

Framing Financial Incentives to Increase Physical Activity Among Overweight and Obese Adults

A Randomized, Controlled Trial

Mitesh S. Patel, MD, MBA, MS; David A. Asch MD, MBA; Roy Rosin, MBA; Dylan S. Small, PhD; Scarlett L. Bellamy, ScD; Jack Heuer, EdD; Susan Sproat, MS; Chris Hyson, MEd; Nancy Haff, MD; Samantha M. Lee, MD; Lisa Wesby, MS; Karen Hoffer, BS; David Shuttleworth, MS; Devon H. Taylor, BS; Victoria Hilbert, MPH, RD; Jingsan Zhu, MBA, MS; Lin Yang, MS; Xingmei Wang, MS; and Kevin G. Volpp, MD, PhD

Background: Financial incentive designs to increase physical activity have not been well-examined.

Objective: To test the effectiveness of 3 methods to frame financial incentives to increase physical activity among overweight and obese adults.

Design: Randomized, controlled trial. (ClinicalTrials.gov: NCT 02030119)

Setting: University of Pennsylvania.

Participants: 281 adult employees (body mass index ≥ 27 kg/m²).

Intervention: 13-week intervention. Participants had a goal of 7000 steps per day and were randomly assigned to a control group with daily feedback or 1 of 3 financial incentive programs with daily feedback: a gain incentive (\$1.40 given each day the goal was achieved), lottery incentive (daily eligibility [expected value approximately \$1.40] if goal was achieved), or loss incentive (\$42 allocated monthly upfront and \$1.40 removed each day the goal was not achieved). Participants were followed for another 13 weeks with daily performance feedback but no incentives.

Measurements: Primary outcome was the mean proportion of participant-days that the 7000-step goal was achieved during

intervention. Secondary outcomes included mean proportion of participant-days achieving the goal during follow-up and mean daily steps during intervention and follow-up.

Results: The mean proportion of participant-days achieving the goal was 0.30 (95% CI, 0.22 to 0.37) in the control group, 0.35 (CI, 0.28 to 0.42) in the gain-incentive group, 0.36 (CI, 0.29 to 0.43) in the lottery-incentive group, and 0.45 (CI, 0.38 to 0.52) in the loss-incentive group. In adjusted analyses, only the loss-incentive group had a significantly greater mean proportion of participant-days achieving the goal than control (adjusted difference, 0.16 [CI, 0.06 to 0.26]; $P = 0.001$), but the adjusted difference in mean daily steps was not significant (861 [CI, 24 to 1746]; $P = 0.056$). During follow-up, daily steps decreased for all incentive groups and were not different from control.

Limitation: Single employer.

Conclusion: Financial incentives framed as a loss were most effective for achieving physical activity goals.

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For author affiliations, see end of text.

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Higher levels of regular physical activity are associated with lower rates of cardiovascular disease, diabetes, obesity, hypertension, and all-cause mortality (1-5). However, more than half of adults in the United States do not attain the minimum recommended level of physical activity to have these health benefits (6, 7). The Centers for Disease Control and Prevention and many state public health departments have recommended the workplace as an environment to implement interventions to increase physical activity (8-11). But evidence suggests that most workplace physical activity interventions are not effective, particularly for more sedentary persons (12-14).

Workplace wellness programs are growing in popularity throughout the United States, and more than 80% of large employers now use some form of financial incentive for health promotion (15-17). Beginning in 2014, the Patient Protection and Affordable Care Act increased the proportion of employee health insurance premiums that can be used as outcome-based wellness incentives from 20% to 30% and as high as 50% if tobacco use is targeted (18, 19). This provides a signifi-

cant opportunity to use incentive-based programs to change health behaviors, but the optimal design of financial incentives to increase physical activity has not been well-examined (20).

Behavioral economics incorporates principles from psychology to help understand why persons make decisions that are not in line with longer-term health goals. Many persons know physical activity is good for their health but do not do enough of it. Instead, they often deviate from these goals in a predictable manner and from a common set of decision errors (18, 19, 21). For example, persons tend to be more motivated by immediate rather than delayed gratification (22) and by losses rather than gains (23), and they tend to avoid the feeling of regret (24). These insights reveal that the de-

See also:

Web-Only
Supplement

EDITORS' NOTES**Context**

Financial incentives are commonly used in workplace wellness programs aimed at increasing physical activity. The most effective approach to offering incentives, however, is not known.

Contribution

In this trial, the up-front allocation of a financial reward and subsequent loss when physical activity goals were not met resulted in greater daily exercise than no incentive. Providing a reward when goals were met, however, did not increase physical activity.

Implication

The manner in which financial incentives are offered may influence the success of health promotion programs.

sign and delivery of an incentive has an important influence on its effectiveness.

The objective of this study was to test the effectiveness of 3 financial incentive designs, each with the same expected economic value. In the gain-incentive group, participants received a fixed amount of money each day the step goal was achieved. This design follows traditional economic principles in that it is largely transactional: A certain constant reward is promised for a predetermined effort. Persons in the 2 other incentive groups were offered incentives of the same expected value, but those incentives were designed to leverage the fact that persons tend to be loss averse, are more engaged by variable reinforcement than by constant reinforcement, and tend to avoid the feeling of regret.

