (female, n = 584; white European, Asian, Maori, and Pacific Islander ethnicities) in New Zealand schools Mean age: 14 years (range 13-17)	IG: received 2 TM (mixed formats)/day × 9 weeks based on cognitive-behavioral therapy, followed by monthly TM and access to a mobile Web site CG: received nondepression-focused message (eg, environment sustainability and cybersafety)	Depression incidence Program perceptions	Perceptions of being more positive and ridding of negative thoughts higher in IG versus CG ($P < .001$) 82.4% of participants reported finding the intervention to be useful

Abbreviations: BMI, body mass index; RCT, randomized controlled trial; TM, text messaging; CG, control/comparison group; HCQ, hydroxychloroquine; IG, intervention group; MI, motivational interviewing; NEAT, Nutrition and Enjoyable Activity for Teen; PA, physical activity; QOL, quality of life; RSOD, risky single occasion drinking; SMR, stage of motivational readiness; TCBR, total cancer behavioral risk.
[a]N = 27.

(7.4%) did not report the gender.[34,36] The majority of ethnicities/races represented in the studies was non-Caucasian (n = 16; 59.3%) and included African American/black, Eastern Indian, Hispanic or Latino, Chinese, or a mix of ethnicities other than Caucasian. Five (18.5%) studies did not specify ethnicity in the sample.[18,21,25,33,39] The setting for 10 (37%) studies was a school.[10,19,22,23,25,29,30,31,37,41] Twelve (44.4%) studies[16,18,21,24,26,27,32,33,35,36,38,40] were conducted in a clinic or hospital setting, and 5 (18.5%) studies[17,20,28,34,39] were community-based. Fifteen (55.5%) studies[10,16,19,24-28,30-32,35-38] were conducted in an urban area, whereas 2 (7.4%)[17,18] were conducted in a rural area. Ten (37%) studies[20-23,33,34,39,40-42] did not specify urban/rural setting.

Intervention Characteristics

The interventions reported among studies addressed a range of health topics including obesity and physical activity,[10,26,30,31,34] diabetes,[18,24,33] smoking,[22,37,39] asthma,[32,35,36] mental health,[19,41] HIV,[20,28] multiple health topics,[27,42] treatment attendance,[16] motherhood,[17] skin care,[21] alcohol consumption,[23] skin cancer,[25] marijuana use,[38] and lupus.[40] The majority of studies reported interventions that attempted to promote healthy lifestyle behavior change (n = 19; 70.3%); the remainder promoted monitoring/adherence (n = 8; 29.6%).[16,18,21,24,32,33,35,40]

The intervention in 13 (48.1%) studies consisted only of messages delivered via TM[16-19,21,23-25,28,32,33,35,39] and 14 (51.8%) studies used TM along with other intervention components.[10,20,22,26,27,30,31,34,36-38,40-42] Sixteen (59.2%) studies reported using 1 or more theories to guide the intervention.[10,17,22,26-30,33-39,41] The most commonly cited theories were social cognitive theory,[10,26,27,34,39] the theory of planned behavior,[28,39] and the transtheoretical model.[30,37]

Effectiveness of TM as an Intervention

Although most studies tended to report at least some benefits for participants, there was a variation in the effectiveness of the interventions included in the sample. Five studies focusing on monitoring or adherence showed at least some improvement or benefit from the intervention.[16,21,32,33,40] Three other studies reported positive outcomes such as participants' self-reports of intervention benefits[18,35] or frequent responses to TM received during the intervention.[24] Behavior change studies focused on reducing cigarette smoking, alcohol consumption, or marijuana use also reported positive results. Two RCTs found a larger decrease in cigarettes smoked per day in the intervention than the control group.[22,37] Two other studies showed significant decreases from the baseline for the number of drinks during a typical week[23] as well as marijuana desire—though marijuana is not used.[38]

Behavior change studies, which focused on topics related to obesity or physical activity as well as HIV prevention, had mixed results. The majority of studies addressing obesity or physical activity were RCTs. Of these, 3 studies found no significant differences between the intervention and control or comparison groups for physical activity[10] or weight loss.[26,34] One study, however, found a significant increase in self-reported physical activity in the intervention group relative to the control group.[30] Although 1 study examining HIV prevention showed no change in attitudes toward condoms following in-person meetings or receiving TM,[20] another quasi-experimental study found greater condom use in the intervention group than in the control group.[28]

