Journal of Diabetes Science and Technology
Volume 7, Issue 3, May 2013

OBESITY TECHNOLOGY

Outcomes of a 12-Month Technology-Based Intervention to Promote Weight Loss in Adolescents at Risk for Type 2 Diabetes

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Abstract

Background:

Obese adolescents are at risk for type 2 diabetes mellitus (T2DM). Obesity interventions delivered through media, such as the web and text messages [short message service (SMS)] may be beneficial when targeting obese adolescents..

Methods:

A randomized controlled trial, Pace-Internet for Diabetes Prevention Intervention (PACEi-DP), compared three forms of an obesity intervention to usual care (UC): (a) website only (W); (b) website, monthly group sessions, and follow-up calls (WG); and (c) website and SMS (WSMS). Participants were overweight or obese adolescents at risk for T2DM (n = 101; age 12–16 years; mean body mass index (BMI) percentile = 97.6; 74.3% Hispanic). In addition to the website, WSMS participants received SMS supporting intervention goals and behavioral strategies and communicated via SMS with a case manager. WG participants had additional group activities related to weight loss and received follow-up calls from a health coach. UC participants were given printed materials and encouraged to attend three initial group sessions. Repeated measures mixed model regression analyses tested treatment effects for anthropometric, behavioral, and behavioral change strategy outcomes.

Results:

There were no treatment effects for BMI, adiposity, physical activity, or diet at 12 months. Treatment effects were observed for sedentary behavior, with the W arm having a greater decrease in sedentary behavior (4.9 to 2.8 h/day) than the UC arm (p = .006).

Conclusion:

Although not sufficient to produce weight loss, the combination of web intervention and group sessions with telephone follow-up yielded improvements in sedentary behavior and in the use of behavior change strategies expected to lead to behavior change.

J Diabetes Sci Technol 2013;7(3):759–770

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Abbreviations: (BMI) body mass index, (PACEi-DP) Pace-Internet for Diabetes Prevention Intervention, (QOL) quality of life, (RCS) relative change scores, (SMS) short message service, (T2DM) type 2 diabetes mellitus, (UC) usual care, (W) website only, (WG) website, monthly group sessions, and follow-up calls, (WSMS) website and short message service

Keywords: adolescents, diabetes, mobile, obesity, web

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Introduction

Type 2 diabetes mellitus (T2DM) is increasing among children and adolescents. According to 2003–2005 data from the SEARCH for Diabetes Study, the prevalence of T2DM among youth 10–19 years of age was 19.0/100,000 among African Americans,[1] 5.9/100,000 among Hispanics,[2] and 3.7/100,000 among non-Hispanic whites.[3] Increases have been attributed to the rise in childhood obesity, unhealthy eating, and physical inactivity.[4,5] In addition, obese adolescents are more likely to have poor quality of life (QOL)[6] and symptoms consistent with psychological conditions such as depression and low self-esteem.[7]

In 2011, 95% of adolescents aged 12 to 17 years used the Internet[8] and 77% owned cell phones.[9] Due to these trends, web- and mobile-based interventions are increasing in the research field and showing promising results. Web-based interventions have been effective in promoting healthy eating[10] and physical activity[11] among adolescents. Mobile-based interventions have been used successfully for providing self-care tips and reminders to adolescents with diabetes, resulting in improved glycemic control.[12,13] The greatest willingness to use online technology for health purposes has been reported among adolescents with chronic disease.[14] Overweight adolescents have also recommended the use of technology to help them with weight-loss efforts.[15]

To our knowledge, no technology-based interventions have targeted improvements in physical activity, diet, and weight loss among overweight adolescents who meet accepted criteria for being at risk for T2DM. We conducted a randomized controlled trial to evaluate the effectiveness of an intervention targeting this population that was offered to participants recruited through clinical sites but primarily delivered through combinations of three modalities: the web, group sessions for adolescents and parents, and short message service (SMS). Based on preliminary work with other populations, we offered these modalities in different combinations and hypothesized that, compared with usual care, all active treatment conditions would produce better behavioral, weight, and quality-of-life and psychological outcomes.