METHODS**Design Overview**

We conducted a 26-week randomized, controlled trial between 6 March and 6 September 2014, consisting of 13-week intervention and follow-up periods. A total of 281 participants gave their informed consent and were randomly assigned to a control group or to 1 of 3 groups with different financial incentive designs, each with the same expected economic value.

All participants were given a goal of achieving at least 7000 steps per day, and this target reflects several deliberate design elements. First, this level of physical activity is endorsed by the American College of Sports Medicine to be approximately equivalent to meeting the federal guidelines for the minimum recommended levels of physical activity needed to achieve health benefits (25, 26). Second, this level is 40% higher than the average daily step count of 5000 among U.S. adults (27, 28). Prior studies using an even higher goal of 10 000 steps have found that more sedentary persons may be less likely to participate, and it was a priority in this study to engage as many persons as possible (12).

Third, instead of simply asking participants to increase steps, a minimum threshold puts greater emphasis on encouraging more sedentary persons to be physically active and less emphasis on getting highly active persons to be even more active.

Step counts were tracked using the Moves smartphone application (ProtoGeo Oy), which uses accelerometers within the phone and has been shown by our prior work to be accurate (29). Each participant was given a unique personal identification number to enter into the smartphone application and verify permission that the study team could access step-count data. Once the application was installed on the phone, the participant never had to reopen it, although they could as often as they wished. Instead, participants had to allow the application to run passively on the phone, have the phone powered on, and carry it with them (for example, in a pocket or on a belt clip or arm band) while they were active. The University of Pennsylvania Institutional Review Board approved this study.

Setting and Participants

Eligible participants were employees of the University of Pennsylvania in Philadelphia, Pennsylvania, were aged 18 years or older, and had a body mass index (BMI) of at least 27 kg/m² (estimated from self-reported height and weight). We chose this BMI threshold to help ensure that our sample represented overweight or obese persons. Participants were recruited by e-mail from February to March 2014 and excluded if they were already participating in another physical activity study, were not able or willing to carry an iPhone (Apple) or Android (Google) smartphone with the mobile application installed, were pregnant or lactating, intended to become pregnant within 6 months, or stated that they could not complete the study. E-mails were sent to all University of Pennsylvania staff employees (approximately 10 000 persons). All eligible participants provided electronic informed consent, completed a sociodemographic questionnaire, self-reported measures of height and weight, and reported recent physical activity using the long form of the International Physical Activity Questionnaire (30).

Randomization and Interventions

Participants enrolled online using Way to Health, an automated technology platform based at the University of Pennsylvania that integrates wireless devices, conducts clinical trial randomization and enrollment processes, delivers messaging (text message or e-mail) and surveys, automates transfers of financial incentives, and securely captures data for research purposes (31). Way to Health was used in prior behavioral intervention studies (32-34). All participants received \$25 for enrolling and \$75 for participating through the primary end point at 13 weeks along with completion of a survey on their experience. However, there was no participation incentive for the follow-up period. Participants were mailed a bank check at the end of each month with all accumulated earnings. All participants selected whether they preferred to receive study communications by e-mail, text message, or both.

Participants were electronically randomly assigned to the control group or to 1 of 3 intervention groups with an equivalent expected economic value of \$1.40, which is a value used in prior work (34). For 26 weeks, participants in all 4 groups received daily feedback on whether they had achieved the 7000-step goal in the prior day. The control group received no other intervention aside from daily feedback. For the 13-week intervention, the intervention groups included a gain incentive in which participants received \$1.40 for each day they met the goal, a loss incentive in which \$1.40 was taken away from a monthly incentive (\$42 allocated upfront) each time the daily goal was not met, or a daily lottery incentive. Persons in the lottery-incentive group selected a 2-digit number between 00 and 99. One winning number was randomly selected daily during the intervention period. If a participant's number had a single-digit match (an 18% chance), he or she won \$5. If the participant's number had a 2-digit match (a 1% chance), he or she won \$50. Participants were eligible to collect the reward only if the 7000-step goal was achieved on the prior day. Ineligible participants were informed what they would have won if they had achieved the goal, drawing on evidence that the desire to avoid regret can be motivating (23, 24, 35, 36). Incentives were offered only during the 13-week intervention, but daily performance feedback was delivered for the entire 26 weeks.

Outcomes and Follow-up

The primary outcome was the mean proportion of participant-days that the 7000-step goal was achieved during the 13-week intervention. We hypothesized that participants in all 3 financial-incentive groups would have a significantly greater mean proportion of participant-days achieving the goal than the control group, with participants in the loss- and lottery-incentive groups performing the best. Secondary outcomes included the number of steps per day during intervention and follow-up and the mean proportion of participant-days that the 7000-step goal was achieved during follow-up.

Neither the participants nor the study coordinator could be blinded to the group assignment. All investigators, statisticians, and data analysts were blinded to group assignments until the 26-week study ended.

Statistical Analysis

One participant randomly assigned to the gain-incentive group was later found to be ineligible because of enrollment in another physical activity study. One participant randomly assigned to the lottery-incentive group switched to a phone that was not eligible for use before the study began and therefore did not receive the intervention. Both of these participants were excluded from the analysis. All other randomly assigned participants were included in the intention-to-treat analysis.

