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Use of a Computerized Tracking System to Monitor and Provide Feedback on Dietary Goals for Calorie-Restricted Diets: The POUNDS LOST Study

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Abstract

The use of self-monitoring as a tool to facilitate behavioral modification is common in many lifestyle-based weight loss interventions. Electronic tracking programs, including computer-based systems and smart phone applications, have been developed to allow individuals to self-monitor their behavior digitally. These programs offer an advantage over traditional self-report modalities in that they can provide users with direct feedback about dietary and/or physical activity adherence levels and thereby assist them in real-time decision making. This article describes the use of an Internet-based computerized tracking system (CTS) that was developed specifically for the POUNDS LOST study, a 2-year randomized controlled trial designed to test the efficacy of four macronutrient diets for weight and fat reduction in healthy, overweight men and women (body mass index range = 25.0–39.9 kg/m^2). The CTS served many functions in this study, including data collection, dietary and exercise assessment and feedback, messaging system, and report generation. Across all groups, participants with high usage of the CTS during the initial 8 weeks lost greater amounts of weight than participants with low usage (8.7% versus 5.5% of initial body weight, respectively; $p < .001$) at week 32. Rates of CTS utilization were highest during the first year of this 2-year intervention, and utilization of the CTS declined steadily over time. The unique features of the CTS combined with technological developments, such as smart phone applications, offer significant potential to improve the user's self-monitoring experience and adherence to health promotion programs designed specifically for individuals with obesity and type 2 diabetes.

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Introduction

To combat the twin epidemics of obesity and type 2 diabetes mellitus,[1] effective strategies are needed to assist individuals in modifying their energy intake and expenditure in such a way that encourages weight loss or healthy weight management. Because weight gain results from a positive energy balance,[2] reduction in energy

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Abbreviations: (CTS) computerized tracking system, (PDA) personal digital assistant

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intake, or calorie restriction, is a primary treatment target, typically in conjunction with increased energy expenditure.[3,4] There is substantial research supporting the use of self-monitoring as a tool to facilitate behavioral modification in lifestyle-based weight loss interventions.[5,6] Traditionally, pen-and-paper methods have been employed as the modality through which individuals record their dietary intake and/or exercise behavior. Electronic tracking programs, including computer-based systems and smart phone applications, have been developed to allow individuals to self-monitor their behavior digitally.[7]

Most studies to date suggest that electronic tracking programs, when used solely as recording devices, are insufficient for improving weight loss outcomes above and beyond traditional self-report methods.[6–8] However, a unique feature that electronic tracking programs can offer is the ability to provide users with direct feedback regarding their level of dietary and exercise adherence. In these instances, electronic modalities may improve adherence levels over traditional self-report methods. For example, automated feedback about dietary intake and exercise goals was the single best predictor of weight loss in a 6-month study by Krukowski and colleagues[9] that tested the effects of an Internet-based behavioral weight loss treatment program. In addition, systems providing immediate on-screen feedback about progress toward behavioral goals have been found to improve overall adherence to dietary change and weight loss outcomes.[10–15] Similar to other self-report modalities, however, sustaining participant engagement or long-term utilization of computer-based tracking systems appears to be a significant challenge. For example, the SHED-IT study reported that only 41% of participants assigned to a 3-month Internet-based weight loss intervention met the designated minimum adherence criteria (i.e., ≥50 days of entry).[16]

Given their portability, reliability, and multiple functions, hand-held devices, such as personal digital assistants (PDAs) and smart phones, may have the potential to increase utilization of electronic tracking programs.[17–19] The newest and possibly most desirable element of smart phones is the capacity to download and install personal and professional applications that run directly on the phone. The popularity and increasing use of smart phones has made them one of the most important technologies since 2000. The average smart phone data usage nearly tripled from 55 MB of data per month in 2010 to 150 MB in 2011. By 2016, it is projected that smart phone data usage will exceed 2000 MB per month.[20]

