ORIGINAL ARTICLE

Heterogeneity in the Effects of Reward- and Deposit-based Financial Incentives on Smoking Cessation

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Abstract

Rationale: Targeting different smoking cessation programs to smokers most likely to quit when using them could reduce the burden of lung disease.

Objectives: To identify smokers most likely to quit using pure reward-based financial incentives or incentive programs requiring refundable deposits to become eligible for rewards.

Methods: We conducted prespecified secondary analyses of a randomized trial in which 2,538 smokers were assigned to an $800 reward contingent on sustained abstinence from smoking, a refundable $150 deposit plus a $650 reward, or usual care.

Measurements and Main Results: Using logistic regression, we identified characteristics of smokers that were most strongly associated with accepting their assigned intervention and ceasing smoking for 6 months. We assessed modification of the acceptance, efficacy, and effectiveness of reward and deposit programs by 11 prospectively selected demographic, smoking-related, and psychological factors. Predictors of sustained smoking abstinence differed among participants assigned to reward- versus deposit-based incentives. However, greater readiness to quit and less steep discounting of future rewards were consistently among the most important predictors. Deposit-based programs were uniquely effective relative to usual care among men, higher-income participants, and participants who more commonly failed to pay their bills (all interaction P values < 0.10). Relative to rewards, deposits were more effective among black persons ($P = 0.022$) and those who more commonly failed to pay their bills ($P = 0.082$). Relative to rewards, deposits were more commonly accepted by higher-income participants, men, white persons, and those who less commonly failed to pay their bills (all $P < 0.05$).

Conclusions: Heterogeneity among smokers in their acceptance and response to different forms of incentives suggests potential benefits of targeting behavior-change interventions based on patient characteristics.

Clinical trial registered with www.clinicaltrials.gov (NCT 01526265).

Keywords: financial incentives; smoking cessation; behavior change; heterogeneity of treatment effect

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At a Glance Commentary

Scientific Knowledge on the Subject: Financial incentives promote smoking cessation with success rates at least as good as pharmacotherapies. Because these incentive programs are cost effective and cost saving for large employers, they are being widely adopted in workplace wellness programs. However, it is unknown which types of smokers respond optimally to which types of incentive programs.

What This Study Adds to the Field: In prespecified secondary analyses of data from our recent randomized trial of four incentive programs for smoking cessation, we found several patient factors that predict success and modify the relative effectiveness of incentives structured as pure rewards of approximately $800 and incentives structured as financial deposits of $150 that are refundable on successful cessation along with rewards of $650. Just as genotypic analyses offer promise to improve the precision of targeted pharmaceuticals, these data suggest that phenotyping smokers may enable clinicians, insurers, and employers to target different incentive programs to different smokers to augment overall rates of smoking cessation.

Smoking remains the leading cause of preventable lung disease worldwide, and indeed of all preventable morbidity and mortality (1, 2). Recent evidence from two randomized controlled trials (RCTs) conducted among employees of large companies (3, 4) and a Cochrane review (5) suggests that financial incentives are among the most effective of all interventions to promote smoking cessation (6), and that their effects are sustained to similar degrees as are those of other therapies for smoking cessation (3).

Motivated by this evidence, and by provisions of the Affordable Care Act that promote workplace wellness incentives (7), large employers now spend more than $600 per employee each year on financial incentives to promote healthy behaviors, such as smoking cessation (8). Although the designs of these programs differ across employers, we are not aware of attempts to base program design on the individual characteristics of the people to whom they are offered. Rather, programs typically offer the same incentive structure to all eligible participants. This one-size-fits-all approach does not reflect the possibility that people respond heterogeneously to incentive programs, including those that use rewards or penalties.

Knowledge of such heterogeneity of treatment effects is limited (5, 9) because most incentive trials to date have been too small to support adequately powered subgroup analyses. However, our recently completed RCT (3) was specifically and prospectively designed for such subgroup analyses. Here, we identify participant characteristics that are most strongly associated with the effectiveness of incentive programs structured as pure rewards or as a combination of rewards and refundable deposits. We also report participant characteristics associated with acceptance, or uptake, of the assigned programs, which was a unique focus of our trial. Finally, we report participant characteristics that modify the effectiveness, acceptance, and efficacy conditional on acceptance of the different incentive programs.