Methods

Provider and Participant Selection and Recruitment

Eighteen pediatric practices were recruited to participate as the primary provider sites for recruitment into the study, 12 of which served economically and ethnically diverse adolescent patient populations. Providers underwent a 2 h counseling training aimed at improving their ability to motivate participation in the study and were asked to identify potential at-risk 12–16-year-old patients who were due for their annual visit or who have an existing appointment for a physical exam or well visit. Fliers posted in waiting rooms and local media were used to promote recruitment through all settings. Consent was obtained from both parent and adolescent prior to scheduling a baseline assessment. The San Diego State University and University of California, San Diego, committees on protection of human subjects approved the study. **Figure 1** shows the flow of participants from inquiries through randomization and 12-month assessments.

Inclusion Criteria

Eligible adolescents were between the ages of 12 and 16 years and at "high risk" for diabetes, as defined by the American Diabetes Association expert consensus panel,[16] i.e., overweight [body mass index (BMI) > 85th percentile for age and sex, weight and height >85th percentile, or weight >120% of ideal for height] plus any two of the following risk factors: family history of T2DM in a first- or second-degree relative, race/ethnicity (American Indian, African-American, Hispanic, Asian/Pacific Islander), or signs of insulin resistance (acanthosis nigricans, hypertension, dyslipidemia, polycystic ovary syndrome). The age range of 12–16 years was chosen because we wanted children old enough to comprehend and engage in intervention activities but young enough to assure us of their availability prior to leaving for college, the military, or other settings away from home.

Other inclusion criteria for both teens and parents included access to the Internet at home, work, or school for both parent and teen; having a functioning telephone; ability to speak and read English (for adolescent) or English or Spanish

