TBM

ORIGINAL RESEARCH

A randomized feasibility pilot trial of a financial incentives intervention for dietary self-monitoring and weight loss in adults with obesity

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Abstract

Financial incentives could be used to improve adherence to behavioral weight loss interventions, increasing their effectiveness. This Phase IIb randomized pilot study evaluated the feasibility and acceptability of a study protocol for providing financial incentives for dietary self-monitoring and/or weight loss. Community-dwelling adults with obesity were enrolled in a 24 week, group-based weight loss program. Participants were randomized in a 2 × 2 factorial design to receive financial incentives for both dietary self-monitoring and weekly weight loss, just one, or neither. Participants could earn up to $300, evolving from fixed weekly payments to intermittent, variable payments. The notice of reward was provided by text message. The study was conducted in three successive cohorts to evaluate study procedure changes, including dietary approach, recruitment and retention strategies, text messaging, and incentives. Descriptive statistics calculated separately for each cohort described study performance relative to predefined targets for recruitment, including minority representation; retention; adherence; and weight loss. Acceptability was assessed via postintervention qualitative interviews. In Cohort 1 (n = 34), a low-carbohydrate diet was used. Recruitment, retention, adherence, and weight loss were adequate, but minority representation was not. For Cohort 2 (n = 31), employing an additional recruitment method and switching to a reduced-calorie diet yielded adequate recruitment, minority representation, retention, and adherence but less weight loss. Returning to a low-carbohydrate diet in Cohort 3 (n = 28) yielded recruitment, minority representation, retention, adherence, and weight loss similar to Cohort 2. Participant feedback informed changes to text message timing and content and incentive amount. Through successive cohorts, we optimized recruitment and retention strategies and text messaging. An adequately powered trial is warranted to evaluate the efficacy of these incentive structures for reducing weight. The trial registration number is NCT02691260.

Keywords

Obesity, Financial incentives, Randomized trial, Text messaging

Implications

Practice: Incentives for dietary self-monitoring, weekly weight loss, or both could be used to improve adherence to evidence-based weight management programs.

Policy: Employers and payers who wish to incentivize health behavior should adopt scalable, evidence-based programs to increase adherence to health lifestyles.

Research: An adequately powered randomized controlled trial is needed to determine the relative effectiveness of incentivizing dietary self-monitoring or weekly weight loss, or both.

INTRODUCTION

More than one-third of adults in the USA have obesity (i.e., body mass index [BMI] of at least 30 kg/m^2) [1]. Obesity contributes to cardiovascular disease risk factors, such as hypertension and diabetes [2]. Numerous randomized controlled trials (RCTs) have evaluated the efficacy of behavioral weight loss interventions that prescribe changes to dietary intake and/or increased physical activity along with behavior change techniques, such as dietary self-monitoring and goal setting. These interventions have yielded an average weight loss of 5%–8% over 6 months [3] and decreased the incidence of Type 2 diabetes by more than half after 3 years [4]. Consequently, the 2013 Guideline for the Management of Overweight and Obesity in Adults recommends behavioral treatment as first-line therapy for adults with obesity, with a sustained weight loss of 3%–5% as a treatment goal [5].

Although behavioral interventions yield clinically significant weight loss on average, the variability in adherence to these interventions [6] contributes to variability in their effectiveness, including: some people lose too little weight to yield improvements in clinical parameters; some do not lose weight; and some even gain additional weight. Furthermore, there is variability in obesity rates and intervention outcomes by race/ethnicity. Black and Latinx American adults have higher rates of obesity than non-Hispanic White adults [7] and tend to be underrepresented in weight loss studies, engage in

fewer weight loss behaviors [8, 9], have lower rates of intervention adherence, and experience lower average weight loss [9–11]. For these reasons, it is important to ensure the representation of these racial/ethnic minority groups in weight loss studies. To improve the proportion of people who achieve clinically significant weight loss, novel behavioral strategies are needed to improve intervention adherence. One potential solution is to apply the principles of operant conditioning.

Operant conditioning

Operant conditioning refers to the process of learning voluntary behavior. Operant conditioning is rooted in Edward Thorndike's Law of Effect, which states that behavior is altered in strength by its consequences [12, 13]. Thus, if an action is followed by a desired outcome, then the likelihood of that behavior being repeated increases; in contrast, if an action produces an undesirable outcome, then the likelihood of it being repeated decreases. Operant conditioning can occur via reinforcement (establishing a behavior pattern) or punishment (reducing a behavior pattern) [14]. Both reinforcement and punishment may be positive (provision of a stimulus) or negative (removal of a stimulus). Reinforcement (and punishment) may be delivered on different types of schedules. A continuous reinforcement schedule involves the provision of a reward after every performance of the desired behavior. In contrast, an intermittent schedule involves the provision of a reward after either a certain number of responses (ratio interval) or a certain amount of time (interval ratio). Intermittent schedules can be characterized as either fixed (delivered after every n responses or time) or variable (delivered after a mean of n responses or time). Following the withdrawal of a reinforcer, the response rate typically declines, a process referred to as extinction. Although continuous schedules lead to an early, steady rate of responding, intermittent schedules may be preferable because they are more economical (i.e., because a reward is not provided after each instance of the desired behavior) and produce behavior that is more resistant to extinction [15].

In addition to quality/quantity, reinforcement timing is critical. Humans can perceive a contingent relationship between a desired response and a delayed reward. Yet, across populations and reward types, the further the reward is provided from the occurrence of the desired response, the less its perceived present value [16]. For example, when people are presented with the option of receiving a small amount of money immediately versus a large amount later, they tend to prefer the smaller, immediate reward [17]. This phenomenon is referred to as delay discounting [18].

Researchers have applied these principles to shape human health behavior. For example, researchers have tested whether the provision of financial incentives in the form of cash or material items increases smoking cessation [19], abstinence from alcohol or illicit substances [20], and medication adherence [21]. These applications have involved the comparison of reinforcement schedules (e.g., a guaranteed reward for achieving the desired outcome [fixed ratio] vs. the chance of receiving a reward via lottery [variable ratio]), positive versus negative reinforcement (e.g., receiving money vs. having money taken away via a deposit contract or payroll deduction [22]), amount and type of incentive [23], and whether rewards are contingent on individual versus group performance [24, 25]. Overall, these approaches have shown that reinforcement can increase short-term desired behavior.

Financial incentives for weight loss

The principles of operant conditioning have been applied to improve short-term and long-term weight loss in research studies and implemented in real-world programs. For example, employers and payers have offered financial incentives of various forms (e.g., vouchers for goods and insurance premium discounts) for weight loss [26–28]. Such programs are being implemented even without a strong evidence base to inform the optimal incentive structure.

In designing financial incentive programs, one issue is whether to use positive or negative reinforcement. The two typically have not been compared head-to-head. Most RCTs have used negative reinforcement, where nonadherent participants lose money [22, 25, 29, 30]. One significant drawback to negative reinforcement is that individuals with lower incomes may be unable to "buy into" such programs or may suffer disproportionately if they enroll but fail to lose weight. Thus, positive-reinforcement programs may be preferable. Accordingly, in this study, we are utilizing positive reinforcement.