Methods

We performed a secondary analysis of a five-arm RCT of interventions to promote smoking cessation among CVS Health employees, family, and friends (3, 10). All participants were offered usual care, which included information about local smoking cessation resources; a cessation guide; and, for employees receiving CVS Health benefits, free access to nicotine-replacement therapy and behavioral counseling. Participants randomly assigned to one of the four intervention arms also received financial incentives with expected values of $800. Two of the incentive programs targeted individuals, and two targeted groups of six participants. One each of the individual- and group-oriented programs entailed an $800 reward; the other required a deposit of $150 to be refunded along with a $650 reward for successful participants (3). For the current analyses, we combined the two reward programs and the two deposit programs because we did not establish *a priori* hypotheses regarding participant characteristics that would modify the effects of individual versus group programs. Furthermore, we observed similar effectiveness of the individual and group programs on average (3).

Outcomes

We explored associations between baseline participant characteristics and three outcomes: (*1*) acceptance of the assigned incentive program, (*2*) efficacy of the assigned program conditional on acceptance, and (*3*) effectiveness of the program among all those assigned to it. Acceptance was defined as participants' stated agreement to use the assigned incentive program. In the two arms requiring deposits, acceptance also required participants to make their $150 deposits by credit or debit card within 60 days of enrollment or before their selected quit date, whichever came first.

Efficacy was assessed in an as-treated analysis in which participants who declined their assigned intervention were analyzed in the usual care arm. We chose this design because participants who declined their assigned intervention retained access to usual care interventions.

For analyses of effectiveness, consenting participants who declined their assigned intervention remained in their assigned arm in intention-to-treat analyses, even though they were treated identically to those in the usual care arm. Thus, the interventions' overall effectiveness equaled the product of their acceptance and efficacy conditional on acceptance (11).

Success in the efficacy and effectiveness analyses was defined as sustained smoking abstinence for 6 months (12). Achieving sustained abstinence required submission of salivary samples with cotinine less than 10 ng/ml (13) at 14 days, 30 days, and 6 months following the target quit date. For participants using nicotine-replacement therapy, urinary samples with anabasine less than 3 ng/ml (14) at these same time points connoted sustained abstinence. Participants who did not submit samples were coded as actively smoking.

Development of Parsimonious Models

Logistic regression models were used for all analyses. All variables measured at baseline that had prior theoretical or empirical bases

for associations with smoking cessation were eligible for inclusion in models for the acceptance and effectiveness of incentive programs (Table 1).

We sought to identify the most parsimonious models to ascertain independent predictors of the acceptance and effectiveness of reward- and deposit-based programs, separately, using the MASS package available in the R programming environment (15). In contrast to a traditional prediction model, which might include all potential predictors, our approach used stepwise selection of covariates to be included in the model based on the Akaike information criterion (AIC) (16). A variable was retained if its inclusion yielded a lower AIC value for the model, indicating improved model fit after accounting for a penalty applied for each