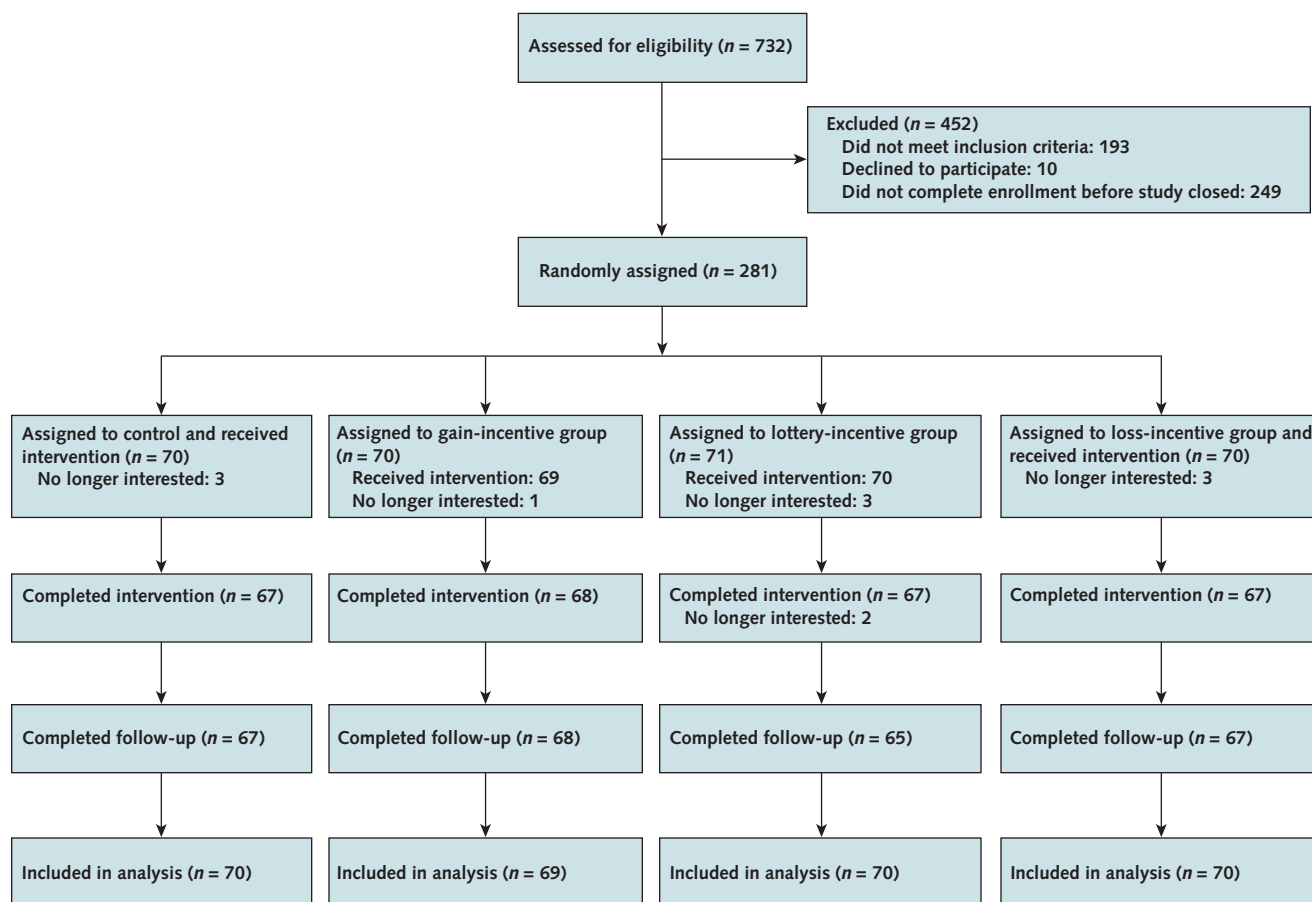
For each participant on each day of the study (participant-day level), we obtained the number of steps achieved as a continuous variable. Data could be missing for any day if a participant turned off the smart-

phone or the application, disabled the study team's permission before data were accessed, or did not carry the smartphone at all. For the main analysis, we used only collected data (a step-count value was received). This approach is based on the assumption that missing data occur at random and do not bias outcomes for groups with differing levels of missing data. Using the continuous steps data, we estimated the mean daily steps among participants in each group during the intervention and follow-up. We dichotomized the data at the participant-day level to create a binary variable indicating that the participant achieved the 7000-step goal (value, 1) or did not achieve it (value, 0). Using this binary variable, we estimated the mean proportion of participant-days achieving the goal for the group of participants in each group during the intervention and follow-up and for each week during the study.

For adjusted analyses, we used PROC GLIMMIX in SAS, version 9.4 (SAS Institute), to fit a generalized linear model with participant random effects, a random intercept, time-fixed effects (at the weekly level), and treatment-fixed effects (by study group) (37–40). We assumed a normal distribution for models using the continuous outcome and obtained the difference in steps among groups using the least-squares means (LSMEANS) command. We assumed a binomial distribution with logit link for models using the binary outcome to estimate adjusted difference in the proportion of participant-days achieving the goal and used the bootstrap procedure, resampling participants, to obtain 95% confidence intervals and *P* values (41, 42). We used a pseudolikelihood method (38) but also performed a sensitivity analysis for the main models using the quadrature approximation with 12 nodes specified (43).