A second design issue concerns incentive type. Earlier RCTs involving positive reinforcement used gifts or lotteries as incentives [31–33]. These incentive types are limited because gifts are differentially valued and lotteries do not guarantee a reward. Money may be preferred because it can be exchanged for valued goods and services. Accordingly, in this study, we are utilizing a cash equivalent (i.e., money uploaded to a debit card).

A third design issue—and one that is being investigated in this study—is whether to incentivize the desired clinical outcome of weight loss or a behavioral skill that supports weight loss. Dietary self-monitoring is one of the strongest predictors of initial weight loss and subsequent weight loss maintenance [34]. Incenting weight loss alone may not ensure that dietary self-monitoring will be learned because less enduring behavioral strategies, such as extreme caloric restriction, might be used.

Similarly, incenting dietary self-monitoring alone may not ensure that sufficient weight loss will be achieved, as people may exceed caloric or macronutrient recommendations even as they record their intake. We anticipate that incentivizing both initial weight loss and dietary self-monitoring will yield better initial weight loss than incentivizing just one. To our knowledge, no study has incentivized these two outcomes individually and jointly using positive reinforcement.

Study goals

Our long-term objective is to determine whether providing positive reinforcement via monetary incentives for weight loss and/or dietary self-monitoring improves the proportion of people who achieve clinically significant weight loss. Previous studies utilizing this approach are inadequate to inform the implementation of such programs for several reasons. First, some studies have incentivized weight loss and self-monitoring simultaneously, making it impossible to evaluate the unique and joint contributions of incentives for them [35, 36]. We overcome this limitation by employing a 2 × 2 design to evaluate the effect of incentivizing them individually and jointly. Second, some studies incentivized final weight loss or weight loss at infrequent intervals. Additionally, these studies had a gap between the desired behavior and incentive, which may cause participants to discount the value of incentives (e.g., [23, 37]). We overcome these limitations by incentivizing weekly weight loss and providing incentives in near real time. To do so, we utilized a software solution that collates data from a dietary smartphone application (app) and a cellular body weight scale [38, 39]. The software includes preprogrammed algorithms that analyze the data each week to determine whether participants meet the criteria to receive a financial incentive. Notice of reward is provided via text message, and credit is uploaded to a MasterCard the next day.

In preparation for an adequately powered RCT to evaluate the effectiveness of various incentive strategies for improving short- and long-term weight loss, we conducted a Phase IIb randomized pilot study per the Obesity-Related Behavioral Intervention Trials (ORBIT) model of intervention development [40]. The goals of this pilot were to: (a) assess the feasibility and acceptability of the trial protocol, as assessed by screening-to-enrollment ratio, dropout, and retention rates for all conditions and postqualitative interviews, and (b) seek evidence of a clinically significant signal over noise, indicated by weight loss in the intervention conditions compared to control condition and nondifferential dropout in the control condition. In this report, we provide the methods and results of our Phase IIb randomized pilot study.

METHODS

Design

Participants were randomized in a 2 × 2 factorial design to receive financial incentives for both dietary self-monitoring and weekly weight loss, just one, or neither. We conducted this study in three successive cohorts to evaluate study procedure changes. In each cohort, four weight loss groups were created, one corresponding to each condition. Also, in each cohort, participants in all four conditions received the same 24 week, group-based weight loss program; the only difference between conditions was the incentive structure: Participants could earn incentives for both dietary self-monitoring and weekly weight loss, just one, or neither. In the three incentive conditions, participants could earn the same amount per week (up to $30).

Setting, study population, and recruitment

The study was conducted at Duke University Medical Center in Durham, NC, where approval was received from the institutional review board. The first participant was recruited in May 2016, enrollment was completed in September 2017, and the final outcome assessment occurred in April 2018.

Adults with obesity were recruited from Durham, NC, where 57% of inhabitants are non-White and the obesity prevalence is nearly 30% [41]. We placed print advertisements in the community and were contacted by people who saw our entry in clinicaltrials.gov. Interested individuals called study staff to receive a brief overview of the study, complete telephone screening, and schedule an individual screening visit to confirm eligibility and provide written informed consent. The consent form indicated which dietary approach participants would be following and that participants would be randomized to receive different text messages about weight loss. The consent did not specifically mention the presence or absence of financial incentives.

We determined eligibility via a combination of telephone and in-person screening. We have reported eligibility criteria [38]. Briefly, inclusion criteria included age 18–70 years, BMI ≥30 kg/m^2, and possession of a smartphone with data and texting plan. Exclusion criteria included pregnancy, breastfeeding, or lack of birth control if premenopausal; recent weight loss; medical conditions that may affect weight; and baseline weight >380 lbs due to the upper limit of the BodyTrace cellular scales provided to participants.

Randomization

Eligible persons were randomized with equal allocation to one of four conditions using a computer-generated randomization sequence that a statistician created and uploaded to the study Research Electronic Data Capture (REDCap) database [42]. At the end of the screening visit, study

personnel accessed the allocation assignment, which provided the group meeting day and time but no information about the incentive structure. We considered participants as randomized if they provided a baseline weight at the beginning of the first group session. At that session, participants in the three incentive conditions learned that they could earn incentives and were provided with the criteria they would need to meet to receive them. Participants in the control condition were not told that other groups could earn incentives.

Behavioral weight loss program

We delivered the incentives intervention alongside a standard, 24 week weight loss program that is delivered in groups in person [43]. We use a highly efficacious weight loss program so that any lack of effect of incentives on weight loss could be attributed minimally to the weight loss program. The program involved biweekly group sessions that lasted 1–1.5 hr. Each group met on the same day of the week and at the same time of the day. A registered dietitian led the meetings.

One goal of this pilot study was to determine the optimal dietary approach for a future RCT. We considered both a low-carbohydrate diet (LCD) and a reduced fat and calorie diet (or low-fat diet, LFD) because RCTs have shown similar 24 month outcomes for each [44]. We prescribed an LCD in two cohorts and an LFD in the other. For the LCD, carbohydrate intake was restricted to 20 g/day, but there was no caloric prescription [45]. For the LFD, total fat intake was restricted to less than 30% of daily energy intake, and saturated fat was restricted to less than 10% of daily energy intake. We provided each LFD participant with an individualized calorie budget, which we calculated by subtracting 500 calories per day from the maintenance energy requirement using sex and weight obtained at the screening visit. Regardless of the dietary approach, all participants were asked to enter all food and liquid intake into MyFitnessPal. LCD participants were instructed to monitor their daily carbohydrate intake, whereas LFD participants were instructed to monitor their daily caloric and fat intake, in the app.

At the first meeting, staff provided participants with a lay press diet book (corresponding to LCD [46] or LFD [47]), handouts developed in a previous weight management RCT [48], and a BodyTrace scale. Participants downloaded the MyFitnessPal mobile phone app to their smartphones and set up accounts (with assistance if needed). They also received instructions about how to use the scales at home (e.g., lay it on a flat, uncarpeted surface and tap lightly to zero it out before weighing).