Table 1. Patient Characteristics

Total Patients in RCT Eligible for Analysis **Analytic Sample with All Covariates** **Percent of Full Sample**	**Acceptance** **n = 2,070** **n = 2,014** **97.3**			**Cessation at 6 Months** **n = 2,538** **n = 2,471** **97.4**		
	No (*n = 980*)	**Yes** (*n = 1,034*)	***P* Value**	**No** (*n = 2,183*)	**Yes** (*n = 288*)	***P* Value**
Median age, yr (IQR)	33 (25 to 46)	33 (26 to 46)	0.60	33 (25 to 46)	34 (26 to 49)	0.009
Female, n (%)	617 (63)	642 (62)	0.69	1,377 (63)	175 (61)	0.45
Race, n (%)*						
White	766 (78)	823 (80)	0.61	1,719 (79)	230 (80)	0.30
Black	96 (10)	101 (10)		217 (10)	21 (7)	
Other	118 (12)	110 (11)		247 (11)	37 (13)	
Household income, n (%)						
>100k	77 (8)	111 (11)	0.046	190 (9)	32 (11)	<0.001
$80 to 100k	57 (6)	73 (7)		133 (6)	25 (9)	
$60 to 80k	107 (11)	110 (11)		232 (11)	43 (15)	
$40 to 60k	175 (18)	181 (18)		379 (17)	65 (23)	
$30 to 40k	146 (15)	111 (11)		281 (13)	37 (13)	
$20 to 30k	196 (20)	207 (20)		436 (20)	43 (15)	
$10 to 20k	128 (13)	153 (15)		323 (15)	23 (8)	
$10k	94 (10)	88 (9)		209 (10)	20 (7)	
Has insurance benefits, n (%)	393 (40)	443 (43)	0.21	893 (41)	128 (44)	0.25
Married or living with partner, n (%)	421 (43)	460 (44)	0.49	937 (43)	157 (55)	<0.001
⩾1 yr of college, n (%)	549 (56)	677 (65)	<0.001	1,291 (59)	205 (71)	<0.001
Years of smoking, n (%)						0.66
<10	363 (37)	374 (36)	0.53	793 (36)	105 (36)	
10 to 20	266 (27)	304 (29)		604 (28)	86 (30)	
>20	351 (36)	356 (34)		786 (36)	97 (34)	
Cigarettes per day, n (%)			0.03			<0.001
<10	199 (20)	255 (25)		468 (21)	86 (30)	
10 to 20	438 (45)	413 (40)		927 (42)	126 (44)	
>20	343 (35)	366 (35)		788 (36)	76 (26)	
Fagerström scale groups, n (%)†			0.76			<0.001
Low dependence	203 (21)	231 (22)		437 (20)	96 (33)	
Low to moderate dependence	301 (31)	312 (30)		668 (31)	90 (31)	
Moderate dependence	433 (44)	452 (44)		976 (45)	97 (34)	
High dependence	43 (4)	39 (4)		102 (5)	5 (2)	
Stages of change, n (%)‡						
Preparators (plan to quit in next 30 d)	608 (62)	680 (66)	0.08	1,360 (62)	224 (78)	
Contemplators (plan to quit in next 6 mo)	372 (38)	354 (34)		823 (38)	64 (22)	<0.001
Exposed to smoke at home, n (%)	461 (47)	506 (49)	0.40	1,062 (49)	134 (47)	0.50
Successfully quit for a 24-h period in last year, n (%)	595 (61)	665 (64)	0.095	1,374 (63)	178 (62)	0.71
Currently using other methods to quit smoking, n (%)	110 (11)	125 (12)	0.55	262 (12)	38 (13)	0.56
Median substitute reinforcer, value (IQR)	79 (55 to 102)	79 (55 to 101)	0.95	79 (54 to 102)	82 (58 to 106)	0.061
Median complimentary reinforcer, value (IQR)	43 (27 to 62)	44 (27 to 65)	0.32	44 (27 to 63)	41 (25 to 63)	0.153
Natural log of the Kirby discounting value	−3.2 (−5.1 to −2.3)	−4.1 (−5.1 to −2.3)	0.07	−3.2 (−5.1 to −2.3)	−4.1 (−5.6 to −3.2)	<0.001
Median months failed to pay bills in past year (0 to 12) (IQR)	1 (0 to 3)	1 (0 to 4)	0.25	1 (0 to 3)	0 (0 to 3)	0.70
Median reported spare money this week (0 = very little, 10 = a lot) (IQR)	1 (0 to 3)	2 (0 to 4)	0.21	1 (0 to 4)	2 (0 to 4)	0.011

Definition of abbreviations: IQR = interquartile range; RCT = randomized controlled trial.

*Race was self-reported.

†The level of dependence is based on the score on the Fagerström Test for Nicotine Dependence. Scores range from 1 to 10, with higher scores indicating a more intense physical dependence on nicotine. Low dependence corresponds to a score of 1 or 2, low-to-moderate dependence a score of 3 or 4, moderate dependence a score of 5 to 7, and high dependence a score of 8 to 10.

‡The participants were asked, "Are you seriously thinking of quitting smoking?" and were given three options to select: yes, within the next 30 d (preparation stage); yes, within the next 6 mo (contemplation stage); or no, not thinking of quitting (precontemplation stage). The values for contemplation stage include 10 participants in the precontemplation stage: two participants in the usual-care group, two participants in the individual-reward group, two participants in the collaborative-reward group, three participants in the individual-deposit group, and one participant in the competitive-deposit group.

additional variable required to achieve that fit.