Several sensitivity analyses were conducted to assess the robustness of our findings. For the primary and secondary outcomes using the binary and continuous variables, respectively, the main model was further adjusted by using device-fixed effects for smartphone type (iPhone or Android). The model was also evaluated by using all data and coding missing data (when a step value was not received) as “not achieving the goal” (in contrast to using only collected data), which is a method used in prior work (33). Further, evidence suggests that step-count values less than 1000 are unlikely to represent accurate data capture of actual activity (27, 44, 45). Therefore, to avoid these observations from downward biasing mean daily step outcomes, we did a sensitivity analysis using the model with values less than 1000 excluded from the sample.

A priori, we estimated that a sample of at least 260 participants (65 per group) would ensure 80% power to detect a 0.20 difference between each intervention group and the control group. We used a conservative Bonferroni adjustment of the type I error rate with a 2-sided α value of 0.017. This calculation assumed that the mean proportion of participant-days achieving the goal in the control group would be 0.40. We increased

Figure 1. Study flow diagram.

One participant randomly assigned to the gain-incentive group was later found to be ineligible due to previous enrollment in another physical activity study. One participant randomly assigned to the lottery-incentive group switched to a phone that was not eligible for use before the study began and therefore did not receive the intervention.

the participant enrollment target to 280 to account for a potential 8% dropout rate.

Role of the Funding Source

This work was funded by the National Institute on Aging. Support was also provided by the U.S. Department of Veterans Affairs and the Robert Wood Johnson Foundation. The funding sources had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; or preparation, review, or approval of the manuscript.

RESULTS

Figure 1 reports trial enrollment and participation. In all 4 groups, at least 95% of the participants completed the 13-week intervention and at least 92% completed the entire 26-week study. Participants had a mean age of 39.7 years (SD, 11.6) and a mean BMI of 33.2 kg/m² (SD, 5.6); 78% were women. Participant baseline characteristics were generally well-balanced across the 4 study groups (Table 1), with 183 participants (65.6%) using an iPhone and 96 (34.4%) using an Android. The percentage of participant-days on which

step-count data were missing during the intervention was 15% for the control group, 10% for the gain-incentive group, 18% for the lottery-incentive group, and 13% for loss-incentive group.

The mean proportion of participant-days that the 7000-step goal was achieved at the weekly level peaked at about 0.48 in the loss-incentive group, 0.42 in the lottery-incentive group, and 0.41 in the gain-incentive group, but it was never greater than 0.33 in the control group (Figure 2). These levels decreased slightly toward the end of the intervention for all groups. Unadjusted mean estimates are displayed by group for the intervention and follow-up in Table 2.

Adjusted differences in the mean proportion of participant-days achieving the goal are displayed in Table 3. Only the loss-incentive group had a significantly greater mean proportion of participant-days achieving the goal than the control group (adjusted difference, 0.16 [95% CI, 0.06 to 0.26]; *P* = 0.001). Adjusted differences in mean daily steps are displayed in Table 4. The loss-incentive group had greater mean daily steps than the control group, but they were not significantly differ-

ent (adjusted difference, 861 steps [CI, 24 to 1746 steps]; $P = 0.056$).

During follow-up, the mean proportion of participant-days achieving the goal decreased among all groups. The loss-incentive group had the greatest mean proportion of participant-days achieving the goal (0.30 [CI, 0.24 to 0.37]), but it was not significantly different from the control group (adjusted difference, 0.07 [CI, -0.02 to 0.14]; $P = 0.110$). For all outcomes, results of sensitivity analyses adjusted by device and using different methods of accounting for missing data were qualitatively similar to those of the main model (Tables 3 and 4).

Sensitivity analyses using the quadrature approximation supported the findings of the main models using the pseudolikelihood method for both mean proportion of participant-days achieving the goal and mean daily steps (Appendix Tables 1 and 2, available at www.annals.org).

No adverse events were reported during the entire study.

DISCUSSION

Employers are increasingly using workplace wellness programs to target health outcomes. Although the popularity of these programs is growing, the optimal design of financial incentives to change health behav-

iors is uncertain. In this randomized, controlled trial using financial incentives to increase physical activity, we found that the design of the incentive significantly influenced outcomes. The gain incentive, in which an employee received a fixed amount each day he or she met goal, was no more effective than control. In comparison, a loss incentive, in which rewards were allocated upfront and taken away each day the goal was not achieved, resulted in a 50% relative increase in the mean proportion of time participants achieved physical activity goals.

These findings expand our understanding of using financial incentives to increase physical activity. A study by Finkelstein and colleagues (46) enrolled 51 adults and randomly assigned them to a control group in which each participant received \$75 to participate or an intervention group in which each participant received \$50 to participate plus \$10, \$15, or \$25 more per week depending on their level of physical activity. The intervention group achieved 1.8 more hours of physical activity per week at an average cost of \$17.50, but the study duration was only 4 weeks and there was no follow-up without incentives.