At every meeting, study personnel recorded participant weights upon arrival for all three cohorts and blood pressure readings for the LCD cohorts. They also provided participants with handouts relevant to the session topic. The dietitian provided didactic diet instruction and review of behavioral weight loss strategies (for further detail, see [38]). We did not provide individual meal plans. Rather, participants were encouraged to apply the principles to alter the preparation and/or portion sizes of foods they typically eat. At the first group session and at an individual study visit at 25 weeks, study staff obtained weight on a study-provided scale in light clothing with shoes removed.

In the last two group meetings, we asked participants to sign up for a time for their 25 week outcome assessment. For all cohorts, we mailed a reminder letter for their outcome assessment appointments. We offered participants the choice of whether to keep the BodyTrace scale (worth approximately $85) or receive $25 on their MasterCard for completing the 25 week assessment. At the 25 week assessment visit, we asked participants if they would be willing to complete a telephone interview about their study experience, for which we paid $25. We purposefully selected interviewees to represent all cohorts, conditions, and participants who did and did not achieve clinically significant weight loss of ≥5%. We audio recorded the interviews and took notes in a structured template to facilitate rapid analysis and changes to the protocol between cohorts.

Incentive structure

The incentive schedule was informed by the aforementioned operant conditioning principles and applied to participants in the three incentive conditions only. In the first 4 weeks, we used a fixed reinforcement schedule in which participants could earn $10 each week. For the remaining 20 weeks, we used an intermittent reinforcement schedule in which participants could earn $0–$30 each week; the amount varied and was unknown and unpredictable to participants. The total amount that could be earned across the study was $300 per participant. Based on previous studies [23, 37, 49], these amounts were considered sufficient to motivate behavior change but not so large as to seem coercive. The weekly amount that participants could earn was the same in all three incentive conditions so that any advantage of the combined condition could not be attributed to receiving more money. However, if those in the combined condition fulfilled only one of the two criteria, then they received half the incentive. We paid participants within 1 day of earning an incentive to minimize the delay of incentive receipt.

Across all four conditions, and across both dietary approaches, we provided identical instructions for participants to log all food and liquid intake in MyFitnessPal and to self-weigh regularly using the BodyTrace scales. In the combined and dietary self-monitoring conditions, females had to log at least 1,000 kcal and males 1,200 kcal on at least 5 days per week, including one weekend day, to qualify for

an incentive. These amounts are less than the daily caloric prescription that we provide to participants and allow for the possibility that participants do not log everything they eat. A previous study indicated that the process, rather than the amount, of calorie tracking is most important [50].

Although we encouraged participants to weigh themselves every day, we indicated that they needed to provide a minimum of two weights per week so that we could calculate the weekly weight loss. We also encouraged them to weigh themselves at the beginning and end of the week so that measurements would be more likely to reflect weight loss than if measurements were on two consecutive days. We calculated the weekly weight loss by taking the difference between the first and last recorded weights of each week. To qualify for an incentive, weight loss had to be >0 lb in any week. Although we encouraged people to have a weekly weight loss goal of 1–2 lbs, actual weight loss may not be linear. Reinforcing any amount >0 allows for natural variability in which weight loss is greater for some weeks than others. There is also a possibility of gaming the system (e.g., by having other individuals stand on the scale). Thus, we compared weights obtained by BodyTrace scales to those obtained on the same day at group sessions and found 98% correspondence.

Dietary and weight data were obtained from MyFitnessPal and BodyTrace scales' application programming interfaces (APIs) using a Duke-developed software system called "Prompt." Prompt connected each participant's unique study identification code with the participant's MyFitnessPal account and BodyTrace scale ID. We preprogrammed over 100 algorithms in Prompt to analyze data each week to determine who met incentive criteria each week[39]. On Day 1 of each week (starting in Week 2), corresponding to the day of their group session, participants received a text message indicating the amount they earned or could have earned the previous week. The text message encouraged participants to self-monitor and self-weigh. A staff member selected the appropriate prewritten text message to send to each participant each week. Study staff then scheduled the payment, which was uploaded on a reloadable MasterCard provided at the first group session, usually within 24 hr.

Data sources

One goal of this Phase IIb randomized pilot study was to assess the feasibility and acceptability of the trial protocol, which we accomplished using mixed methods [51, 52]. We investigated: (a) recruitment methods and rates, including minority representation, (b) retention rates, (c) intervention adherence rates, and (d) reactions to the incentives structure, text messages, and retention letter. Relevant recruitment data included the total number of persons screened by telephone and in person, reasons provided for nonparticipation, and participant race and ethnicity, all recorded in REDCap. We aimed for a screening-to-enrollment rate of at least 25%.

We recorded data on attempts to schedule outcome assessment visits, reasons for nonattendance (if provided), reschedule attempts, and attendance at the outcome assessment visit. We aimed to obtain final outcome assessments for 80% of participants who provided a baseline weight because this criterion is common in weight management studies (e.g., [43]).

For intervention adherence, Prompt collected data from the APIs on the number of daily calories logged in MyFitnessPal, each weight recorded on BodyTrace scales, and the corresponding dates. These data allowed us to examine how often participants recorded a sufficient number of calories to qualify for an incentive, how often they weighed themselves at least twice per week to enable the calculation of weekly weight loss, and how often they met the criteria to earn an incentive. To isolate the impact of incentives on weight loss, it is important to have high fidelity to the weight loss program. We recorded session attendance and completed fidelity checklists for each session.

Qualitative interviews addressed participants' experiences in the group sessions, with the BodyTrace scales and MyFitnessPal, with the incentive structure, and with text messages. We have reported participant experiences with the scales and tracking app [39]. Following a structured interview script, we asked participants in the three incentive conditions to describe how the incentives affected their motivation to lose weight, their likelihood of self-weighing and recording their dietary intake, and how they reacted to the uncertainty about the amount of incentive they would receive each week. We asked participants in all conditions about their reactions to the text messages, including how the messages affected their weight loss efforts and motivation to adhere to the diet, and about the timing and frequency of the messages. We also asked about reactions to the retention letter, including the pictograph.

A second goal of this Phase IIb randomized pilot study was to seek evidence of a clinically significant signal over noise. Weight loss was calculated as the difference between the baseline weight obtained at the first group session and the Week 25 weight obtained at an individual outcome assessment visit. Our primary outcome was the proportion of participants achieving a clinically significant weight loss of ≥5%. We aimed to have ≥35% of participants lose ≥5% of baseline weight in each condition. This prevalence of weight loss is considered clinically significant, as it is required for Federal and Drug Administration approval of weight loss medications [53]. We expected a greater proportion of people to lose ≥5% of baseline weight in the three incentive conditions

compared to the control condition, although we did not have an a priori effect size criterion. We also expected nondifferential dropout in the no-incentives condition.