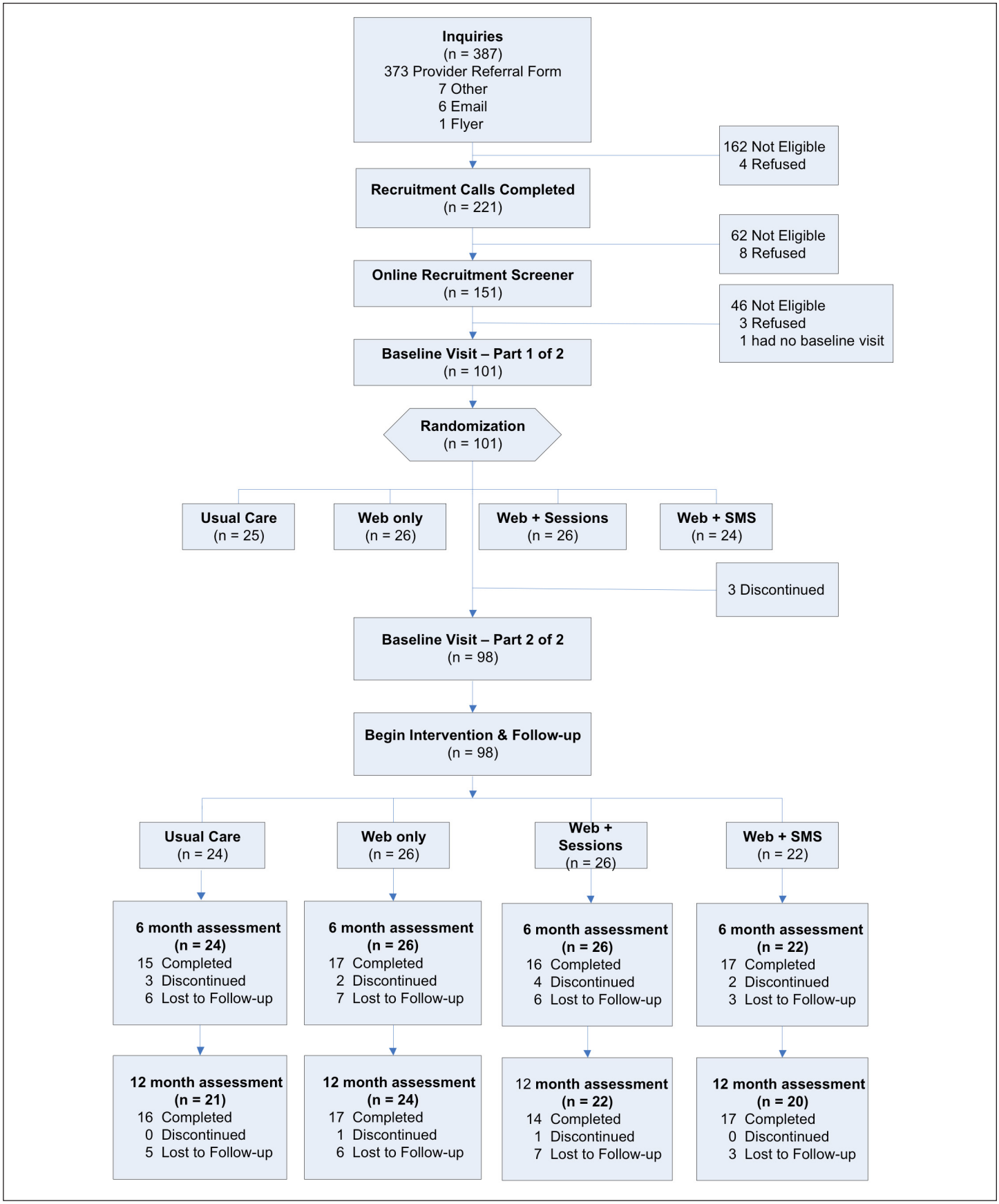

Figure 1. Study flow diagram.

(for the parent); and willingness to participate in online activities and attend monthly group sessions. Patients were excluded if they had a diagnosis of diabetes, were pregnant, were not planning to be in the San Diego area over the entire study period, or had any medical condition that would prevent them from participating in the intervention.

Intervention Design

Theoretical concepts from the behavioral determinants model[17] and the transtheoretical model of behavior change[18] were used to design the intervention. Intervention components focused on education about behavioral goals and promoting use of evidence-based behavior change strategies.

Behavioral goals were divided into two categories: nutrition targets (fat, fruit/vegetable/fiber consumption) and physical-activity-related targets (total physical activity and sedentary behavior). All groups addressed these behavioral goals.

A team of investigators and staff with several years of experience with nutrition and physical activity intervention studies targeting both adolescents and adults developed the intervention. All intervention components, including the website, counseling calls, group sessions, text messages, and printed materials, were pretested with adolescents or parents as appropriate prior to initiation of the randomized controlled trial. During the development phase of the intervention, content was piloted and revised after input from a diverse group of adolescents regarding reading level, understanding of concepts, ability to hold their attention, and usability of information.

Program Website

The program website and its tutorials were designed to promote weight loss and healthy behaviors related to obesity. Based on the "stoplight approach,"[19] participants were encouraged to limit red-light foods (low nutrient, high calorie/fat) and red-light activities (unproductive, low energy), increase green-light foods (high nutrient, low calorie/fat) and green-light activities (high energy), and eat yellow-light foods and do yellow-light activities in moderation. The website and its tutorials provided educational topics and challenges based on weekly nutrition or physical activity goals, skill building exercises, a reward system to encourage success, evaluation for assessment of progress, weekly weigh-in, and feedback on progress. All participants received a pedometer and a body weight scale. Participants were encouraged to report their steps daily and to report their body weight weekly. The website also included information on recommended food portion sizes, categorization of foods into the stoplight plan, and a resource library that included tip sheets, recipes, and web tutorials on several behavior change strategies, such as goal setting, seeking social support, and positive self-statements.

The application and content of the program website was divided into three phases, with phase 1 (weeks 1–17) entailing education on healthy behaviors needed for weight loss, phase 2 (weeks 18–34) designed to be both more interactive (e.g., true/false quizzes, interactive activities/games) and allow the participant to select challenges and goals to help to master skills and behaviors introduced in phase 1, and phase 3 (weeks 35–51) designed to be interactive and encourage working on multiple behaviors at the same time. The parent completed an adult version of the program website (except for skills and rewards) and, in the website, monthly group sessions, and follow-up calls (WG) condition, participated in group counseling aimed at skill building to support their adolescent's behavioral goals. Usability of the program website was monitored and recorded. Parents did not receive the counselor calls or text message intervention components.

Study Arms

Participants were randomized to four study arms: (1) website only (W), (2) WG, (3) website and SMS (WSMS), and (4) usual care (UC).

The W arm included individual case management that included weekly "check-in" emails, monthly mailed tip sheets, and access to the program website and its web tutorials. The purpose of the weekly emails was to remind the participants to complete the web tutorials. If participants did not log on to the web program, they received repeated reminders via email and, if necessary, a phone call from a health counselor.