A meta-analysis (20) evaluated the use of financial incentives to increase exercise adherence. Seven randomized, controlled trials were included in the final analysis. Although pooled results indicated that incen-

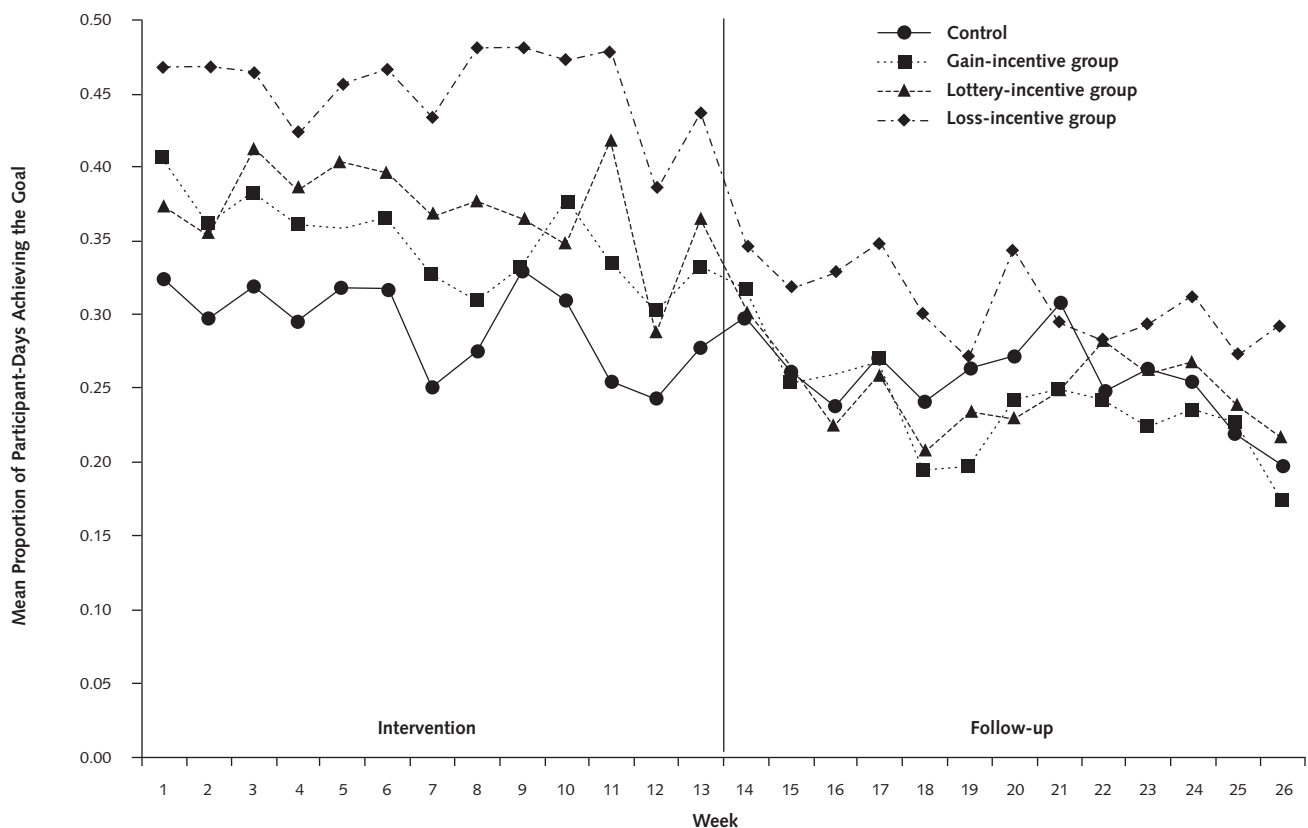
Table 1. Characteristics of Study Participants*

Characteristic	Control Group (n = 70)	Gain-Incentive Group (n = 69)	Lottery-Incentive Group (n = 70)	Loss-Incentive Group (n = 70)
Women, n (%)	55 (78.6)	55 (79.7)	53 (75.7)	54 (77.1)
Mean age (SD), y	39.4 (12.2)	37.1 (10.9)	40.3 (11.2)	41.9 (11.6)
Self-reported baseline measures				
Mean BMI (SD), kg/m ²	33.2 (5.3)	32.6 (4.5)	33.1 (5.6)	33.8 (6.8)
Median physical activity in the past 7 d (IQR), MET-min†	2568.8 (1077.0-4941.0)	2812.2 (1408.0-4806.0)	2785.0 (1336.5-4965.5)	2764.5 (933.0-4456.0)
Race/ethnicity, n (%)				
White non-Hispanic	45 (64.3)	41 (59.4)	44 (62.9)	49 (70.0)
African American non-Hispanic	16 (22.9)	16 (23.2)	16 (22.9)	13 (18.6)
Other non-Hispanic	6 (8.6)	10 (14.5)	7 (10.0)	6 (8.6)
Hispanic	3 (4.3)	2 (2.9)	3 (4.3)	2 (2.9)
Education, n (%)				
Less than college	1 (1.4)	2 (2.9)	2 (2.9)	2 (2.9)
Some college	15 (21.4)	15 (21.4)	13 (18.6)	12 (17.1)
College graduate	54 (77.1)	52 (75.4)	55 (78.6)	56 (80.0)
Marital status, n (%)				
Single	27 (38.6)	26 (37.7)	27 (38.6)	25 (35.7)
Married	31 (44.3)	31 (44.9)	32 (45.7)	36 (51.4)
Other	12 (17.1)	12 (17.4)	11 (15.7)	9 (12.9)
Annual household income, n (%)				
<\$50 000	21 (30.0)	24 (33.3)	24 (34.3)	15 (21.4)
\$50 000-\$100 000	25 (35.7)	32 (46.4)	22 (31.4)	29 (41.4)
>\$100 000	20 (28.6)	12 (17.1)	20 (28.6)	18 (25.7)
iPhone/smartphone, n (%)	46 (65.7)	43 (62.3)	45 (64.3)	49 (70.0)

BMI = body mass index; IQR = interquartile range; MET = metabolic equivalent.