Data analysis

The a priori design of this pilot study was to analyze data after the completion of each cohort and use our observations to guide changes to the subsequent cohort, with the ultimate goal of determining the feasibility and participant acceptability of our strategies and processes. Following best practices for analyzing data from a pilot study,[54] we conducted descriptive rather than inferential statistics for each cohort. This approach is consistent with the ORBIT model of intervention development [40]. Recruitment and minority representation rates, retention rates, intervention adherence rates, and weight loss were represented by quantitative data. We calculated means and standard deviations for continuous variables and proportions for categorical variables. Available sample sizes are provided for each measure, thus indicating the level of data missingness. We defined the screening-to-enrollment ratio as the proportion of people who consented out of those for whom telephone screening was attempted. We defined the retention rate as the proportion of participants who provided a weight at the Week 25 individual study visit of those who provided a baseline weight at the first group session. Using baseline and 25 week weights, we calculated summary statistics on weight loss, percentage of weight loss, and the proportion of participants who achieved a clinically significant weight loss ≥5%. For the estimation of weight loss at 25 weeks, we assumed that missing data (15%–19%) were missing at random (MAR). As such, the missingness probability could depend on a randomized condition and/or baseline weight but, within such strata, it would be random from person to person. Under MAR assumptions, our estimates and confidence intervals are unbiased and consistent.

Acceptability was assessed via postqualitative interviews with a subset of participants representing each condition, each cohort, and whether they achieved weight loss ≥5%. The qualitative data were content analyzed. Two investigators generated a priori codes corresponding to domains contained in the interview guide (e.g., reactions to incentives and reactions to text messages). A single investigator applied the coding scheme to each interview summary. The two investigators then reviewed and summarized data from each code.

Our a priori target sample size of 32 per cohort (8 per condition) was based on the feasibility of executing the study within the budget and funding period. A sample size of 10 per cohort was considered sufficient for obtaining informational redundancy.

RESULTS

Feasibility and acceptability of the trial protocol

Recruitment and minority representation

Supplementary Fig. 1 presents the CONSORT flow diagram for each cohort. The recruitment rates were 42%, 32%, and 23% for Cohorts 1, 2, and 3, respectively, with an overall rate of 27%. Table 1 presents the sample size used in analyses by cohort and condition. Our aim was to achieve racial diversity that is representative of the community from which we recruited. Table 2 presents demographic data by cohort for participants who provided a baseline weight at the first group session. Cohort 1 was obtained by placing flyers in the community, at the medical center, on the Facebook South Durham Parents' Group, on study team members' personal Facebook accounts and in the *Indy Week*, a free publication available in public spaces. Cohort 1 was 24% non-White. In Cohorts 2 and 3, we retained all methods but substituted the *Indy Week* advertisement with an advertisement in *The Carolinian*, a free publication targeting the Black American community that is available in public spaces. These methods resulted in more racially diverse samples in Cohorts 2 and 3 (48% non-White in Cohort 2 and 39% non-White in Cohort 3). Other notable differences between cohorts were a lower proportion of married individuals in Cohorts 2 and 3 and a slight downward shift in education level and income in Cohort 3. Table 3 shows demographic characteristics by study arm. As would be expected by randomization, characteristics were similar across arms.

Retention

In all cohorts, we attempted to maximize retention for the outcome assessment visit by asking participants to sign up for an individual outcome assessment appointment time during the last three group sessions. Participants who did not attend these sessions received telephone calls and a letter asking them to schedule their appointments. We enhanced the retention letter for Cohort 3 with a figure displaying the potential for bias if only participants

Table 1 | Sample size by condition and cohort

Condition	Cohort 1	Cohort 2	Cohort 3
Incentives for weight loss and self-monitoring	6/7	7/9	7/7
Incentives for self-monitoring only	6/8	8/9	6/8
Incentives for weight loss only	7/8	8/9	7/8
No incentives for weight loss or self-monitoring	8/8	8/8	8/8

Numbers are shown with *x*/*y*, where *x* = analyzed and *y* = randomized.

Table 2 | Baseline characteristics by cohort

	Cohort 1 (*n* = 34)	Cohort 2 (*n* = 31)	Cohort 3 (*n* = 28)
Age, *M* (*SD*)	49.67 (12.47)	47.06 (13.52)	47.32 (13.07)
Weight, *M* (*SD*)	234.44 (44.58)	251.23 (45.80)	231.00 (46.24)
BMI, *M* (*SD*)	38.93 (7.18)	40.45 (7.04)	37.30 (6.44)
Female sex, *n* (%)	30 (88.24%)	26 (83.87%)	24 (85.71%)
Race, *n* (%)			
White	25 (73.53%)	16 (51.61%)	17 (60.71%)
Black or African American	4 (11.76%)	14 (45.16%)	9 (32.14%)
Asian	0 (0.00%)	1 (3.23%)	0 (0.00%)
Native American or Alaska Native	1 (2.94%)	0 (0.00%)	0 (0.00%)
More than one race	4 (11.76%)	0 (0.00%)	2 (7.14%)
Hispanic or Latino ethnicity, *n* (%)	0 (0.00%)	1 (3.23%)	1 (3.57%)
Marital status, *n* (%)			
Single, never married	3 (8.82%)	9 (29.03%)	9 (32.14%)
Married or partnered	24 (70.59%)	15 (48.39%)	12 (42.85%)
Divorced or separated	5 (14.71%)	5 (16.13%)	5 (17.86%)
Widowed	2 (5.88%)	1 (3.23%)	2 (7.14%)
Education level, *n* (%)			
High school graduate or equivalent	0 (0.00%)	2 (6.45%)	1 (3.57%)
Posthigh school education, no degree	6 (17.65%)	6 (19.35%)	5 (17.86%)
Associate's or bachelor's degree	16 (47.06%)	12 (38.71%)	15 (53.57%)
Postgraduate work or graduate degree	12 (35.29%)	11 (35.48%)	7 (25.00%)
Income, *n* (%)			
Less than $30,000	3 (8.82%)	4 (12.90%)	4 (14.29%)
$30,000–$59,999	6 (17.65%)	9 (29.03%)	9 (32.14%)
$60,000 or more	21 (61.76%)	15 (48.39%)	13 (46.43%)
Number of people supported by salary, *n* (%)			
1	10 (29.41%)	10 (32.26%)	14 (50.00%)
2	10 (29.41%)	7 (22.58%)	7 (25.00%)
3	6 (17.65%)	5 (16.13%)	3 (10.71%)
4	5 (14.71%)	3 (9.68%)	2 (7.14%)
5+	3 (8.82%)	3 (9.68%)	2 (7.14%)
Financial stress level, *n* (%)			
After paying bills, still have enough for special things	23 (67.65%)	20 (64.52%)	17 (60.71%)
Enough to pay bills but little spare for special things	9 (26.47%)	8 (25.81%)	7 (25.00%)
Enough to pay bills because cut back on things	1 (2.94%)	3 (9.68%)	3 (10.71%)
Difficulty paying bills no matter what	0 (0.00%)	0 (0.00%)	1 (3.57%)
Employment status, *n* (%)			
Working full time	20 (58.82%)	21 (67.74%)	15 (53.57%)
Working part time	5 (14.71%)	2 (6.45%)	8 (28.57%)
Unemployed, searching for work	0 (0.00%)	2 (6.45%)	1 (3.57%)
Unemployed, not searching for work, retired, or disabled	8 (23.53%)	6 (19.35%)	4 (14.29%)