Few studies have examined the utility of portable electronic recording devices for promoting behavior change and weight loss, and findings have been mixed. For example, Yon and associates[21] found no group differences in weight loss or frequency of self-monitoring among participants assigned to self-monitor their dietary intake through either traditional methods or PDAs. However, in another 6-month intervention study, the use of PDAs increased adherence to dietary self-monitoring significantly more than traditional paper diaries.[22] Moreover, adherence to self-monitoring was nearly double in the PDA plus feedback group as compared with the traditional self-monitoring group (60% versus 31%) during this intervention.[22]

This article describes the use of an Internet-based computerized tracking system (CTS) that was developed specifically for the POUNDS LOST study, a 2-year randomized controlled trial designed to test the efficacy of four macronutrient diets.[23–25] We examined the utility of such a system in an overweight sample to determine the potential advantages and disadvantages of a computer-based self-monitoring and feedback system for improving adherence to diet and physical activity, long-term weight loss outcomes, and other key health outcomes. Parts of this data have been published in abstract form.[26,27]

Method

General Description of the Computerized Tracking System

The Web-based CTS developed for use in the POUNDS LOST study was designed to serve three user groups: participants, counselors and other research staff, and investigators (steering committee). The CTS was hosted at Pennington Biomedical and served both intervention sites: Pennington Biomedical Research Center and Harvard School of Public Health. Data from the CTS were transmitted to the coordinating center at scheduled intervals.

The CTS served many functions, including data collection, dietary assessment and feedback, exercise assessment and feedback, messaging system between counselor and participants, and report generation for participants, counselors, and steering committee members. The CTS was available to all users of the system at any time of the day.

Development of the Computerized Tracking System

The CTS was developed over a time period of 1 year by a team of dietitians, health psychologists, and software developers. Each module (e.g., dietary records, physical activity records, session attendance, participant–counselor contact records, and reporting) had its own Web page or set of Web pages as well as online help within the CTS. Beta versions of the CTS were extensively tested by designated users at both intervention sites prior to deployment.

Participants and Study Design

Participants were 811 healthy, obese/overweight men and women (body mass index range = 25.0–39.9 kg/m^2) between the ages of 30 and 70 years who volunteered to participate in this 2-year study,[23] which was designed to test the efficacy of four macronutrient diets for weight and fat reduction and improvement of health parameters. Participants were instructed to follow their assigned diet for the entire 2 years of this clinical trial.

Detailed descriptions of participant characteristics, as well as inclusion and exclusion criteria for the POUNDS LOST study have been reported previously.[23] Participants were randomly assigned and stratified by gender to one of four dietary conditions: (1) low fat (20% of energy), average protein (15% of energy); (2) moderate fat (40%), average protein (15%); (3) low fat (20%), high protein (25%); or (4) moderate fat (40%), high protein (25%). All four dietary approaches were low in saturated fat and reduced in total energy intake based on the individual's dietary prescription. The first cohort began the trial in October 2004 and the last ended December 31, 2007, with recruitment occurring from December 2004 through December 2005.

This study was approved by the appropriate ethics committees and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All persons gave their informed consent prior to their inclusion in the study.

Overview of the Intervention and Primary Findings of the POUNDS LOST Trial

The POUNDS LOST intervention involved a combination of regularly scheduled group and individual sessions with the goal of providing all participants with similar educational exposure to nutrition and behavioral self-management skills for weight loss.[24] Following randomization to one of the four diets, each participant met individually with an interventionist (registered dietician). Before this individual visit, the interventionist calculated each participant's macronutrient goals and caloric prescription designed to promote a weight loss of approximately 1.5 lbs per week (0.7 kg/week).

Following the initial training session, participants were instructed to begin recording their food intake and exercise behavior in the CTS every day of this 2-year intervention. At each subsequent individual session, which occurred every 8 weeks following the start of the group-based intervention, counselors utilized the CTS to review adherence reports with the participants. Additionally, counselors were able to access the CTS in between sessions to review adherence levels of each of their assigned participants, as well as provide feedback regarding overall adherence or observed changes in adherence to each participant through the messaging system within the CTS. At each group session, counselors recorded each participant's body weight, measured by a calibrated scale, and session date into the CTS.