* Percentages may not sum to 100 due to rounding.

† Calculated using the International Physical Activity Questionnaire protocol.

Figure 2. Weekly unadjusted mean proportion of participant-days achieving the 7000-step goal.

tives were effective, the optimal design of incentives was not well-evaluated. The weekly incentive ranged from \$2.79 to \$46.82, but most studies delivered incentives only at the end of the study. The authors of the meta-analysis concluded that the quality of existing evidence was poor and that they could not draw reason-

able conclusions about the effect of incentive design on physical activity outcomes.

In comparison, our study had an expected value of \$9.80 per week and incentives were designed to be delivered daily because persons tend to prefer immediate gratification rather than delayed rewards (22).

Table 2. Unadjusted Mean Physical Activity Outcomes*

Period	Mean (95% CI)			
	Control Group (n = 70)	Gain-Incentive Group (n = 69)	Lottery-Incentive Group (n = 70)	Loss-Incentive Group (n = 70)
Intervention†				
Proportion of participant-days achieving 7000-step goal‡	0.30 (0.22–0.37)	0.35 (0.28–0.42)	0.36 (0.29–0.43)	0.45 (0.38–0.52)
Steps per day, n§	5031 (4406–5656)	5406 (4799–6013)	5251 (4625–5876)	5880 (5265–6497)
Follow-up 				
Proportion of participant-days achieving 7000-step goal‡	0.24 (0.18–0.31)	0.25 (0.19–0.31)	0.23 (0.17–0.30)	0.30 (0.24–0.37)
Steps per day, n§	4539 (3916–5162)	4692 (4084–5301)	4529 (3901–5158)	5065 (4466–5664)

* Participants in all groups received daily feedback through the entire 26 wk. Participants in incentive groups received these incentives during only the intervention.

† Wk 1–13.

‡ Assigned a value of 0 on days on which the goal was not met and on days with missing data and a value of 1 on days on which the participant had a step count of ≥ 7000 .

§ Does not include days on which step-count data were not transmitted.

|| Wk 14–26.

Table 3. Adjusted Differences in Proportion of Participant-Days Achieving the 7000-Step Goal*

Group Comparison, by Model	Intervention (wk 1-13)		Follow-up (wk 14-26)	
	Difference in Proportion of Participant-Days Achieving the Goal (95% CI)	P Value	Difference in Proportion of Participant-Days Achieving the Goal (95% CI)	P Value
Main model†				
Gain incentive vs. control	0.06 (−0.04 to 0.15)	0.25	0.01 (−0.08 to 0.10)	0.85
Lottery incentive vs. control	0.06 (−0.03 to 0.15)	0.156	−0.01 (−0.09 to 0.06)	0.78
Loss incentive vs. control	0.16 (0.06 to 0.26)	0.001	0.07 (−0.02 to 0.14)	0.110
Main model adjusted by device‡				
Gain incentive vs. control	0.06 (−0.04 to 0.15)	0.23	0.01 (−0.08 to 0.09)	0.87
Lottery incentive vs. control	0.07 (−0.02 to 0.15)	0.151	−0.01 (−0.09 to 0.06)	0.77
Loss incentive vs. control	0.16 (0.06 to 0.26)	0.001	0.07 (−0.01 to 0.14)	0.106
Main model adjusted by device‡ and with missing data coded as not meeting goal				
Gain incentive vs. control	0.06 (−0.03 to 0.15)	0.21	−0.01 (−0.09 to 0.06)	0.71
Lottery incentive vs. control	0.06 (−0.03 to 0.15)	0.22	−0.02 (−0.09 to 0.06)	0.62
Loss incentive vs. control	0.14 (0.05 to 0.24)	0.004	0.06 (−0.02 to 0.13)	0.120

* Boldface values meet the significance threshold of $P < 0.017$.

† Adjusted for repeated measures of daily participant step counts and for temporal trends by week using all collected data. For each day, each participant had a binary outcome measure (0 or 1) based on whether he or she achieved the 7000-step goal. Difference in proportions was estimated for each group relative to the control group. CIs and P values were obtained using the bootstrapping procedure.

‡ Type of smartphone.

Our findings add new insight and indicate that the same magnitude of incentives can have a significantly different effect on outcomes depending on how the incentive is designed. Specifically, financial incentives might be more effective if their design moved beyond a mere transaction and instead reflected predictable opportunities to enhance behavior change (18, 19, 21).