To minimize type-II errors, we subsequently removed variables that were not significantly associated with the outcome at *P* less than 0.05, even if their inclusion reduced the model AIC. We assessed the relative importance of each retained variable by calculating the increase in the model's AIC value when that variable is removed. Before selecting predictors according to AIC, we forced the three design variables into all models: randomized treatment assignment and the two stratifying variables of annual household income and receipt of health benefits through CVS (17).

Effect Modification Analyses

We explored patient characteristics that modified the comparative efficacy and effectiveness of the reward and deposit programs by examining interactions between these characteristics and the three main contrasts between rewards and usual care, deposits and usual care, and rewards and deposits. To identify factors that modified intervention acceptance, we evaluated only the contrast between reward and deposit programs because all enrollees were considered to have accepted usual care.

We evaluated 11 patient characteristics that were hypothesized *a priori* to modify the acceptance, efficacy, or effectiveness of incentives. These factors included sex and race, which have previously been shown to influence quit rates (18); three factors previously linked to response to smoking cessation interventions (Prochaska stage of change (19), the Fagerström Test for Nicotine Dependence (20), and use of adjunctive cessation aids, such as nicotine-replacement therapy); measures of both substitute reinforcers (activities that replace smoking, such as hobbies) and complementary reinforcers (activities engaged in conjunction with smoking, such as drinking coffee) (21, 22); and the magnitude of temporal discounting as reflected by the Kirby scale (23). Temporal discounting is a measure of the degree to which people prioritize present rewards (such as $100 today) over future rewards (such as $110 next month); as such, it is a measure of impulsivity (24) and tends to correlate with unhealthy behaviors, such as smoking (24, 25). Finally, given our focus on response to financial incentives, we examined both annual household income and the number of months out of the past 12 that participants reported not having enough money to pay their bills. We hypothesized that the latter variable would measure participants' general economic well-being, independent of their income.

In testing for effect modification, we considered interactions to be significant at *P* less than or equal to 0.10 and did not adjust for multiple comparisons. We evaluated each interaction term separately in a model adjusted for all main effects to estimate stratum-specific effects of each program on acceptance, efficacy, and effectiveness. We also report results from a fully adjusted model that retained all significant interaction terms and main effects.

Results

Of the 2,538 trial participants, 2,471 (97.4%) had complete data for all preselected variables for analysis. These 2,471 participants' annual household incomes were broadly distributed, with roughly 10% of participants' households earning more than $100,000 annually, and another 10% earning less than $10,000 annually (Table 1). Approximately one-third of participants had been smoking for more than 20 years, and one-third were smoking more than one pack each day at the time of enrollment.

Factors Associated with Sustained Abstinence from Smoking

As previously reported, overall rates of sustained abstinence through 6 months were 6.0%, 10.2%, and 15.7% among participants in the control group, deposit groups, and rewards groups, respectively (3). In unadjusted analyses, participants who attained sustained smoking abstinence were slightly older and more likely to have higher incomes, be married, have had at least a year of college, smoke fewer cigarettes per day, be in the preparatory stage of change on the Prochaska scale rather than the contemplative or

Table 2. Parsimonious Model of Sustained Smoking Abstinence for 6 Months among Participants Assigned to Reward-based Incentives (n = 990)

	OR	95% CI	*P* Value	AIC Increase*
Fagerström scale			<0.001	17.27
Moderate vs. high dependence	1.11	0.41–3.89		
Low to moderate vs. high dependence	1.99	0.73–6.97		
Low dependence vs. high dependence	3.20	1.18–11.27		
Pre/contemplators vs. preparators	0.55	0.37–0.82	0.004	7.00
Married or living with partner vs. other	1.76	1.21–2.56	0.003	6.90
Natural log of Kirby discounting score (1-unit increase)	0.88	0.81–0.97	0.008	4.78
Base model (design variables)†				
Intervention arm				
Collaborative vs. individual rewards	1.05	0.74–1.51	0.78	
Household income			0.028	
$80–100k vs. >100k	1.91	0.78–4.78		
$60–80k vs. >100k	2.54	1.17–5.84		
$40–60k vs. >100k	1.85	0.89–4.11		
$30–40k vs. >100k	2.23	1.01–5.16		
$20–30k vs. >100k	1.37	0.64–3.07		
$10–20k vs. >100k	0.74	0.29–1.86		
$10k vs. >100k	1.08	0.41–2.83		
Has benefits vs. no benefits	1.07	0.74–1.55	0.72	

Definition of abbreviations: AIC = Akaike information criterion; CI = confidence interval; OR = odds ratio.