Missing data: ethnicity (*n* = 1 in Cohort 1); marital status (*n* = 1 in Cohort 2); income (*n* = 4 in Cohort 1, *n* = 3 in Cohort 2, and *n* = 3 in Cohort 3); number of people supported by salary (*n* = 3 in Cohort 2); financial stress (*n* = 1 in Cohort 1); and employment status (*n* = 1 in Cohort 1).
BMI body mass index; *SD* standard deviation.

who achieved weight loss returned for outcome assessments [55]. We met our target of 80% retention for all three cohorts (85%, 81%, and 82%, respectively, for Cohorts 1–3). Across cohorts, retention rates were 87%, 86%, 79%, and 79% for the *combined*, *dietary self-monitoring*, *weight loss*, and *no-incentive* conditions, respectively. Among the 16 (of 93) participants who were not retained, 2 were male, 7 were White, 7 were Black, and 2 identified with more than one race.

Intervention adherence

Table 4 shows data representing various aspects of intervention adherence. Participants attended more than half of group sessions across cohorts and conditions, with slightly lower attendance in the *no-incentives* condition for Cohorts 1 and 3. We learned from postintervention qualitative interviews and informal feedback to the interventionist that nonattendance by a few people had a snowball effect, resulting in

Table 3 | Baseline characteristics by condition

	Incentives for weight loss and self-monitoring (*n* = 23)	Incentives for self-monitoring only (*n* = 22)	Incentives for weight loss only (*n* = 24)	No incentives for weight loss or self-monitoring (*n* = 24)	Total (*N* = 93)
Age, *M* (*SD*)	45.00 (11.84)	50.64 (15.35)	47.04 (11.30)	49.67 (13.13)	48.06 (12.93)
Weight, *M* (*SD*)	242.35 (50.32)	233.23 (44.65)	241.21 (46.30)	238.88 (44.43)	239.00 (45.8)
BMI, *M* (*SD*)	40.43 (7.97)	37.94 (7.14)	38.24 (6.54)	39.16 (6.31)	38.95 (6.96)
Female sex, *n* (%)	23 (100.00%)	18 (81.82%)	19 (79.17%)	20 (83.33%)	80 (86.02%)
Race, *n* (%)					
White	16 (69.57%)	16 (72.73%)	12 (50.00%)	14 (58.33%)	58 (62.37%)
Black or African American	6 (26.09%)	5 (22.73%)	10 (41.67%)	6 (25.00%)	27 (29.03%)
Asian	0 (0.00%)	1 (4.55%)	0 (0.00%)	0 (0.00%)	1 (1.08%)
Native American or Alaska Native	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (4.17%)	1 (1.08%)
More than one race	1 (4.35%)	0 (0.00%)	2 (8.33%)	3 (12.50%)	6 (6.45%)
Hispanic or Latino ethnicity, *n* (%)	2 (8.70%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	2 (2.15%)
Marital status, *n* (%)					
Single, never married	4 (17.39%)	7 (31.82%)	6 (25.00%)	4 (16.67%)	21 (22.58%)
Married or partnered	16 (69.57%)	5 (22.73%)	13 (54.17%)	17 (70.83%)	51 (54.84%)
Separated or divorced	3 (13.04%)	6 (27.27%)	4 (16.67%)	2 (8.33%)	15 (16.13%)
Widowed	0 (0.00%)	3 (13.64%)	1 (4.17%)	1 (4.17%)	5 (5.38%)
Education level, *n* (%)					
High school graduate or equivalent	1 (4.35%)	1 (4.55%)	1 (4.17%)	0 (0.00%)	3 (3.23%)
Posthigh school education, no degree	5 (21.74%)	4 (18.18%)	2 (8.33%)	6 (25.00%)	17 (18.28%)
Associate's or bachelor's degree	10 (43.48%)	10 (45.45%)	11 (45.83%)	12 (50.00%)	43 (46.24%)
Postgraduate work or graduate degree	7 (30.43%)	7 (31.82%)	10 (41.67%)	6 (25.00%)	30 (32.26%)
Income, *n* (%)					
Less than $30,000	5 (21.74%)	3 (13.64%)	1 (4.17%)	2 (8.33%)	11 (1.18%)
$30,000–$59,999	2 (8.70%)	7 (31.82%)	10 (41.67%)	5 (20.83%)	24 (25.81%)
$60,000 or more	14 (60.87%)	7 (31.82%)	13 (54.17%)	15 (62.50%)	49 (52.69%)
Number of people supported by salary, *n* (%)					
1	6 (28.57%)	12 (57.14%)	10 (41.67%)	6 (25.00%)	34 (36.56%)
2	7 (33.33%)	4 (19.05%)	5 (20.83%)	8 (33.33%)	24 (25.81%)
3	4 (19.05%)	2 (9.52%)	4 (16.67%)	4 (16.67%)	14 (15.05%)
4	3 (14.29%)	3 (14.29%)	2 (8.33%)	2 (8.33%)	10 (10.75%)
5+	1 (4.76%)	0 (0.00%)	3 (12.50%)	4 (16.67%)	8 (8.60%)

(Continued)

Table 3 | Continued

	Incentives for weight loss and self-monitoring (*n* = 23)	Incentives for self-monitoring only (*n* = 22)	Incentives for weight loss only (*n* = 24)	No incentives for weight loss or self-monitoring (*n* = 24)	Total (*N* = 93)
Financial stress level, *n* (%)					
After paying bills, still have enough for special things	17 (73.91%)	12 (54.55%)	17 (70.83%)	14 (58.33%)	60 (64.52%)
Enough to pay bills but little spare for special things	4 (17.39%)	7 (31.82%)	6 (25.00%)	7 (29.17%)	24 (25.81%)
Enough to pay bills because cut back on things	2 (8.70%)	2 (9.09%)	1 (4.17%)	2 (8.33%)	7 (7.53%)
Difficulty paying bills no matter what	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (4.17%)	1 (1.08%)
Employment status, *n* (%)					
Working full time	16 (16.57%)	11 (50.00%)	15 (62.50%)	14 (58.33%)	56 (60.22%)
Working part time	4 (17.39%)	6 (27.27%)	1 (4.17%)	4 (16.67%)	15 (16.13%)
Unemployed, searching for work	0 (0.00%)	0 (0.00%)	1 (4.17%)	2 (8.33%)	3 (3.23%)
Unemployed, not searching for work, retired, or disabled	3 (13.04%)	5 (22.73%)	6 (25.00%)	4 (16.67%)	18 (19.35%)

Missing data: ethnicity (*n* = 1 in Arm A); marital status (*n* = 1 in Arm B); income (*n* = 2 in Arm A, *n* = 5 in Arm B, and *n* = 2 in Arm D); number of people supported by salary (*n* = 2 in Arm A and *n* = 1 in Arm B); financial stress (*n* = 1 in Arm B); and employment status (*n* = 1 in Arm C).
BMI body mass index; *SD* standard deviation.