The WG arm consisted of access to the program website and its web tutorials, monthly mailed tip sheets, and monthly 90 min group sessions of 5–10 adolescents and their parents where they discussed the behavioral skills from the web tutorials. Participants in this condition also received brief (~20 min) bimonthly phone calls from the health counselor reviewing concepts presented in the web tutorial and reinforcing behavioral strategies such as goal setting and problem solving of barriers/solutions. Attendance and participation in the group sessions were rewarded with mileage incentives and a lottery for prizes such as cookbooks or other materials to assist with healthy behavior change. Nutrition demonstrations and physical activities were also integrated in each group session.

The WSMS arm included the program website and its web tutorials, monthly mailed tip sheets, and a minimum of three text messages per week that related to weekly challenges and intervention goals. Reminder text messages were sent if the participant did not log on to the website by the fourth day of the intervention. Participants could also communicate via text messages with a health counselor if they had questions. Participants were provided with cell phones and prepaid text message plans that allowed research staff to monitor SMS use.

Participants in the UC arm were given printed materials produced by the American Diabetes Association and the American Heart Association. Participants were encouraged to attend three 1 h group nutrition sessions at Rady Children's Hospital of San Diego during the first 6 weeks at no charge. They also received monthly tip sheets by mail. This combination of intervention elements reflected the prevailing community standard of care for adolescents judged to be at risk for T2DM.

Outcome Measures

Prior to randomization and initial counseling and encouragement from the primary care physician, baseline anthropometric, psychosocial, and behavioral measures were collected. The primary outcome was BMI z-score. All other measures were considered secondary and exploratory. All measures were collected at baseline, 6 months, and 12 months.

Anthropometric Measures

Body mass index was calculated from height and weight as kilograms per square meters. Height (without shoes) was measured using a stadiometer with the subject standing erect against a wall with heels close to the wall. Weight was measured using a calibrated digital scale. National norms from the Centers for Disease Control and Prevention were used to calculate BMI z-scores using age- and sex-specific median, standard deviation, and power of the Box–Cox transformation.[20] Percentage of body fat was assessed by dual energy X-ray absorptiometry (Hologic Discovery W model).

Behavioral Measures

The youth/adolescent questionnaire, a validated self-administered food frequency questionnaire for adolescents,[21] was used to assess dietary intake. The 7-day physical activity recall interview, developed for the Stanford Five-City Project,[22] was used to measure physical activity. Sedentary behavior was assessed using an eight-item survey based on a survey developed by Robinson[23] that measured hours spent doing various sedentary behaviors during school and non-school days.

Psychological Measures

Health-related QOL (total and related to physical functioning) was assessed using the validated pediatric quality-of-life inventory,[24] a 23-item survey with a 0 to 100 scale, with higher scores indicating better QOL. Depressive symptoms were measured with the validated Center for Epidemiologic Studies depression scale short-form questionnaire,[25] a 10-item survey with a score range of 0 to 30, with a score of 10 or higher indicating clinical depressive symptomology. Self-esteem was measured using the validated Rosenberg self-esteem scale,[26] a 10-item survey where each item has a 4-point ordinal response scale and a score range of 10 to 40, with higher scores indicating greater self-esteem.

Behavior Change Strategies

Participants reported their use of skills to change physical activity and dietary behaviors, consistent with the transtheoretical model's processes of change.[18] Example of these skills included, "I look for information about physical

activity or sports," "I set goals to eat at least five servings of fruits and vegetables per day," and "I make backup plans to be sure I reduce my sedentary time." Questions were grouped by behavior, and mean scores were computed (score range from 1 to 5), with higher scores indicating greater strategy use.

Analysis

Comparisons of demographic characteristics across the four study groups and by study completion status were tested using Chi square tests. The distributions of the outcome variables were checked for missing values, outliers, and normality. Non-normally distributed variables were log or square-root transformed.

Group effects on each of the outcome measures at 12 months were tested with mixed model analyses using maximum likelihood repeated measures. Intent-to-treat analyses were conducted using all available data from participants who enrolled, were randomized, and started the interventions (n = 101) assuming data were missing at random. Intervention groups were coded as three dummy variables (W, WSMS, WG). Each outcome model was specified with the between-subject dummy variables for treatment group and a within-subject variable of time (0 = baseline; 1 = 6 months; 2 = 12 months). Models also included three two-way interactions of intervention group × time to test the differential effect of each treatment condition compared with the control condition over time. P values presented are for these three two-way interaction terms.