*The stepAIC procedure in R selects the best model based on the combination of variables that achieves the lowest AIC. The AIC for the best-fitting model was 822.35. The AIC shown in the last column indicates the absolute increase in the AIC (from 822.35 in the best model) if that single variable is removed from the full model shown in the table. Variables are presented in order of decreasing changes, indicating less predictive improvement related to that predictor.

†The AIC for the base model, which included the three design variables (intervention arm, household income, and insurance benefits), was 858.86.

precontemplative stages, and exhibit less nicotine dependence as defined by Fagerström scores less than or equal to four (all $P < 0.01$) (Table 1). Successful abstainers also displayed less impulsivity, as reflected by less steep temporal discounting functions ($P < 0.001$), and reported more spare money ($P = 0.01$). Participants who did and did not quit reported similar levels of substitute ($P = 0.06$) and complementary reinforcers ($P = 0.15$), and had failed to pay their bills for a similar number of months in the preceding year ($P = 0.70$).

After forcing in the three design variables of randomization arm, income, and receipt of health benefits, the most parsimonious model of participant characteristics associated with achieving sustained abstinence after assignment to reward programs included four additional variables. In order of decreasing importance, these independent predictors were: having lower levels of nicotine dependence, being in a preparatory as opposed to contemplative or precontemplative stage of change, being married, and less steep temporal discounting (Table 2). Reduced temporal discounting was also the strongest of five independent predictors of accepting reward programs (*see* Table E1 in the online supplement).

The parsimonious model of participant characteristics associated with sustained abstinence after assignment to deposit programs included seven variables. In decreasing order of importance, these were: being in a preparatory as opposed to contemplative or precontemplative stage of change, having a shorter history of smoking, older age, having attended at least 1 year of college, having failed to pay bills for more months, having more spare money, and having less steep temporal discounting functions (Table 3). College education, being in preparatory stage of change, and having more spare money were the three independent predictors of accepting deposit-based programs (*see* Table E2).

Modifiers of Intervention Effectiveness

We assessed 10 prespecified potential modifiers of the overall effectiveness of financial incentives. The values of all stratum-specific odds ratios and interaction *P* values are presented in Table E3. Here, we briefly note the four variables that significantly modified one or more of the primary contrasts.

The effectiveness of deposits relative to usual care was greater among participants with higher incomes (interaction $P = 0.069$) and participants who more commonly failed to pay their bills (interaction $P = 0.010$), without any corresponding changes in the effectiveness of reward-based incentives (Figure 1). Of note, participants' household incomes were minimally correlated with the number of months they failed to pay their bills (Pearson $r^2 = -0.048$; 95% confidence interval, -0.087 to -0.009).

The relative effectiveness of deposits versus usual care was also significantly greater among men than women (interaction $P = 0.068$). The effectiveness of rewards versus usual care was significantly greater among white than black persons (interaction $P = 0.076$). Finally, whereas rewards were significantly more effective than deposits among white persons, deposits were nonsignificantly superior to rewards among black persons (interaction $P = 0.022$) (Figure 1; *see* Table E3).

Modifiers of Intervention Acceptance

Reward programs were more commonly accepted than deposit programs across all tested subgroups. However, deposits were relatively more commonly accepted (i.e., the gaps in acceptance rates between deposits and rewards were smaller) among higher-income participants, men, white persons, and those who more commonly failed to pay their bills (all interaction $P < 0.05$) (Figure 2). No other measured participant characteristic modified the difference in acceptance between rewards and deposits (*see* Table E4).