The primary results of the POUNDS LOST trial[23–25] showed that the macronutrient composition of the prescribed calorie-restricted diets did not affect changes in body weight, waist circumference, and other health outcomes between groups. Participants in each dietary condition lost an average of 6 kg, or 7% of their initial body weight, at month 6. Of the 80% of participants who completed the entire trial, the average weight loss across all dietary conditions was 4 kg at year 2.

Participant Module

Participants could enter data into the CTS from any computer connected to the Internet. Following data entry, the CTS automatically calculated kilocalories from fat, protein, and carbohydrate as well as total kilocalories using the U.S. Department of Agriculture nutrient database. The formula used to calculate percentage of deviation from macronutrient and calorie goals was the following: [(Actual value - Prescribed value)/Prescribed value] × 100. The procedure used to evaluate adherence to each dietary intervention for each individual participant was based on his or her unique caloric and macronutrient goals. Adherence to dietary goals was based on deviations from prescribed values (not percentages), and the macronutrient and caloric deviation scores were mathematically independent from one another.

At the end of each day, each participant was given feedback in the form of graphs about his or her dietary adherence (percentage of deviation from goal for kilocalorie, fat,

and protein; see **Figure 1**), exercise adherence (percentage of deviation from goal for prescribed exercise minutes), and changes in body weight. Approximately 1 year into the intervention, a decision was made to provide participants with feedback immediately upon entering a full meal at one of the sites (site 2). The change in the timing of feedback was made with the goal of improving system utilization. Participants at site 1 received feedback only at the end of the day throughout the entire study.

Counselor Module

Interventionists and other staff members entered data into the CTS each time contact was made with a participant at individual or group sessions or via telephone, email, or mail. The counselors also entered body weight (measured at intervention and groups sessions), attendance at group sessions, and intervention makeup sessions. Participant reports on session attendance, dietary adherence, deviations from adherence, minutes of physical activity, and weight loss were generated by the CTS for use by the counselors, the intervention committee, and the steering committee. **Table 1** shows entry and output of information in the CTS. These reports served as an important index of adherence to the diets and were used by the treatment team to provide feedback to the participants.