Of the studies in which the intervention consisted solely of messages communicated using TM, 8 focused on monitoring/adherence and 7 focused on behavior change. The studies focusing on monitoring/adherence reported greater attendance rates for mental health[16] and lupus[40] treatment, greater adherence to treatment regimens for acne[21] and asthma,[35] and no change in HgbA1c scores among patients with diabetes.[33] Three monitoring/adherence studies also reported that when directly asked, participants reported satisfaction with the TM intervention.[16,18,21] Positive outcomes were reported in 5 of the behavior change interventions that relied solely on TM, including decreased alcohol consumption,[23] increased sun-safety behaviors,[25] and greater condom use.[28] However, another study showed no difference between groups that received tailored or nontailored TM interventions for cigarette-smoking beliefs or self-efficacy.[39]

The studies that included TM as one of the multiple intervention components (n = 13; 48.1%) all promoted health behavior change. Seven of these studies demonstrated the efficacy of the intervention tested. Studies reported a significant increase in disease self-management,[27] physical activity,[30] asthma symptoms,[36] and success in managing negative thoughts,[41] as well as a significant decrease in total behavioral cancer risk,[42] body mass index (BMI),[31] and cigarettes smoked per day.[37] Yet, 3 studies found no significant effects of intervention on physical activity,[34] HIV-related knowledge and risk behaviors,[20] or weight loss.[26] The 2 remaining studies reported more mixed results. One study found no difference in physical activity between the condition using TM and the control condition over time but reported a greater reduction in sedentary activity and recreational computer use in the TM group than in the control group.[10] Another study reported no difference in 7-day abstinence rates or quit attempts between a TM group and a control group but a greater decrease in cigarettes smoked per day in the TM group.[22]

Adverse effects. Although we found no interventions that produced adverse effects, 1 study reported an intervention that was less effective than the no-intervention condition. Love-Osborne and colleagues[31] found that the proportion of participants who maintained or decreased their BMI was greater in the control group than in the intervention group. However, they also found increased sports participation in the control group, which they argue may have accounted for this result.

Sustained effects. There is no consensus for what constitutes a sustained effect of an intervention.[43] Three studies in our

Table 3. Bias Evaluation for Randomized Trials (n = 10).

Reference	Random Sequence Generation (Selection Bias)	Allocation Concealment (Selection Bias)	Blinding of Participants and Personnel (Performance Bias)	Blinding of Outcome Assessment (Detection Bias)	Incomplete Outcome Data (Attrition Bias)	Selective Reporting (Reporting Bias)	Other Bias	Comments
Dewar et al[10]	U	H	U	H				No details on randomization procedures
Haug et al[22]			H					
Huang et al[26]	U	U	H	U	L	L	H	Tailored TM and phone counseling not described; effect of mobile component unknown
Huang et al[27]	L	L	H	L	L	L	H	Tailored TM and phone counseling not described; effect of mobile component unknown
Lana et al[29]	U	U	H	U	H	L	L	No details on randomization procedures
Love-Osborne et al[31]	H	H	H	H	L	L	H	No details on randomization procedures; the authors noted several confounders in both groups
Nguyen et al[34]	U	U	U	H	H	L	H	No details on randomization procedures; no true control group
Seid et al[36]	H	H	L	L	L	L	U	
Shi et al[37]	U	U	U	U	H	L	H	Potential recruitment bias with cluster randomization
Skov-Ettrup et al[39]	U	U	L	U	H	L	H	>60% attrition in both intervention groups; design does not allow conclusion of whether the effect was caused by tailoring or TM frequency

Abbreviations: H, high risk of bias; L, low risk of bias; TM, text messaging; U, unclear bias.

systematic review[10,39,41] followed participants for about 1 year postintervention. Of those, 2 reported that the intervention did not impact the lifestyle outcomes or potential mediators, largely owing to attrition[10,39] and potential issues with intervention fidelity.[10] At the time of publication of their study, Whittaker et al did not report on the 12-month results of their intervention.[41]