Modifiers of Intervention Efficacy

Race was the only variable to significantly modify the efficacy of incentive programs

Table 3. Parsimonious Model of Sustained Smoking Abstinence for 6 Months among Participants Assigned to Deposit-based Incentives (n = 1,024)

	OR	95% CI	*P* Value	AIC Increase*
Pre/contemplators vs. preparators	0.39	0.22–0.64	<0.001	12.18
Smoking history, yr			<0.001	10.85
10–20 vs. <10	0.90	0.53–1.55		
>20 vs. <10	0.26	0.12–0.56		
Age (1-yr increase)	1.05	1.02–1.07	0.001	8.64
⩾1 yr of college vs. less than college	1.86	1.16–3.05	0.011	4.78
Months failed to pay bills in last year (1-mo increase)	1.07	1.01–1.12	0.010	4.20
Spare money this week (1-unit increase; reference = very little; range, 0–12)	1.10	1.01–1.19	0.031	2.52
Natural log of Kirby discounting score (1-unit increase)	0.89	0.80–0.99	0.038	2.23
Base model (design variables)†				
Intervention arm				
Competitive vs. individual deposits	1.10	0.72–1.69	0.65	
Household income			0.190	
$80–100k vs. >100k	0.99	0.39–2.42		
$60–80k vs. >100k	1.19	0.53–2.65		
$40–60k vs. >100k	1.08	0.53–2.24		
$30–40k vs. >100k	0.58	0.25–1.31		
$20–30k vs. >100k	0.45	0.19–1.01		
$10–20k vs. >100k	0.56	0.21–1.38		
$10k vs. >100k	0.66	0.22–1.81		
Has benefits vs. no benefits	1.17	0.75–1.80	0.49	

Definition of abbreviations: AIC = Akaike information criterion; CI = confidence interval; OR = odds ratio.

*The stepAIC procedure in R selects the best model based on the combination of variables that achieves the lowest AIC. The AIC for the best-fitting model was 643.45. The AIC shown in the last column indicates the absolute increase in the AIC (from 643.45 in the best model) if that single variable is removed from the full model shown in the table. Variables are presented in order of decreasing changes, indicating less predictive improvement related to that predictor.

†The AIC for the base model, which included the three design variables (intervention arm, household income, and insurance benefits), was 682.46.