Relative change scores (RCS) of each of the outcome measures were calculated as [(score on 12-month measure - baseline measure)/baseline measure] × 100. Relative change scores were used in partial correlation analyses to test the correlations between change in (1) anthropometrics and behavioral outcomes and (2) behavioral outcomes and use of change strategies. The partial correlations between baseline depression RCS were also assessed. Analyses using RCS variables were stratified by sex and adjusted for baseline age.

Analyses were conducted using SPSS version 17 (IBM Inc., Chicago, IL) and exact p values are reported for two-sided tests with statistical significance set at $p < .05$.

Sample size was determined from previous studies[27–29] that indicated that a 1- to 1.5-point between-group difference in BMI is clinically significant and that a change in BMI of 1.3 among adolescents aged 12–16 years of age enrolled in a similar intervention has a standardized effect size d of 0.80 (with $\sigma = 1.63$).[27] With 26 adolescents per group, an effect size of 0.70 could be detected with two-tailed alpha set at 0.05 and power at 0.80.

Results

Sample demographic characteristics by treatment group are presented in **Table 1**. A total of 101 adolescents enrolled and randomized: 74.3% were Hispanic, 64 were girls, and 37 were boys, with a mean age of 14.3 years and mean BMI percentile of 97.6 (standard deviation = 0.023). Of the 101 enrolled, 64 (63%) completed the 12-month assessment. Participant dropout was unrelated to treatment arm, age, sex, or race/ethnicity. Demographic characteristics did not vary significantly by condition.

Declines in weekly computer program login frequencies were observed. Among the adolescents with complete 12-month computer log data, in the W group, the number of participants logged-in decreased steadily from 16 (out of 19) participants at week 1 to 4 participants at week 50. In the WSMS group, 15 (out of 19) participants logged-in at week 1 decreased to 3 participants at week 50. In the WG group, 8 (out of 15) participants logged-in at week 1 dropped to 1 participant at week 50.

Effects on Anthropometrics, Psychological Status, and Quality of Life

Treatment effects from baseline to 12 months on BMI z-score, BMI percentile, and percentage of body fat were not observed (**Table 2**). Baseline quality-of-life and self-esteem scores were high, and depression scores were low and remained relatively the same at 6 and 12 months, indicative of good psychological wellbeing across all groups and over time. Although there were no group × time effects on psychological status or QOL, after adjusting for age, positive

Table 1.
Baseline Demographic Characteristics by Treatment Group

	W	WSMS	WG	UC	Overall
Participants, *n*	26	24	26	25	101
Age, mean (standard deviation) years	14.1 (1.4)	14.3 (1.8)	14.3 (1.5)	14.5 (1.5)	14.3 (1.5)
Gender, *n* (%)					
Male	10 (38.5)	12 (50.0)	8 (30.8)	7 (28.0)	37 (36.6)
Female	16 (61.5)	12 (50.0)	18 (69.2)	18 (72.0)	64 (63.4)
Hispanic, *n* (%)	20 (76.9)	21 (87.5)	20 (76.9)	14 (56.0)	75 (74.3)
Race/ethnicity, *n* (%)					
White	7 (26.9)	2 (8.3)	6 (23.1)	3 (12.0)	18 (17.8)
African-American	4 (15.4)	3 (12.5)	2 (7.7)	7 (28.0)	16 (15.8)
Native American	0 (0)	1 (4.2)	0 (0)	0 (0)	1 (1.0)
Asian or Pacific Islander	1 (3.8)	0 (0)	2 (7.7)	1 (4.0)	4 (4.0)
Multiethnic or other	1 (3.8)	0 (0)	1 (3.8)	1 (4.0)	3 (3.0)
Said preferred not to state	6 (23.1)	4 (16.7)	4 (15.4)	4 (16.0)	18 (17.8)
Did not state	7 (26.9)	14 (58.3)	11 (42.3)	9 (36.0)	41 (40.6)

correlations were observed among girls between RCS of physical functioning QOL and RCS of fruit and vegetable consumption change strategies ($r = 0.594$; $p \leq .001$), RCS of physical activity change strategies ($r = 0.400$; $p = .021$), RCS of sedentary behavior change strategies ($r = 0.511$; $p = .002$), and RCS for dietary fat strategies ($r = 0.594$; $p < .001$). Also among girls, a negative correlation between baseline depression score and RCS of physical activity was found, adjusting for age ($r = -0.359$; $p = .047$). Significant correlations among boys were not observed.