Table 4 | Intervention adherence by condition and cohort, mean (*SD*)

	Incentives for weight loss and self-monitoring	Incentives for self -monitoring only	Incentives for weight loss only	No incentives for weight loss or self-monitoring	Total
Number of group sessions attended					
Cohort 1 (of 13)	8.78 (2.22)	9.25 (1.91)	8.75 (2.66)	6.25 (3.54)	8.27 (2.78)
Cohort 2 (of 13)	8.43 (2.76)	7.00 (3.21)	5.75 (2.49)	7.50 (4.47)	7.13 (3.31)
Cohort 3 (of 14)	7.14 (4.22)	9.60 (1.14)	7.29 (3.15)	6.75 (2.49)	7.52 (3.06)
Number of calories tracked per weekday on days where some kcal were tracked					
Cohort 1	1,278.18 (150.26)	1,354.14 (287.67)	1,260.84 (231.58)	1,016.29 (274.75)	1,227.90 (261.89)
Cohort 2	1,386.10 (280.49)	1,617.64 (595.82)	1,223.29 (156.50)	1,185.70 (367.10)	1,365.92 (424.69)
Cohort 3	1,089.22 (141.13)	1,345.52 (234.93)	1,271.37 (491.94)	1,004.47 (542.44)	1,177.26 (366.69)
Number of calories tracked per weekend day on days where some kcal were tracked					
Cohort 1	1,290.45 (218.04)	1,380.36 (213.88)	1,270.01 (220.24)	1,035.22 (267.99)	1,244.65 (255.01)
Cohort 2	1,466.82 (282.69)	1,617.98 (678.04)	1,110.21 (474.93)	1,188.62 (380.63)	1,376.35 (499.16)
Cohort 3	1,145.85 (257.90)	1,379.86 (226.16)	1,070.13 (701.31)	966.34 (651.57)	1,148.02 (481.67)
Number of weekdays (of 5) tracked per week					
Cohort 1	3.41 (1.75)	4.19 (1.65)	2.69 (2.11)	2.41 (1.50)	3.17 (1.83)
Cohort 2	3.84 (1.54)	3.82 (1.33)	0.90 (0.86)	2.42 (1.41)	2.77 (1.73)
Cohort 3	2.86 (1.82)	3.25 (1.64)	2.12 (1.76)	1.89 (1.99)	2.57 (1.77)
Number of weekend days (of 2) tracked per week					
Cohort 1	1.35 (0.72)	1.65 (0.68)	1.06 (0.84)	0.92 (0.56)	1.24 (0.73)
Cohort 2	1.55 (0.66)	1.50 (0.54)	0.19 (0.23)	0.90 (0.60)	1.04 (0.75)
Cohort 3	1.08 (0.80)	1.38 (0.70)	0.85 (0.69)	0.67 (0.73)	1.01 (0.73)
Number of study days (of 168) participants tracked the minimum number of calories					
Cohort 1	108.30 (57.91)	121.10 (52.65)	85.14 (55.26)	42.13 (35.23)	89.91 (57.51)
Cohort 2	113.1 (51.47)	121.4 (43.92)	23.80 (17.25)	64.75 (47.34)	85.71 (55.91)
Cohort 3	75.86 (62.25)	105.0 (54.4)	44.50 (60.04)	48.20 (67.83)	69.54 (61.92)
Number of times self-weighed per week					
Cohort 1	4.93 (1.44)	5.91 (0.99)	4.32 (2.22)	4.03 (1.95)	4.79 (1.80)
Cohort 2	4.96 (1.96)	4.89 (1.70)	3.09 (1.00)	4.16 (2.63)	4.21 (1.98)
Cohort 3	4.48 (1.97)	5.78 (0.42)	4.13 (1.92)	2.25 (2.17)	4.03 (2.13)

(Continued)

Table 4 | Continued

	Incentives for weight loss and self-monitoring	Incentives for self -monitoring only	Incentives for weight loss only	No incentives for weight loss or self-monitoring	Total
Number of weeks (of 24) self-weighed at least twice					
Cohort 1	21.22 (5.14)	23.50 (1.07)	18.11 (7.93)	18.88 (6.58)	20.38 (5.96)
Cohort 2	20.43 (5.77)	15.75 (10.29)	17.63 (5.66)	17.00 (9.24)	17.61 (7.85)
Cohort 3	19.43 (6.08)	18.00 (8.83)	17.00 (6.73)	9.86 (8.53)	16.00 (8.08)
Number of weeks (of 24) incentives earned for dietary tracking					
Cohort 1	9.78 (3.11)	10.13 (3.60)	NA	NA	9.94 (3.25)
Cohort 2	9.57 (3.95)	10.13 (3.18)	NA	NA	9.87 (3.44)
Cohort 3	11.50 (9.59)	16.17 (9.09)	NA	NA	13.83 (9.23)
Number of weeks (of 24) incentives earned for interim weight loss					
Cohort 1	8.97 (2.29)	NA	8.38 (3.07)	NA	8.53 (2.60)
Cohort 2	7.71 (2.98)	NA	6.50 (2.45)	NA	7.07 (2.69)
Cohort 3	12.00 (5.74)	NA	11.57 (4.69)	NA	11.79 (5.04)
Incentives earned (of $300)					
Cohort 1	$214.11 (61.05)	$234.50 (80.55)	$189.25 (70.89)	NA	$212.68 (70.31)
Cohort 2	$203.14 (78.82)	$231.25 (78.09)	$151.00 (54.44)	NA	$194.78 (76.03)
Cohort 3	$162.14 (100.32)	$236.67 (115.62)	$160.86 (57.74)	NA	$184.05 (94.86)