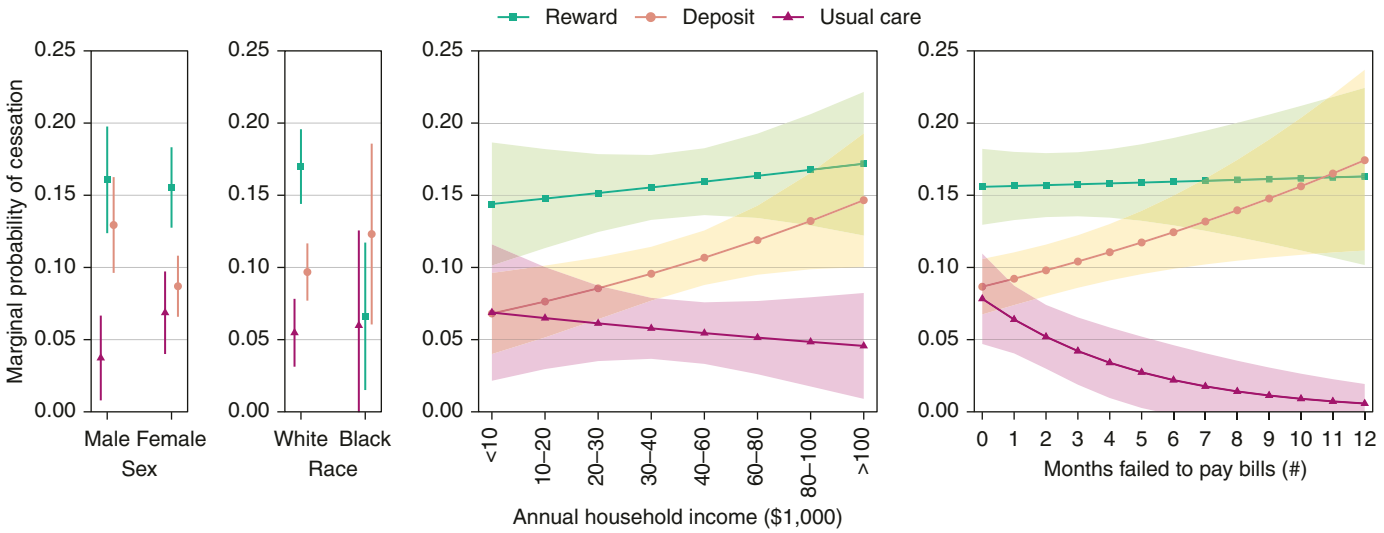

Figure 1. Six-month sustained smoking abstinence (overall effectiveness) following assignment to reward- and deposit-based incentive programs. Estimates are derived from a model that included the four interaction terms displayed and all covariates included in Table 1. *Bars* and *shaded* regions represent 95% confidence intervals. All interactions between incentive type (reward vs. deposit) and the patient characteristic (sex, race, annual household income, or months failed to pay bills) are significant at the prespecified threshold of $P < 0.10$.

among participants who accepted them. Specifically, rewards were significantly less efficacious relative to usual care among black than among white persons, and deposit programs were significantly more efficacious than rewards among black than among white persons (*see* Table E5). This explains the relative effectiveness of deposits relative to rewards among black persons despite the fact that deposits were relatively more commonly accepted among white persons.

Discussion

This analysis of the largest RCT of financial incentives for smoking cessation yields several important findings about how smokers' characteristics influence their success in quitting. First, we found that patient characteristics have considerable influence on the chances that a given smoker will quit when offered a given intervention. To provide context for the magnitudes of these effects, consider two hypothetical patients offered the reward-based program, and assume that these two patients differ only on the 11 variables we had hypothesized as potential effect modifiers *a priori*. The first patient has optimal values on these 11 variables (defined, for categorical variables, as the value associated with the highest quit rate, and for continuous variables as at the 90th percentile of the distribution). The second patient has suboptimal values on these 11 variables (defined as the value associated

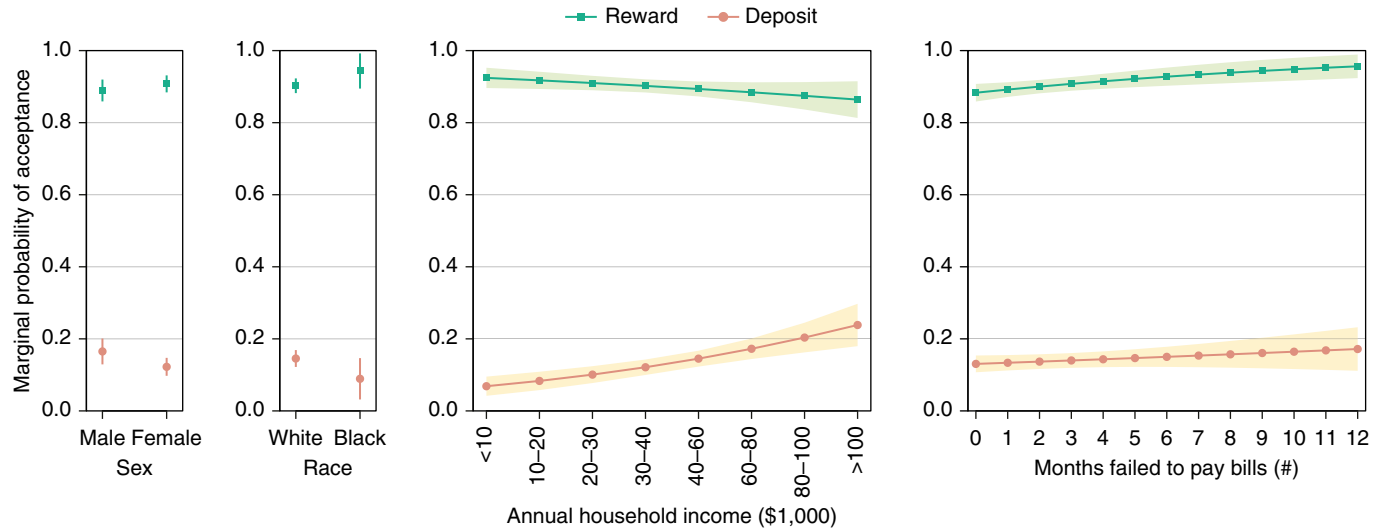

Figure 2. Acceptance of reward- and deposit-based incentive programs. Estimates are derived from a model that included the four interaction terms displayed and all covariates included in Table 1. *Bars* and *shaded* regions represent 95% confidence intervals. All interactions between incentive type (reward vs. deposit) and the patient characteristic (sex, race, annual household income, or months failed to pay bills) are significant at the prespecified threshold of $P < 0.10$.

with the lowest quit rate or at the 10th percentile). Our data suggest that the first patient would have a 39.0% chance of quitting with rewards, whereas the second patient would have only a 0.11% chance of quitting. Similar differences were found for different patients assigned to deposit programs.