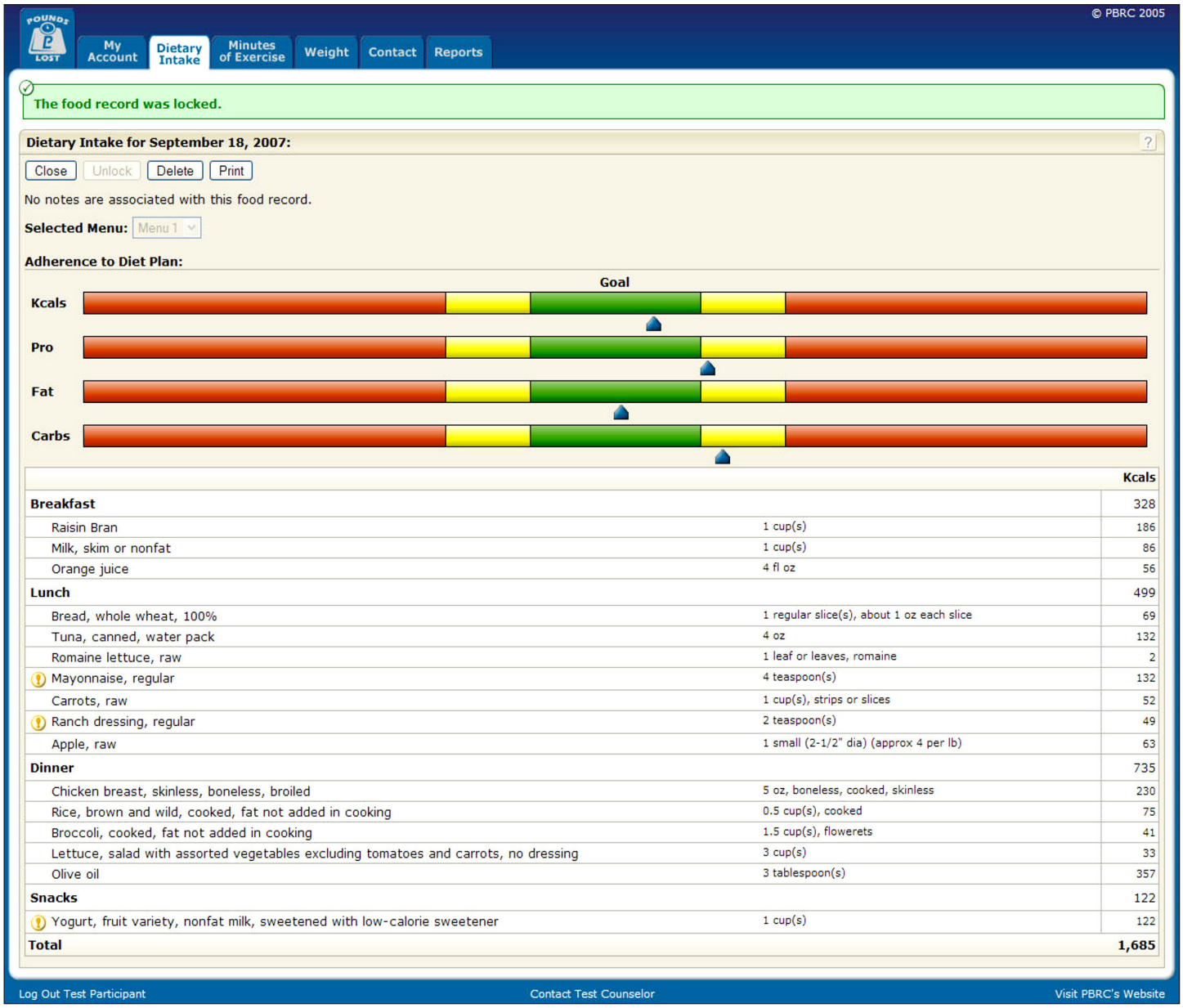

Figure 1. Feedback given to the participant after entering food intake into the CTS.

Assessment of Adherence

For the POUNDS LOST study, a number of indicators of adherence to the prescribed interventions were measured and automatically computed by the CTS: (1) attendance to individual sessions, (2) attendance to group sessions, (3) frequency of submitting dietary self-monitoring records, (4) frequency of submitting physical activity records, (5) deviation from total daily kilocalories goal, (6) deviation from daily protein goal, (7) deviation from daily fat goal, and (8) deviation from daily carbohydrate goal. To examine whether these adherence markers were capturing a unidimensional versus a multidimensional construct, Williamson and coauthors[24] conducted exploratory and confirmatory factor analyses. These analyses identified two factors that accounted for 66% of the variance: (1) behavioral adherence and (2) dietary adherence. Behavioral adherence was defined by attendance at individual and group counseling sessions and electronic entry of food records and exercise records into the CTS. In contrast, the dietary adherence dimension was defined by self-monitoring data related to deviation from caloric and macronutrient goals. Using these definitions of adherence, Williamson and coauthors[25] also found early behavioral adherence, but not dietary adherence, to be associated with changes in percentage of weight loss and waist circumference at 6 and 24 months.

Table 1.
Entry and Output of Information in the Computerized Tracking System

	Participant	Counselors	Steering committee
Input			
Body weight		✓	
Contact information	✓	✓	
Food intake	✓		
Number of days of food records		✓	
Physical activity	✓		
Number of days of physical activity records		✓	
Session attendance		✓	
Other notes		✓	
Output			
Attendance	✓[a]	✓[a]	✓[b]
Dietary adherence	✓[a]	✓[a]	✓[b]
Physical activity	✓[a]	✓[a]	✓[b]
Weight change	✓[a]	✓[a]	✓[b]

[a] By individual.
[b] By individual, cohort, and site (not by treatment group).

Messaging and Other Capabilities

Both the participant and the research staff had the ability to send messages using the CTS. Interventionists could send messages to an individual participant or all participants in their group, but participants could only contact their group leader through the CTS. Counselors could record data related to dietary adherence, attendance to group and individual sessions, and other relevant information in the form of progress notes in the CTS.

Blinding of Data

The information obtained through the CTS was considered process data; thus it was treated in a different manner than the outcome data. However, clear procedures were in place to ensure counselors and investigators were blinded to specific diet group results.