Effects on Diet, Physical Activity, Sedentary Behavior, and Behavior Change Strategies

Significant treatment effects were observed for sedentary behavior and fruit and vegetable change strategies (**Table 3**). Specifically, adolescents in the W arm decreased their sedentary behavior from 4.9 to 2.8 average hours per day compared with the UC group, which only decreased from 5.4 to 5.3 average hours per day of sedentary behavior at 12 months ($p = .006$). Treatment effects for fruit and vegetable change strategies were also observed comparing the WG group to UC group, 2.4 to 3.0 versus 2.3 to 2.1, respectively ($p = .024$).

Although treatment effects from baseline to 12 months on physical activity and diet outcome behaviors were not observed, among girls, RCS of change strategies for fruit and vegetable consumption was positively correlated with RCS of fruit and vegetable consumption ($r = 0.508$; $p = .003$). Significant correlations among boys were not observed.

Discussion

We found that a 12-month obesity intervention for adolescents at risk for T2DM that utilized a website program had positive effects on sedentary behavior. Additionally, when this website program was combined with group sessions, positive effects on use of behavioral change strategies for fruit and vegetable consumption were found. However, 12 months of access to the same website program coupled with SMS or group sessions and counselor calls had no effects on sedentary behavior or behavior change strategies. Although there were no intervention effects on the main outcomes of BMI, adiposity, diet, and physical activity, the use of change strategies for fruit and vegetable consumption was positively correlated with fruit and vegetable consumption among girls.

Although all three intervention arms had decreases in sedentary behavior, it is not clear why the W arm had the greatest decrease in sedentary behavior. The purpose of the counseling calls and group meetings was to reinforce the concepts

Table 2.
Estimated Marginal Means and Standard Errors for Body Mass Index, Adiposity, Quality of Life, Psychological Outcomes at Each Time Point by Group

	W, mean (SE)	*P* value[a]	WSMS, mean (SE)	*P* value[a]	WG, mean (SE)	*P* value[a]	UC, mean (SE)
BMI z-score		0.876		0.934		0.824	
Baseline	2.2 (0.07)		2.2 (0.07)		2.2 (0.07)		2.2 (0.07)
Month 6	2.1 (0.08)		2.1 (0.08)		2.2 (0.08)		2.2 (0.08)
Month 12	2.1 (0.09)		2.1 (0.09)		2.0 (0.09)		2.2 (0.09)
BMI percentile		0.953		0.985		0.614	
Baseline	98.1 (0.01)		97.9 (0.01)		97.8 (0.01)		98.1 (0.01)
Month 6	97.7 (0.01)		97.5 (0.01)		97.5 (0.02)		97.6 (0.01)
Month 12	97.2 (0.01)		97.1 (0.01)		97.5 (0.01)		97.2 (0.01)
Percentage body fat		0.185		0.448		0.771	
Baseline	46.2 (1.21)		44.6 (1.25)		46.0 (1.21)		46.1 (1.23)
Month 6	44.9 (1.35)		43.6 (1.41)		45.7 (1.37)		45.6 (1.39)
Month 12	43.5 (1.61)		42.6 (1.66)		45.3 (1.67)		45.6 (1.43)
Total QOL		0.234		0.485		0.262	
Baseline	76.8 (2.46)		79.4 (2.61)		80.4 (2.49)		75.9 (2.53)
Month 6	82.0 (2.06)		83.7 (2.14)		85.5 (2.01)		78.9 (2.11)
Month 12	87.1 (2.30)		88.0 (2.31)		90.6 (2.44)		82.0 (2.36)
Physical functioning QOL		0.057		0.327		0.074	
Baseline	79.3 (2.69)		81.5 (2.85)		82.0 (2.72)		77.9 (2.76)
Month 6	84.5 (2.14)		85.1 (2.23)		87.2 (2.17)		79.7 (2.20)
Month 12	89.7 (2.23)		88.7 (2.25)		92.3 (237)		81.4 (2.31)
Rosenberg self-esteem scale		0.354		0.527		0.258	
Baseline	30.2 (0.95)		32.8 (1.11)		31.5 (0.97)		30.7 (0.97)
Month 6	30.7 (0.90)		33.5 (0.93)		31.8 (0.92)		31.9 (0.92)
Month 12	31.2 (1.11)		34.2 (1.13)		32.0 (1.18)		33.0 (1.14)
Center for Epidemiologic Studies depression scale		0.262		0.783		0.620	
Baseline	6.7 (0.77)		5.6 (0.82)		6.0 (0.78)		6.0 (0.79)
Month 6	5.6 (0.68)		5.3 (0.71)		5.5 (0.70)		5.9 (0.69)
Month 12	4.9 (0.85)		4.9 (0.85)		5.0 (0.91)		5.7 (0.87)