Table 5 | Weight change by condition and cohort

	Incentives for weight loss and self-monitoring	Incentives for self-monitoring only	Incentives for weight loss only	No incentives for weight loss and self-monitoring	Total
Weight change (in pounds), *M* (*SD*)					
Cohort 1	−20.84 (6.47)	−23.63 (17.33)	−22.66 (22.03)	−21.97 (14.28)	−22.32 (15.26)
Cohort 2	−21.21 (9.25)	−8.93 (11.40)	−4.29 (8.29)	−9.04 (9.39)	−11.09 (11.22)
Cohort 3	−15.70 (12.99)	−12.32 (9.98)	−9.16 (24.46)	1.2 (8.46)	−8.39 (15.25)
Overall	−19.43 (9.54)	−16.01 (14.88)	−12.34 (19.67)	−10.02 (14.72)	−14.51 (15.21)
Weight change percentage, *M* (*SD*)					
Cohort 1	−9.06 (3.31)	−10.22 (6.50)	−10.43 (9.16)	−8.22 (4.95)	−9.51 (6.08)
Cohort 2	−7.43 (3.00)	−4.17 (5.74)	−1.51 (3.02)	−3.97 (3.81)	−4.30 (4.36)
Cohort 3	−8.30 (6.86)	−5.96 (4.80)	−3.19 (7.57)	0.47 (3.79)	−4.01 (6.45)
Overall	−8.26 (4.38)	−7.19 (6.19)	−5.24 (7.80)	−3.90 (5.56)	−6.18 (6.20)
Number who achieved ≥5% weight loss, *n* (%)					
Cohort 1	5 (71.43)	7 (87.50)	6 (85.71)	5 (71.43)	23 (79.31)
Cohort 2	5 (71.43)	2 (33.33)	1 (14.29)	1 (20.00)	9 (36.00)
Cohort 3	4 (66.67)	3 (60.00)	2 (40.00)	1 (14.29)	10 (43.48)
Overall	14 (70.00)	12 (63.16)	9 (47.37)	7 (36.84)	42 (54.55)

gradual dropout; participants would have preferred larger groups where they could assimilate and exchange information and support.

Across conditions and cohorts, the mean number of calories tracked (on days when some calories were tracked) per weekday ranged from 1,004 (*no incentives* in Cohort 3) to 1,617 (*incentives for self-monitoring* in Cohort 2) and per weekend day ranged from 966 (*no incentives* in Cohort 3) to 1,618 (*incentives for self-monitoring* in Cohort 2). The mean number of weekdays tracked ranged from 0.9 (*incentives for weight loss* in Cohort 2) to 4.2 (*incentives for self-monitoring* in Cohort 1) and weekend days ranged from 0.2 (*incentives for weight loss* in Cohort 2) to 1.7 (*incentives for self-monitoring* in Cohort 1).

The mean number of days (of 168) on which participants who could earn an incentive for self-monitoring tracked the minimum number of calories (1,000 for women and 1,200 for men) ranged from 75.9 to 121.4, with an overall per-person average of 82.7 (standard deviation [*SD*] = 58.2). The mean number of days on which a sufficient number of calories was tracked was higher in the two groups incentivized to do so versus the other two (108.2 [*SD* = 53.0] vs. 53.3 [*SD* = 50.5]).

The mean number of times per week that participants weighed themselves ranged from 2.3 (*no incentives* in Cohort 3) to 5.9 (*incentives for self-monitoring* in Cohort 1). The mean number of weeks (of 24) that participants weighed themselves at least twice during the week to enable the calculation of weight loss ranged from 9.9 (*no incentives* in Cohort 3) to 23.5 (*incentives for self-monitoring* in Cohort 1).

On average, across cohorts, participants earned incentives for sufficient dietary self-monitoring 10.2 (*SD* = 5.5) weeks in the combined incentives condition and one additional week (11.8 [*SD* = 5.9]) in the *incentives for self-monitoring* condition. The average number of weeks participants in the two groups were incentivized for weekly weight loss differed by less than a week: 9.4 (*SD* = 4.1) weeks in the combined incentives condition and 8.7 (*SD* = 3.9) in the *incentives for weight loss* condition. Average earnings (of $300) over 24 weeks ranged from $151 (*incentives for weight loss* in Cohort 2) to $237 (*incentives for self-monitoring* in Cohort 3). Early in Cohort 1, some participants who did not earn an incentive for dietary self-monitoring due to very low caloric intake nevertheless reported that they should have earned one because they recorded everything they ate. We realized that participants were underreporting portion sizes in MyFitnessPal, resulting in daily caloric intake that was below the threshold required to earn an incentive. We had not taught them to estimate portion sizes adequately for carbohydrate-free foods because these foods were not restricted in the LCD. Furthermore, the default MyFitnessPal interface and functions focus on caloric intake rather than macronutrient intake. To address this mismatch between the diet and the dietary app, we switched to an LFD in Cohort 2.

Reactions to incentive structure, text messages, and retention letter

Across the three cohorts, postintervention qualitative interviews were conducted with 31 participants, who reported mixed reactions to the incentive structure. Some participants were motivated by the incentives, whereas others were not, citing strong (intrinsic) motivation to lose weight. Some Cohort 1 and 2 participants reported dissatisfaction with receiving an incentive of $0 during weeks that they

had met the criteria to earn an incentive. Although occasional nonrewards are consistent with the concept of intermittent reinforcement, we changed the lower limit of the incentive from $0 to $2 in Cohort 3 (corresponding to $1 each for weight loss and self-monitoring in the combined condition) to assess reactions to this change. Even with this change, some Cohort 3 participants reported dissatisfaction with receiving $2 after having received larger amounts in other weeks.

Participants also had mixed reactions to the text messages. Recall that Cohort 1 participants received one text message at 8 am each week regarding whether they earned an incentive. Some of these participants did not look forward to receiving the messages when they knew that they had not met the criteria to receive an incentive; in fact, some chose not to read the text message. In Cohort 2, we added two supplemental motivational/informational text messages per week (identical across conditions), which were delivered on varying days of the week and times of day that were unpredictable to participants. Cohort 2 participants appreciated the content but not the timing of these supplemental messages: they preferred to receive text messages in the morning to help them plan their day, and they did not wish to receive text messages on Sundays due to church attendance. Accordingly, in Cohort 3, we retained supplemental text messages and sent them at 8 am on varying days of the week except Sunday. This schedule was well received.

Participants read and reacted positively to the retention letter. They found the message clear and understood the goal of the letter (i.e., to have them return for outcome assessments to avoid biases associated with nonresponse).

Evidence of clinically significant signal and adequacy of control group

Weight loss is presented by condition and cohort in Table 5. In Cohort 1, mean weight loss was 22.3 lb, mean percentage of weight loss was 9.5%, and 79.3% lost ≥5% of their baseline body weight. In Cohort 2, mean weight loss was 11.1 lb, mean percentage of weight loss was 4.3%, and 36.0% lost ≥5% of their baseline body weight. It is unclear whether less weight loss in Cohort 2 was due to a different dietary approach (LFD instead of LCD) or the greater representation of non-Whites since non-Whites tend to lose less weight in RCTs [56]. Because the LCD has shown superiority to the LFD in the first several months [45], we switched back to an LCD for Cohort 3. To address the aforementioned issue of accurate data entry in MyFitnessPal, we added an extra group session on food measurement and tracking to see if we could enhance weight loss further while maintaining a racially diverse population. In Cohort 3, mean weight loss was 8.4 lb, mean percentage weight loss was 4.0%, and 43.5% lost ≥5% of their baseline body weight.

DISCUSSION

Our financial incentives intervention was designed to incorporate the principles of operant conditioning to improve the proportion of people who achieve clinically significant weight loss from an evidence-based weight loss program. To reduce habituation, the intervention involves positive reinforcement that evolves from a fixed weekly payment to intermittent, variable payments that are unpredictable to participants. We use money as a reinforcer that can be used to obtain goods or services that are meaningful to each participant.