Statistical Methods

To examine the effects of CTS usage on short-term weight loss outcomes (week 32), the four randomized groups were collapsed to compare weight loss between baseline and week 32 for participants who had high versus low usage of the CTS during the early stages of the intervention. Low usage was defined as having no food record on a randomly selected day of the sampled week (week 8), and high usage was defined as having at least one food record on a randomly selected day of the sampled week. Usage was defined in this manner based on preliminary analyses, which indicated that 99% of participants who recorded food intake on a randomly selected day also recorded on another day during sampled weeks.[27] The weight loss outcomes presented at week 32 were based on weights obtained from participants at their week 32 session and thus represented process data collected by the CTS. Analysis of covariance was used to examine changes in percentage of weight loss between participants with low versus high usage of the CTS at week 32 with age, gender, race, baseline weight, dietary adherence, and behavior adherence included as covariates. Analyses of covariance were also used to examine the effects of demographic factors on long-term (24-month) weight loss outcomes with age, gender, race, dietary adherence, behavior adherence, and baseline weight again included as covariates. Since the primary results of the POUNDS LOST trial showed that the macronutrient composition of the prescribed calorie-restricted diets did not affect changes in long-term weight loss,[23] the data across all four dietary groups were combined for all analyses.

Results

System Utilization and Weight Change

Body weights were obtained on 478 participants at their week 32 group session; therefore, a total of 478 participants were included in this analysis. Of these 478 participants, 342 were classified as having high usage and 136 were classified as having low usage based on the definitions provided earlier. The key finding was that weight loss from baseline to week 32 was significantly greater for participants with high versus low usage of the CTS at week 8 (8.7% versus 5.5% of baseline weight; $F(5, 473) = 25.3$; $p < .001$).

Utilization of the Computerized Tracking System Over Time

Utilization of the CTS is shown for each of the sites in **Figure 2**. Initial utilization rates were high, ranging between 70% and 80% on average but declined steadily thereafter. Even within the first year of the intervention, the number of participants who recorded meals in the tracking system decreased significantly over time from 66% at week 8 to 26% at week 52. By the end of year 2, less than 10% of the participants at both sites reported using the system at least one time per week.

Effect of Increasing the Frequency of Feedback on Computerized Tracking System Utilization

The effect of increasing feedback frequency from daily to after each entry was tested by switching the timing of feedback at site 2. **Figure 3** presents rates of CTS utilization 6 weeks prior to the change in the timing of feedback from once a day to after each entry and 6 weeks after the change in the timing of feedback at both sites. The change in the timing of feedback did not appear to increase the frequency with which the CTS system was used.

Effect of Demographic Factors on Behavioral and Dietary Adherence

In line with previously reported results,[24,25] participants who had six or more completed food entries across the initial 6 months were included in these analyses ($N = 671$). The demographic variables of age, gender, and race (white/non-Hispanic or African-American) were found to affect levels of both behavioral and dietary adherence (**Table 2**). Specifically, older participants (age ≥ 52) reported higher levels of behavioral adherence but lower levels of dietary adherence than younger individuals. Men were also found to have higher levels of behavioral adherence than women but had similar levels of dietary adherence. Additionally, white/non-Hispanic participants had higher levels of behavioral adherence than African-American participants, but there was a trend for African-American participants to have higher levels of dietary adherence.