SE, standard error.
[a] P value is for group × time interaction in the mixed model comparing the treatment group with the UC comparison group.

presented in the web tutorials, deliver additional support and guidance if needed, and potentially improve adherence. Because fairly equal weekly computer program login frequencies were observed in all intervention arms despite the W arm having less intervention touch points, it is possible that those in the W arm were more self-motivated than the other intervention participants. It is also possible that the WSMS arm, which had the least change in sedentary behavior of the three intervention arms, was not as effective as the W arm if the text messages were considered a nuisance and were ignored. We did not collect data on perceptions or satisfaction with text messages, however.

The present finding of minimal intervention effects is consistent with other interventions targeting overweight adolescents at risk for diabetes. A 12-week physical activity and diet intervention in primary care targeting minority

Table 3.
Estimated Marginal Means and Standard Errors for Diet and Physical Activity Behaviors and Behavior Change Strategies at Each Time Point by Group

	W, mean (SE)	*P* value[a]	WSMS, mean (SE)	*P* value[a]	WG, mean (SE)	*P* value[a]	UC, mean (SE)
Percentage calories from fat		0.219		0.979		0.719	
Baseline	29.1 (0.01)		30.3 (0.01)		28.2 (0.01)		33.4 (0.01)
Month 6	29.5 (0.01)		29.4 (0.01)		27.7 (0.01)		32.5 (0.01)
Month 12	30.0 (0.01)		28.5 (0.01)		27.3 (0.01)		32.0 (0.01)
Fruit and vegetable servings per 1000 calories[b]		0.685		0.369		0.398	
Baseline	1.9 (0.01)		2.0 (0.01)		2.3 (0.01)		1.9 (0.01)
Month 6	2.1 (0.01)		2.3 (0.01)		2.6 (0.01)		2.0 (0.01)
Month 12	2.9 (0.01)		2.6 (0.01)		2.9 (0.01)		2.0 (0.01)
Moderate and vigorous physical activity min/week[c]		0.509		0.544		0.339	
Baseline	320.3 (2.1)		312.5 (2.5)		326.1 (2.1)		378.5 (2.3)
Month 6	322.7 (1.3)		306.9 (1.4)		332.9 (1.3)		319.0 (4.0)
Month 12	306.0 (2.2)		301.6 (2.2)		348.6 (2.8)		263.6 (2.5)
Sedentary behavior (average h/day)		**0.006**		0.458		0.221	
Baseline	4.9 (1.12)		3.9 (1.13)		4.6 (1.12)		5.4 (1.12)
Month 6	3.1 (1.11)		3.8 (1.11)		4.3 (1.11)		5.3 (1.14)
Month 12	2.8 (1.14)		3.6 (1.14)		3.8 (1.16)		5.3 (1.15)
Physical activity behavior strategies		0.142		0.098		0.068	
Baseline	2.7 (0.16)		3.1 (0.17)		2.9 (0.17)		2.6 (0.17)
Month 6	2.7(0.14)		3.1 (0.15)		3.0 (0.15)		2.3 (0.15)
Month 12	2.7 (0.16)		3.2 (0.19)		3.0 (0.20)		2.2 (0.19)
Fruit and vegetable behavior strategies		0.132		0.249		**0.024**	
Baseline	2.5 (0.15)		2.5 (0.16)		2.4 (0.15)		2.3 (0.15)
Month 6	2.6 (0.14)		2.6 (0.14)		2.7 (0.15)		2.2 (0.14)
Month 12	2.7 (0.18)		2.7 (0.18)		3.0 (0.19)		2.1 (0.19)
Dietary fat behavior strategies		0.894		0.339		0.635	
Baseline	2.7 (0.19)		2.8 (0.19)		2.7 (0.19)		2.3 (0.19)
Month 6	2.7 (0.17)		2.9 (0.17)		2.7 (0.17)		2.3 (0.17)
Month 12	2.7 (0.18)		3.0 (0.19)		2.8 (0.21)		2.2 (0.20)
Sedentary behavior strategies		0.453		0.594		0.375	
Baseline	2.3 (0.15)		2.3 (0.16)		2.2 (0.15)		2.1 (0.16)
Month 6	2.4 (0.13)		2.3 (0.13)		2.3 (0.13)		2.0 (0.13)
Month 12	2.4 (0.20)		2.4 (0.20)		2.4 (0.17)		1.9 (0.17)