Challenges of Using TM in an Intervention

About half of the articles noted some challenges using TM in an intervention. Phone or phone plan (if applicable) technical problems were easily resolved, and lost or damaged phones were replaced either by the phone companies or the investigators. Some participants changed their phone numbers without informing the investigators and subsequently were lost to long-term follow-up. Regardless of the method to disseminate TM (eg, by individual phone or software programs), investigators did not know, with certainty, whether TM sent to recipients had actually been read by them. Adolescents were less likely to respond to TM immediately in the morning when they were busy with school and therefore had to spend time in the evenings responding to TM from the initial daily round of texting. Boys texted less than girls, but girls were more likely to opt out of TM than boys. In studies that used tailored TM, investigators could not ascertain whether the tailoring or the frequency of TM improved outcomes. Adolescents preferred a variety of TM on a variety of topics each week versus 1 TM on 1 topic per week. They also preferred 2-way versus 1-way communication; however, investigators noted that the former required more staff time and resources. In studies using TM reminders, the constant TM reminders became repetitive. As the novelty wore off, participants ignored these reminders.

Methodological Rigor

Thirteen (48.1%) studies were RCTs,[10,21,22,26,27,31,34,36,37,39,40-42] representing the highest level of evidence (level 1). Four (14.8%) studies were quasi-experimental[16,28,30,33] (level 2 evidence), and the remaining 10 (37%) studies were

single-participant experiments[18-20,23-25,32,38] or qualitative studies using interviews or focus groups[17,35] (level 3 evidence).

Description of reliability and validity of scales or instruments to measure outcomes of, or factors associated with TM interventions, varied among the studies. Six (22.2%) articles[10,16,20,30,37,39] reported internal consistency (Cronbach α) of measurement scales ranging from 0.63 to 0.96, which ranges from unacceptable (lower coefficient) to acceptable or redundant (higher coefficients), depending on an expert opinion.[44] Two (7.4%) articles described instrument validity (eg, convergent validity)[20,30]; however, authors of 10 (37%) articles stated that their selected scales previously were validated by others (referenced in the article) but did not provide specific information on psychometrics.[10,20,27,28,33,34,36,38,41,42] Eleven (40.7%) articles contained no information on reliability and validity on 1 or more scales or instruments.[18-23,25,26,31,40,42] Outcomes also were measured by author-developed checklists, diaries, single items, or self-report inventories.[16,31,35,37-39,40] The only measurements used in more than 1 study were indicators of disease status (eg HgbA1c, blood glucose, BMI), measures of physical activity (eg, actigraph), and the Patient Activation Scale.

Bias in Published Studies

In the 13 RCTs, trials, random sequence generation and allocation concealment (selection bias), and blinding of participants and personnel (performance bias) tended to be unclear or demonstrate high risk of bias (Table 3). We noted several other forms of bias overall, including *chronology bias* (historical controls from the same clinic)[16]; *reporting bias* such as detailed information about medical outcomes not reported,[24] instrument not specified,[28] or end points unclear and lacking findings on control group outcomes[33]; *detection bias* in the form of knowledge of the allocated interventions by outcome assessors[17] or outcome measurement likely to be influenced by lack of blinding[18,19]; *gender bias*[23,30,35,37-41]; *confounding bias* in the form of tailored TM and phone counseling not described or effect of mobile component unknown,[26,27] author-noted confounders,[31] or interviewer bias[35]; *attrition bias*[28,34,37,42]; and *response bias* in the form of self-report.[10,16,20,25,26,30,32,41,42]

Conclusions

Several conclusions might be drawn about the state of interventions promoting healthy lifestyle behaviors among adolescents using TM. Since the previous systematic review, 27 additional studies have been published. Although there was heterogeneity in the effectiveness of the studies examined in this review, most studies reported at least some positive outcomes. Studies focusing on monitoring and adherence, as well as studies where message delivery via TM was the only intervention component, tended to have the most positive findings. It is noteworthy that none of the studies in the sample involved adverse effects of the intervention. One study showed that the intervention group was less likely to lose or maintain their weight than the control group[31]; however, there was no evidence that participants in the experimental group gained weight relative to the control group.