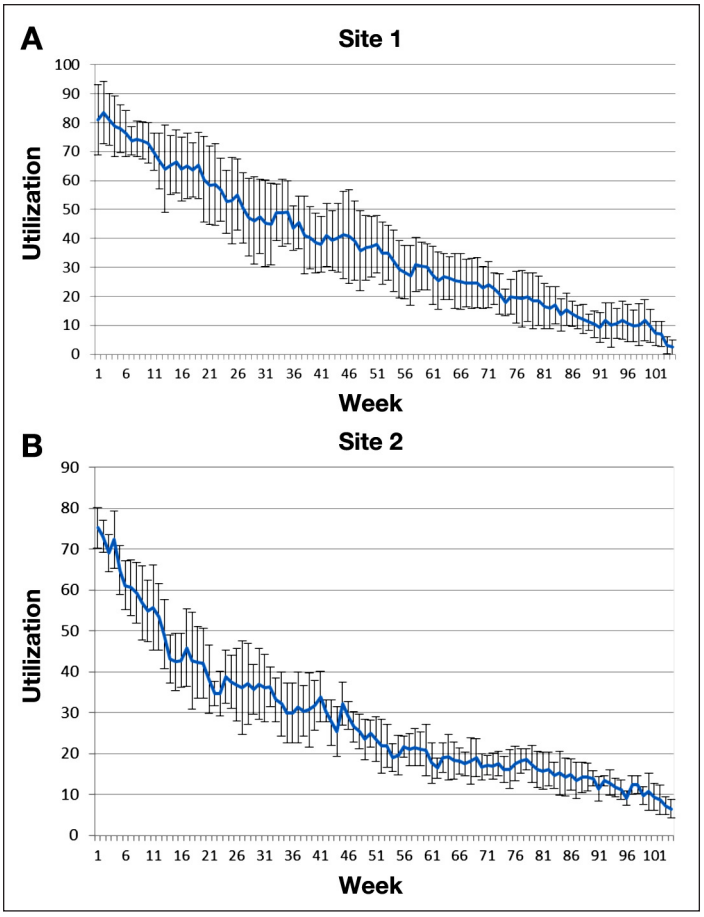

Figure 2. (A) System utilization defined as the percentage of participants who recorded their food intake in the CTS at least one time per week during the 2-year dietary intervention in the POUNDS LOST Study at site 1. This site maintained the methodology for provision of dietary feedback from the CTS at the end of each day throughout the study. The error bars represent the variations that occurred across the six cohorts. **(B)** System utilization defined as the percentage of participants who recorded their food intake in the CTS at least one time per week during the 2-year dietary intervention in the POUNDS LOST Study at site 2. This site changed the methodology for provision of dietary feedback so that feedback was provided after each meal instead of at the end of each day. The error bars represent the variations that occurred across the six cohorts.

Demographic Factors and Long-Term (24-month) Weight Loss Outcomes

A total of 671 participants were also included in these analyses. The demographic variables of age, gender, and race were found to affect weight loss outcomes (**Table 3**).[26] Specifically, older adults (age ≥ 52) lost a greater amount of weight than younger adults, though this difference was no longer statistically significant after accounting for

the effects of gender, race, baseline body weight, as well as levels of behavioral and dietary adherence. Men lost a significantly greater amount of weight than women, and the gender difference in weight loss remained significant after accounting for all covariates. White/non-Hispanic participants lost a greater amount of weight than African-American participants, but this difference was no longer statistically significant after accounting for all covariates.

Discussion

The present article describes the development and multiple functions provided by a CTS specifically designed for the POUNDS LOST trial. One of the key functions of the CTS was to obtain information about participant adherence. Using previously published definitions of adherence,[24] early behavioral adherence, but not dietary adherence, was associated with changes in percentage of weight loss and waist circumference at 6 and 24 months.[25] In the present study, use of the CTS to record food intake during the initial stages of the intervention was found to be directly related to weight loss over time. More specifically, participants with high levels of utilization lost almost twice as much weight during the first 8 months of the intervention as participants with low levels of utilization. Thus the findings of this study suggest that use of the CTS to record food intake directly affects weight loss outcomes. Rates of CTS utilization were highest during year 1 of this 2-year intervention but declined steadily over time.

The information collected by the CTS was also used to examine whether demographic differences in age, gender, and race affected long-term weight loss outcomes after accounting for levels of behavioral adherence, dietary adherence, and baseline body weight. Specifically, older adults lost more weight than younger adults, men lost more weight than women, and white/non-Hispanic individuals lost more weight than African-American individuals. These subgroups also had higher levels of adherence to the behavioral components of the treatment protocol. The subgroup differences in weight loss according to age and race were no longer present after levels of behavioral adherence were taken into account; however, the difference in weight loss between men and