SE, standard error.
[a] P value is for group × time interaction in the mixed model comparing the treatment group with the UC comparison group.
[b] Square root transformed for analyses; squared means and SE presented this table.
[c] Log transformed for analyses; exponentiated means and SE presented this table

overweight adolescents showed decreased fasting insulin but no changes in BMI or adiposity.[30] A 12-month school-based intervention targeting overweight adolescents at risk for diabetes that used coping skills training had no effects on BMI or physical activity but did result in improvements in food choices and self-efficacy for physical activity.[31] Furthermore, our findings on sedentary behavior are in agreement with obesity prevention studies targeting youth who have suggested sedentary behavior to be more likely to improve than BMI, diet, or physical activity.[32] A website nutrition program was ineffective at increasing fruit and vegetable consumption among teens at risk for diabetes.[33] In a study of adolescents 13 to 16 years of age, addition of counseling calls and emails to a community-based intervention did not have an effect on weight loss, diet change, or increased physical activity.[34] Given that, in our study, physical activity, diet, BMI, or adiposity did not change suggests the need for more intensive interventions (e.g., integrating physical activity classes) for overweight adolescents with comorbidities related to risk for T2DM. A 12-month weight management family-based behavioral intervention program targeting overweight children that incorporated a workout routine as part of the intervention was more effective than receiving counseling provided by a dietitian and physician for reducing body weight, adiposity, insulin, and cholesterol.[35]

Despite the high risk for psychological morbidity in overweight adolescents,[6,7] the mean depression, self-esteem, and quality-of-life scores in our sample indicated good psychological health and were not associated with change in BMI or adiposity. However, we did find an inverse correlation in girls between depression and change in physical activity, consistent with other studies,[36,37] and positive correlations between physical functioning QOL and behavioral change strategies. These findings suggest that greater use of health behavior change strategies might be a means to improve psychological wellbeing and QOL, particularly among girls.

Limitations of the study included a high loss to follow-up at 12 months, a finding that is consistent with other research, suggesting higher attrition rates for youth in weight management programs and chronically ill[38] and in computer-based interventions.[39] Furthermore, the large decrease in participants who logged on to the web program over the 12 months in all intervention arms could indicate a decline in interest in the intervention and overall low exposure to the intervention, which could explain the failure to improve the main outcome measures. Diet, physical activity, and sedentary behavior data are based on self-report and thus may be inaccurate. This may be particularly the case for data from the food frequency questionnaire. For example, there was a relatively high report of fruit and vegetable servings per 1000 calories/day at baseline in our study. Given that the average reported at baseline of fruit and vegetable consumption was approximately two servings per 1000 calories/day, at 2000 calories, most adolescents in our study would be close to meeting the recommended five servings of fruits and vegetables per day. Another limitation is that the generalizability of the study findings may be limited to primarily Latino adolescents living in Southern California. Finally, because of the small number of participants per study arm, there was insufficient statistical power to detect study arm differences relative to the control arm on some secondary and exploratory outcomes even though changes on these outcomes were in the expected direction.

Conclusion

Our findings confirm results of other studies that intervening to reduce weight and prevent the onset of T2DM in adolescence is difficult and will require approaches that are different from and more intensive than those evaluated in this study. However, our findings of improved sedentary behavior with technology are promising and timely given increasing evidence of the association between sedentary behavior and morbidity and mortality in adults independent of physical activity.[40]

Funding:

This project (ClinicalTrials.gov identifier NCT00412165) was supported by Grant #5 R18 DK064321 from the National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD.

Disclosure:

Drs. Patrick, Calfas, and Sallis are co-owners of Santech Inc., which is developing products related to the research described in this article. The terms of this arrangement have been reviewed and approved by the University of California, San Diego, in accordance with their respective conflict-of-interest policies.

Acknowledgments:

We thank the physicians and clinic staff at Children's Primary Care Medical Group (South Bay Locations), Rady Children's Hospital of San Diego Pediatric Endocrinology Department, and Kaiser Permanente Pediatrics Department for assistance with recruitment of participants.

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