The Centers for Disease Control and Prevention has recommended that the workplace may be a good environment to implement wellness programs to target changes in health outcomes, such as increasing physical activity (8). However, there is some concern that these programs are not benefiting less healthy employees and instead simply increasing their cost burden (47). For example, programs that have been shown to be effective at changing behaviors among more seden-

tary persons are lacking (48–50). Evidence suggests that workplace interventions tend to better engage more motivated persons with higher baseline physical activity levels (12). However, those who may benefit more from these interventions probably have less motivation and lower baseline physical activity levels. In our study, employees had a mean BMI of 33.2 kg/m², which is one indication that these participants may be more sedentary (51). Among the 279 participants who received the intervention, 269 (96.4%) remained in the study at 13 weeks. No financial incentives were provided during follow-up, but participants continued to receive daily performance feedback. By 26 weeks, 267 participants (95.7% of those who started; 99.3% of those who reached 13 weeks) remained in the study. These high engagement rates may indicate that the

Table 4. Adjusted Differences in Mean Daily Step Counts

Group Comparison	Intervention (wk 1-13)		Follow-up (wk 14-26)	
	Difference in Daily Steps (95% CI)	P Value	Difference in Daily Steps (95% CI)	P Value
Main model*				
Gain incentive vs. control	378 (−499 to 1254)	0.40	74 (−801 to 950)	0.87
Lottery incentive vs. control	248 (−644 to 1139)	0.59	−55 (−943 to 833)	0.90
Loss incentive vs. control	861 (−20 to 1743)	0.056	496 (−371 to 1363)	0.26
Main model adjusted by device†				
Gain incentive vs. control	459 (−382 to 1299)	0.28	131 (−702 to 965)	0.76
Lottery incentive vs. control	280 (−575 to 1135)	0.52	−33 (−879 to 812)	0.94
Loss incentive vs. control	798 (−48 to 1644)	0.064	439 (−386 to 1265)	0.30
Main model adjusted by device† and excluding step counts < 1000				
Gain incentive vs. control	406 (−380 to 1193)	0.31	30 (−741 to 802)	0.94
Lottery incentive vs. control	245 (−556 to 1046)	0.55	−91 (−873 to 691)	0.82
Loss incentive vs. control	713 (−78 to 1505)	0.077	468 (−293 to 1229)	0.23

* Adjusted for repeated measures of daily participant step counts and for temporal trends by week using all collected data.

† Type of smartphone.

methods used in this study show promise for better engaging overweight and obese persons.

Many employers have become more interested in using wearable and mobile devices in wellness programs (52). Based on our findings, a smartphone-based approach to data collection resulted in high engagement probably because it required little additional effort from the participants other than carrying the device (which they may already be accustomed to doing). Because more than two thirds of adults in the United States have a smartphone (53, 54) and these devices are accurate for tracking step counts (29), smartphones may be a more scalable method to deploy interventions that track physical activity. Although our findings show promise for the role of smartphones in monitoring behaviors, they also confirm the notion that these technologies must be combined with carefully tested behavior change strategies to effectively improve health outcomes (52).

Future studies might compare alternate methods of using loss aversion to design incentives and could further test the optimal magnitude and frequency. Insights from this study should be incorporated into evaluations of longer-term sustainability and may benefit from opportunities to incorporate social incentives, such as team-based designs that focus on peer support, teammate accountability, and unity toward a common goal (52).

Our study has several limitations. First, participants were from a single employer in Philadelphia, which may limit generalizability because physical activity is harder in some regions with different climate, outdoor space, and culture. Second, participants needed a smartphone, which potentially makes participation less likely for those without such a device. Third, participants' physical activity was not tracked when they were not carrying their smartphones; thus, the captured physical activity levels may be lower than their actual activity. At the end of the intervention, however, about 93% of respondents stated that they carried their smartphone most or all of the time. Fourth, we did not obtain data on baseline step counts, but randomization resulted in well-balanced study groups. Therefore, outcomes among groups may reflect the differential effectiveness of interventions. In addition, self-reported physical activity did not differ among groups; however, these data seem to reflect overestimates of baseline activity because step-count data indicate that our population may be less physically active than they initially reported. Finally, our study was not well-powered to detect smaller differences or do comparisons among the intervention groups. In addition, the continuous outcome measure had a wider distribution than anticipated and we did not have enough statistical power to adequately detect differences among study groups.

In summary, more than half of adults in the United States do not attain the minimum recommended level of physical activity to achieve health benefits. Although the popularity of wellness programs and the use of mobile technologies to monitor health outcomes are rising, there has been a lack of rigorous study evaluat-

ing their effectiveness and the optimal design of financial incentives had not been well-examined. Our findings suggest that the design of financial incentives is important and that incorporating insights from behavioral economics may significantly improve their effectiveness.

From the Perelman School of Medicine at the University of Pennsylvania, Penn Medicine Center for Health Care Innovation, Wharton School of the University of Pennsylvania, Center for Health Incentives and Behavioral Economics at the Leonard Davis Institute of the University of Pennsylvania, and Philadelphia Veterans Affairs Medical Center, Philadelphia, Pennsylvania; Massachusetts General Hospital, Boston, Massachusetts; and Columbia University Medical Center, New York, New York.

Disclaimer: Dr. Patel had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Requests for Single Reprints: Mitesh S. Patel, MD, MBA, MS, Division of General Internal Medicine, Perelman School of Medicine at the University of Pennsylvania, 423 Guardian Drive, 13th Floor Blockley Hall, Philadelphia, PA 19104; e-mail, mpatel@upenn.edu.

Current author addresses and author contributions are available at www.annals.org.

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Current Author Addresses: Dr. Patel: Division of General Internal Medicine, Perelman School of Medicine at the University of Pennsylvania, 423 Guardian Drive, 13th Floor Blockley Hall, Philadelphia, PA 19104.

Drs. Asch and Rosin: Penn Medicine Center for Health Care Innovation, 13th Floor Blockley Hall, 423 Guardian Drive, Philadelphia, PA 19104.

Dr. Small: The Wharton School, University of Pennsylvania, 4th Floor Jon M. Huntsman Hall, 3730 Walnut Street, Philadelphia, PA 19104.