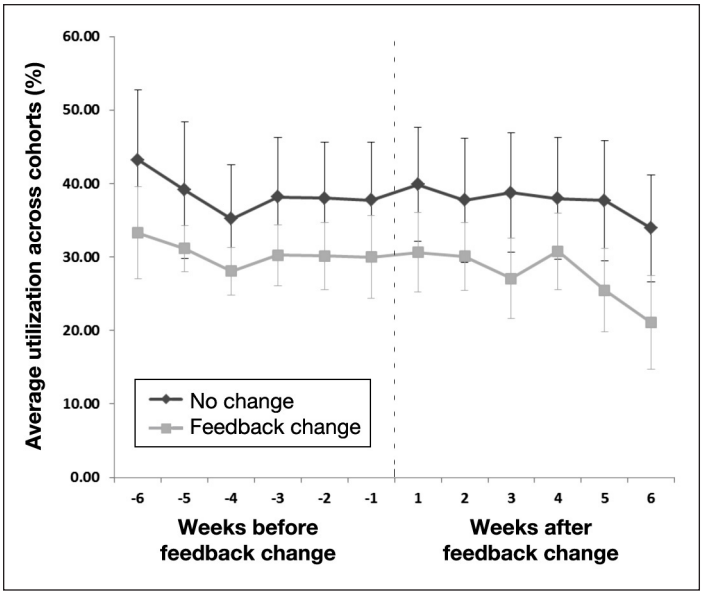

Figure 3. Utilization of the CTS at both sites before and after the change in the timing of dietary feedback. Specifically, site 2 (bottom line, "feedback change") changed the methodology for provision of dietary feedback so that feedback was provided after each meal instead of at the end of each day. Participants at site 1 (top line, "no change") received feedback only at the end of the day throughout the entire study.

Table 2.
Mean Differences in Behavioral Adherence and Dietary Adherence by Age, Gender, and Race

		Behavioral adherence			Dietary adherence		
	n	Mean	Standard deviation	*p* value	Mean	Standard deviation	*p* value
Age				0.001			0.006
≥52 years	326	47.5	21.0		59.7	41.0	
<52 years	345	54.6	19.1		50.8	42.7	
Gender				0.001			0.237
Male	252	55.8	19.4		52.7	43.3	
Female	419	48.3	20.4		56.6	41.3	
Race				0.001			0.063
White/non-Hispanic	579	52.5	19.9		53.9	40.7	
African-American	92	42.3	20.1		62.7	49.4	

women remained significant even after taking behavioral adherence levels into account.

One of the primary advantages of electronic monitoring systems, such as the CTS used in this study, offer over traditional pen-and-paper self-report diaries is that they enable users to receive immediate feedback about reported behaviors and dietary intake. The CTS used in the POUNDS LOST study offers additional features, such as assessment of key behavioral indicators of adherence and a report-generation system for multiple users that may not be available in many current applications. Thus multiple users were able to analyze and incorporate information obtained from the CTS to provide tailored messages to participants regarding their level of dietary and behavioral adherence. This type of feedback could be utilized by individuals with chronic diseases, such as obesity and type 2 diabetes, to enhance adherence to medical recommendations (e.g., monitoring of blood glucose levels).[28]

One of the disadvantages of the CTS was that it could only be accessed through a computer with an Internet connection. As a result, participants needed to record their dietary intake and physical activity behavior on more than one occasion (i.e., the time at which meals were consumed and the time in which data was entered into the system). This extra step may have contributed to the decline in system utilization, particularly as weight loss slowed or weight regain occurred. To try to overcome this potential limitation, we changed the timeframe in which participants received feedback at one site from the end of each day to the end of every entry. This change did not result in any noticeable increase in system usage (see **Figure 3**).

Advances in smart phone technology now provide a platform that can overcome this potential limitation. Future technological advances may also lead to programs that are capable of developing specific dietary options for each individual based on their previously recorded food intake patterns. These types of "intelligent" systems could revolutionize a user's experience with self-monitoring, such that interacting with such a system becomes engaging and fun rather than laborious and repetitive.

The present study had a number of strengths. First, the sample size used in the present study is much larger than the sample sizes used in previous studies examining the effects of electronic tracking systems on weight loss

Table 3.
Mean Differences in Weight Loss (kg) by Age, Gender, and Race.