An important component of our intervention is the use of mobile technologies to minimize the delay between the desired outcome (weight loss) and/or behavior (dietary self-monitoring) and reward. Mobile technologies allow us to capture data and incentivize individuals based on their weight loss behaviors in their daily environment. Our intervention allowed participants to earn and receive incentives even when they did not attend group weight loss sessions, disentangling the reward from the process of submitting records to the study team. This is an important advancement over previous studies of incentives for weight loss, which required participants to attend study sessions to submit records to determine whether they qualified for an incentive [22]. With the high and increasing prevalence of smartphone use—81% of Americans now own a smartphone [57]—interventions such as ours hold great promise for widespread dissemination.

In preparation for a future, adequately powered RCT to evaluate the efficacy of our incentive structures, we conducted a Phase IIb randomized pilot study to assess (a) the feasibility and acceptability of the trial protocol and (b) evidence of signal over noise. We recruited a sufficient number of participants for each cohort in the allotted time frame of 6 weeks. Although we met our target sample size for each cohort, we did not obtain sufficient diversity in Cohort 1. The strategies added to Cohorts 2 and 3 yielded more diversity in race, marital status, and socioeconomic status. We did not observe differential dropout by race. Recruiting and retaining diverse samples into weight management studies is important because demographic subgroups, such as Black and Latinx Americans, have higher rates of obesity than their White counterparts [7] and may respond differently to incentives. Participation of these groups in research studies is important for enhancing generalizability and establishing interventions that are effective for these populations [58]. We acknowledge that effects attributed to race/ethnicity are likely confounded by educational status or other factors attributable to institutional racism.

One indicator of feasibility, average attendance at group sessions, was somewhat lower in this study than in our previous studies [48, 59]. We enrolled a smaller number of participants per group than in previous studies due to budgetary constraints. With a small group, absences are more noticeable and affect the attendance of other group members. Despite lower-than-anticipated adherence rates, retention for outcomes was sufficient. This may be due to the financial incentive and individual nature of the outcome assessment visits.

We assessed the acceptability of the protocol via postqualitative interviews. Upon learning that participants did not read text messages when they contained "bad news" in Cohort 1, we added two motivational/informational text messages per week. When these were sent at desired times in Cohort 3, they were read and well received. Upon learning that participants were disappointed with receiving $0 despite earning criteria for an incentive in Cohorts 1 and 2, we changed the lower bound to $2 in Cohort 3. Based on feedback from participants in Cohort 3, we suspect that the disappointment resulted from the magnitude of difference between the upper and lower limits rather than the absolute value of the lower limit. In an article that was published while we were conducting this study, the authors found that incentives as small as $10 delivered on a variable-ratio schedule motivate weight loss [36]. Decreasing the range of incentives may reduce the disappointment with receiving smaller amounts despite meeting the criteria for an incentive.

In addition to establishing the feasibility and acceptability of our trial protocol, we sought evidence of clinically significant weight loss. We observed much greater weight loss in Cohort 1 than in Cohorts 2 and 3. It is difficult to attribute the differential weight loss to any single factor given the small sample size and the fact that the cohorts differed in demographics, dietary approach, and time of year. Furthermore, there is not a consistent message regarding the impact of incentives across cohorts. In Cohort 1, all conditions lost a similar amount of weight, whereas, in Cohorts 2 and 3, participants who received incentives for both weight loss and dietary self-monitoring and just dietary self-monitoring lost more weight than the other two conditions. Whether this pattern holds should be evaluated in an adequately powered RCT. Importantly, there was nondifferential dropout in the no-incentives control condition. Nondifferential dropout in an adequately powered RCT will provide the conditions to test our hypotheses about the impact of financial incentives interventions on weight loss.

Research and clinical implications

Having established the feasibility of our protocol and treatment acceptability, we are now positioned to conduct an adequately powered RCT to evaluate the efficacy of providing incentives for weight loss and/or dietary self-monitoring compared to no incentives. We learned several lessons in this pilot study to improve study conduct and intervention design. First, we need to make special efforts to recruit diverse participants who represent the communities from which they are recruited. Second, we will send all text messages—which include not only an incentive notification but also informational and motivational notifications—at 8 am on any day except Sunday. Third, we will have larger groups to encourage attendance at group sessions. In previous studies, we enrolled 10–15 participants per group [48, 59] in contrast to the 7–8 participants per group in this study.

Our future RCT will also extend the study time period so that we can evaluate the impact of incentives not only on short-term weight loss but also on long-term weight loss. We focused on improving initial weight loss with an incentives intervention because initial weight loss predicts long-term weight loss [3]. An optimal structure for inducing clinically significant initial weight loss has not been identified. The short duration of our planning study did not allow us to examine long-term weight loss across cohorts. This is important as some studies have indicated that behaviors tend to return to baseline once incentives are removed [60]. The few studies that have evaluated the impact of financial incentives on weight loss maintenance have yielded inconsistent findings [30, 35, 61, 62], suggesting the need for future research in this area.

Insurance providers and employers are already offering financial incentive programs for weight management via discounted premiums, vouchers, and other incentive types. Evaluations of these programs suggest minimal to no effect of incentives, highlighting the need to draw from psychological theory and establish a stronger evidence base. One critical need is to incentivize participants soon after the desired behavior or outcome is achieved. Our information technology solution allowed us to capture weight and diet data from participants in their everyday environments. This, in turn, allowed us to incentivize participants in near real time, closer to when weight loss behaviors occur than has been possible in many past studies. Due to the proliferation of mobile phones and increased availability of wireless scales and related technologies at an affordable price, our approach holds great promise for scalability.

Our method not only allows us to deliver incentives in real time but also reduces the potential for human error in processing data and provides a scalable solution that requires minimal personnel effort. Furthermore, the information technology infrastructure could be utilized, with minimum programming, to incorporate other incentive structures or data from wearable sensors, phone-tethered devices, and

sensors placed in the home environment. Although we incentivized participants with money, many other incentives could be transmitted through software systems, such as coupons, discounts, or home delivery of products. Our financial incentives intervention was applied alongside a gold-standard, group-based intervention to provide a stringent test of the intervention. Yet, the intervention could be paired with electronically delivered behavioral weight loss programs, weight loss medications, or bariatric surgery to improve weight loss. Finally, our approach could be adapted to improve treatment adherence for other refractory health behaviors, such as medication taking or smoking.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Translational Behavioral Medicine* online.

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Compliance with Ethical Standards

Conflicts of Interest: W.S.Y. is a consultant for dietdoctor.com and Guideline Central. All other authors declare that they have no conflicts of interest.

Authors' Contributions: C.I.V. designed the study, obtained funding, interpreted findings, and drafted the manuscript. J. P., and S. L. H., analyzed data, interpreted findings, and critically revised the manuscript. J. M. G., M. A. M., S. D. R., W. S. Y., and R. J. S. contributed to the study design, interpretation of findings, and critically revised the manuscript. E. M. S., & E. L. contributed to the study design and critically revised the manuscript.

Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

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