Despite the trend of reporting at least some positive outcomes, there were a large number of inconsistencies among the studies in the sample. The primary intervention outcomes or factors associated with TM differed for the vast majority of studies, including studies targeting similar topic areas (eg, diabetes self-management and smoking cessation). The authors inconsistently used theory to inform intervention design. Only about half of the studies relied on the established theories of health behavior change. Less than half of the articles reported internal consistency or validity of measures, which leads to concerns about inferences and conclusions drawn by the authors.[45]

There were several similarities and differences between this project and the previous systematic review[8] that examined TM as an intervention to enhance healthy lifestyle. Both systematic reviews examined a variety of health behaviors. Beneficial outcomes were observed across the majority of studies included in both reviews. There was also a fair amount of variation in study quality across the 2 reviews. With regard to differences, Militello et al[8] reported studies of children and adolescents; however, all but 1 of their 7 articles focused on adolescents within the age range of our targeted population. Militello et al[8] focused on RCTs and quasi-experimental studies, whereas the present systematic review also included 2 observational studies reporting on interventions. Most notably, the sample for the present systematic review was 4-fold larger, likely reflecting the increasing numbers of studies on this topic and population since 2011.The increased sample size made it possible to better identify trends in the results of individual studies. Studies focused on promoting monitoring/adherence as well as changes in behavior related to alcohol and cigarette use tended to report positive outcomes. The results for studies of HIV prevention and physical activity were more mixed. Similarly, studies that consisted solely of messages communicated using TM tended to more consistently produce positive outcomes than studies using TM messages along with several other intervention components.

The trends identified in this project are important because they suggest that TM may be more useful for intervention delivery in some contexts than others. The degree to which TM is interwoven into adolescents' everyday lives may make this technology a particularly useful tool for communicating reminders such as one might find in interventions promoting monitoring or adherence. Text messaging can serve as a means to send relatively frequent but unobtrusive messages and promote compliance with routine activities. This potential may also make TM valuable for fostering the cessation of unhealthy behaviors such as alcohol and tobacco use. The ability to share brief but frequent messages is useful for communicating encouragement and reinforcement.

This systematic review had several strengths. We searched the literature in several databases. Moreover, we used rigorous procedures based on PRISMA, including reliability checks of all articles by the lead authors of the systematic review.

Limitations included combining the results of well-designed studies with less rigorously designed studies and combining heterogeneous studies (due to different populations, settings, interventions, or outcome measures). Slightly deviating from the procedure by Militello et al,[8] we did not search Google Scholar or Cochrane Library databases. We did not include theses or dissertations as literature sources. Also, although it would have been desirable to consult comprehensive bibliographies in our search for articles, none could be located that addressed interventions delivered via TM to adolescents.

The results of this systematic review suggest the potential utility of TM interventions to enhance healthy lifestyle behaviors among adolescents. Across a relatively large sample of studies addressing a range of health issues and employing diverse research methodologies, there was consistent evidence that the TM interventions had at least some positive effects. More broadly, this review underscores the importance of efforts to synthesize the findings from health interventions delivered to adolescents using TM. Understanding how and with what effects TM might be incorporated in intervention efforts offers a potentially valuable mechanism for promoting intervention effectiveness. It seems likely that the use of this technology for intervention delivery will only increase in the coming years. Those interventions conducted to date that have been rooted in the established theory, adopted rigorous designs, used validated measures, and effectively controlled for bias offer valuable guides for future research.

SO WHAT? Implications for Health Promotion Practitioners and Researchers

What is already known on this topic?

The previous systematic review of text messaging (TM) interventions to enhance adolescents' healthy behaviors identified 7 articles published prior to 2011—5 showed effectiveness of TM interventions for diabetes self-management, treatment adherence, social support, and physical activity. Studies tended not to be theory-based or target vulnerable populations.

What does this article add?

This systematic review of 27 articles published between 2011 and 2014 provides new information on the effectiveness of TM interventions targeting adolescents; adolescent and setting characteristics; levels of evidence, bias, and methodologic rigor; sole TM interventions versus when combined with other approaches; and challenges of using TM interventions.

What are the implications for health promotion practice or research?

Text messaging interventions can improve healthy lifestyle in adolescents, including those in vulnerable populations. Adolescents easily engage in TM interventions, which may be most effective for monitoring/adherence behaviors and if they are the primary intervention component.

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