	Age		F-value	df	*p* value
	≥52 (*n* = 326)	<52 (*n* = 345)			
	Mean (standard deviation)	Mean (standard deviation)			
Baseline weight (kg)	94.6 (15.2)	91.8 (15.3)	5.3	670	0.022
Month 24 weight (kg)	91.5 (16.3)	87.1 (15.2)	12.8	670	0.001
Weight loss, unadjusted	-3.1 (6.9)[a]	-4.7 (7.4)[a]	8.9	670	0.003
Weight loss, adjusted[b]	-3.4 (6.7)	-4.4 (6.7)	3.2	664	0.073
	Gender		F-value	df	*p* value
	Men (*n* = 252)	Women (*n* = 419)			
	Mean (standard deviation)	Mean (standard deviation)			
Baseline weight (kg)	104.2 (12.9)	86.5 (12.6)	307.0	670	0.001
Month 24 weight (kg)	99.0 (14.4)	83.4 (13.7)	195.6	670	0.001
Weight loss, unadjusted	-5.6 (8.9)[a]	-3.1 (5.8)[a]	0.1	670	0.752
Weight loss, adjusted[c]	-3.8 (7.8)	-4.0 (7.3)	13.9	664	0.001
	Race		F-value	df	*p* value
	White/non-Hispanic (*n* = 579)	African-American (*n* = 92)			
	Mean (standard deviation)	Mean (standard deviation)			
Baseline weight (kg)	93.1 (15.8)	93.6 (11.9)	0.1	670	0.758
Month 24 weight (kg)	88.9 (16.3)	91.5 (12.7)	2.2	670	0.141
Weight loss, unadjusted	-4.2 (7.4)[a]	-2.1 (5.3)[a]	6.8	670	0.009
Weight loss, adjusted[d]	-4.0 (6.7)	-3.3 (7.0)	0.9	664	0.339

[a] Weight loss significant at $p < .001$.
[b] Adjusted for gender, race, baseline body weight, behavioral adherence, and dietary adherence.
[c] Adjusted for race, age, baseline body weight, behavioral adherence, and dietary adherence.
[d] Adjusted for gender, age, baseline body weight, behavioral adherence, and dietary adherence.

outcomes. Second, the 2-year duration of the present study allowed for examination of both short-term and long-term weight loss outcomes. Third, the design of the POUNDS LOST study allowed for examination of differential effects on weight loss outcomes according to diet type. Moreover, participants were found to modify their dietary intake in line with dietary goals, and participant retention was high with 80% of enrolled participants completing the 2-year assessment. An additional strength of this study is the assessment of the impact of changes in the timing of dietary adherence feedback on CTS utilization. To our knowledge, this is the first study to examine this question empirically because the timing of dietary adherence feedback changed from the end of each day to the end of each meal at site 2 after year 1 but remained constant throughout year 2 at site 1.

The present study also had a few notable limitations. First, information about dietary compliance was obtained through self-report and thus may reflect inherent biases.[29] Second, the observed relationship between early CTS usage and later weight loss may not be a causal relationship, as other factors may be the cause of this association. A limited number of indicators of adherence (i.e., eight indicators) were used to comprise the two higher-order factors of behavioral adherence and dietary adherence. Finally, due to the progressive decline in CTS usage, the present study was only able to evaluate the effects of high versus low CTS usage on short-term (week 32) weight loss outcomes using process data obtained from the CTS.

In summary, the CTS designed for the POUNDS LOST study performed many functions, including data collection, dietary assessment and feedback, exercise assessment and feedback, messaging system between counselor and participants, and report generation for participants, counselors, and steering committee members. Participants who had high usage of the CTS during the initial stages of the intervention lost greater amounts of weight at week 32 than participants with low usage. Similar to other electronic self-monitoring systems, utilization of the CTS declined over time, and more frequent access to feedback did not alter the trajectory. Although the Web-based CTS described in this article was solely accessible through a computer, this system has the potential to be modified into a smart phone application, which could provide features beyond current smart phone applications. The unique features of the CTS combined with technological developments offer significant potential to improve the user's self-monitoring experience and adherence to health promotion programs specifically designed for individuals with obesity and type 2 diabetes.

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