Ms. Bellamy: Division of General Internal Medicine, Perelman School of Medicine at the University of Pennsylvania, 423 Guardian Drive, 6th Floor Blockley Hall, Philadelphia, PA 19104.

Dr. Heuer, Ms. Sproat, and Mr. Hyson: Division of Human Resources, University of Pennsylvania, Suite 527A, 3401 Walnut Street, Philadelphia, PA 19104.

Dr. Haff: Massachusetts General Hospital, 730 Gray Bigelow, 55 Fruit Street, Boston, MA 02114.

Dr. Lee: Columbia University Medical Center, 622 West 168th Street, New York, NY 10032.

Ms. Wesby, Ms. Hoffer, Ms. Hilbert, Ms. Yang, Ms. Wang, Mr. Shuttlesworth, Mr. Taylor, Mr. Zhu, and Dr. Volpp: Center for Health Incentives and Behavioral Economics at the Leonard Davis Institute, University of Pennsylvania, 11th Floor Blockley Hall, 423 Guardian Drive, Philadelphia, PA 19104.

Author Contributions: Conception and design: M.S. Patel, D.A. Asch, R. Rosin, N. Haff, D. Shuttlesworth, K.G. Volpp.

Analysis and interpretation of the data: M.S. Patel, D.A. Asch, D.S. Small, S.L. Bellamy, J. Heuer, S.M. Lee, L. Wesby, D. Shuttlesworth, J. Zhu, L. Yang, X. Wang, K.G. Volpp.

Drafting of the article: M.S. Patel, D.A. Asch, S.L. Bellamy, J. Heuer, D. Shuttlesworth, V. Hilbert.

Critical revision of the article for important intellectual content: M.S. Patel, D.A. Asch, D.S. Small, S.L. Bellamy, L. Wesby, D. Shuttlesworth, J. Zhu, K.G. Volpp.

Final approval of the article: M.S. Patel, D.A. Asch, R. Rosin, S.L. Bellamy, S.M. Lee, D. Shuttlesworth, K.G. Volpp.

Provision of study materials or patients: D. Shuttlesworth, D.H. Taylor.

Statistical expertise: D.S. Small, S.L. Bellamy, J. Zhu.

Obtaining of funding: D.A. Asch, K.G. Volpp.

Administrative, technical, or logistic support: M.S. Patel, R. Rosin, J. Heuer, S. Sproat, C. Hyson, N. Haff, L. Wesby, K. Hoffer, D. Shuttlesworth, V. Hilbert, K.G. Volpp.

Collection and assembly of data: L. Wesby, K. Hoffer, D. Shuttlesworth, V. Hilbert.

Appendix Table 1. Sensitivity Analysis for Binary Model of Achieving the 7000-Step Goal During the Intervention and Follow-up*

Group Comparison, by Model†	Intervention (wk 1-13)		Follow-up (wk 14-26)	
	Odds Ratio (95% CI)	P Value	Odds Ratio (95% CI)	P Value
Main model: pseudolikelihood approach				
Gain incentive vs. control	1.44 (0.70–2.94)	0.32	1.03 (0.52–2.04)	0.93
Lottery incentive vs. control	1.46 (0.70–3.02)	0.31	0.84 (0.42–1.68)	0.62
Loss incentive vs. control	2.51 (1.22–5.17)	0.012	1.47 (0.75–2.88)	0.27
Main model: quadrature approach				
Gain incentive vs. control	1.47 (0.69–3.14)	0.15	1.05 (0.50–2.20)	0.89
Lottery incentive vs. control	1.45 (0.67–3.16)	0.57	0.82 (0.39–1.74)	0.61
Loss incentive vs. control	2.61 (1.21–5.61)	0.014	1.52 (0.73–3.15)	0.26

* Boldface values meet the significance threshold of $P < 0.017$.

† Approach refers to the regression estimation method used with PROC GLIMMIX in SAS, version 9.4 (SAS Institute). Pseudolikelihood approach used METHOD=RSPL; quadrature approach used METHOD=QUAD(qpoints=12).

Appendix Table 2. Sensitivity Analysis for Difference in Mean Daily Steps During the Intervention and Follow-up

Group Comparison, by Model*	Intervention (wk 1-13)		Follow-up (wk 14-26)	
	Difference in Daily Steps (95% CI)	P Value	Difference in Daily Steps (95% CI)	P Value
Main model: pseudolikelihood approach				
Gain incentive vs. control	378 (–499 to 1254)	0.40	74 (–801 to 950)	0.87
Lottery incentive vs. control	248 (–644 to 1139)	0.59	–55 (–943 to 833)	0.90
Loss incentive vs. control	861 (–20 to 1743)	0.056	496 (–371 to 1363)	0.26
Main model: quadrature approach				
Gain incentive vs. control	397 (–482 to 1275)	0.38	73 (–790 to 935)	0.87
Lottery incentive vs. control	276 (–618 to 1170)	0.55	–56 (–932 to 819)	0.90
Loss incentive vs. control	879 (–5 to 1763)	0.05	497 (–357 to 1351)	0.25

* Approach refers to the regression estimation method used with PROC GLIMMIX in SAS, version 9.4 (SAS Institute). Pseudolikelihood approach used METHOD=RSPL; quadrature approach used METHOD=QUAD(qpoints=12).