Second, we found that the relative effectiveness of reward- and deposit-based incentive programs for smoking cessation was modified by at least four characteristics of smokers. For example, we found that deposit programs were particularly effective among male smokers, those with higher incomes, and those who more commonly failed to pay their bills. We had hypothesized that deposits may be more effective among men and among higher-income persons given known differences in risk-taking between genders (26) and the greater affordability of making a deposit among higher-income persons.

However, we had also hypothesized that participants who more commonly failed to pay their bills would be those with lower financial reserves (i.e., those that economists refer to as having less financial slack), or who have greater difficulty making ends meet regardless of their incomes. Correspondingly, we predicted that such smokers would less commonly make deposits to invest in their future health (27). Our findings that failure to pay one's bills is almost entirely independent of income, and that persons who engage in this behavior are preferentially motivated by deposit contracts, suggests that this measure may relate to a different construct, such as a greater propensity to take risks.

Third, this study reveals participant characteristics associated with both the acceptance and efficacy conditional on acceptance of incentive programs, which jointly contribute to programs' overall effectiveness (11). For example, the observed high effectiveness of deposits among men and those with higher incomes was largely attributable to these groups' greater acceptance of deposit programs. By contrast, although black persons were less likely than white persons to accept deposit contracts, those black persons who accepted such programs were much more likely to quit smoking than those who accepted rewards programs. The end result was that deposits were nominally more effective than rewards among black persons, in contrast to being significantly less effective than rewards among white persons. Future research is needed to confirm and explain this latter set of findings before specifically targeting different racial groups with different incentive programs.

Finally, we found that among the measured characteristics of smokers that predicted response to incentives, only two (smokers' stage of change and the steepness of their temporal discounting functions) were strongly associated with the effectiveness of both reward- and deposit-based programs. The importance of temporal discounting in predicting response to financial incentive programs complements and extends prior research showing that individuals who more strongly discount future rewards are more likely to smoke (24, 25) and less likely to quit smoking in response to other, non-incentive-based interventions (28, 29).

We had hypothesized that the incentive programs used in this trial, which provided larger "bonus" rewards in the future, may offset the steep temporal discounting displayed by smokers. Instead, it seems that promoting the effectiveness of incentives among smokers with the strongest present biases may require interventions that more directly modify temporal discounting rates. Preliminary evidence that forcing people to imagine their future selves may alter discounting (30–33) provides a promising area for future study, but there is as yet no compelling evidence that incentives or other interventions can be made to work well among these most-difficult-to-treat smokers.

These findings must be interpreted in light of the study's limitations. First, our assessments of predictors and modifiers of incentives' effects are not comprehensive. As in any randomized trial, we limited collection of covariates to those we believed would be most important based on prior evidence. Second, we used relatively liberal standards for determining the significance of effect modifications, with a *P* value cutoff of 0.10 that was not adjusted for multiple comparisons. These analytic choices were established *a priori* given the novelty of the tests for effect modification in smoking incentive trials. Furthermore, our goal was to generate hypotheses regarding how best to tailor future incentive programs to subgroups of smokers, and these hypotheses require confirmation in future trials.

Finally, the reported efficacy analyses are subject to selection biases. In reporting the primary trial results (3), we estimated efficacy by modeling the randomization arm as an instrumental variable (34, 35) in complier average treatment effect analyses (36–38). Similar approaches have yet to be extended to tests of effect modification. However, our goal in this manuscript was not to assess absolute efficacy, but rather to determine whether the relative efficacy of deposit and reward programs differed among subgroups. Such relative comparisons are less likely to be biased by selection effects. Furthermore, because our analyses of overall effectiveness used the intention-to-treat approach, these primary results should be free from bias.

Conclusions

In an era when precision medicine is invoked as a way to target therapies based on genomic variation, this study's findings reflect the same approach based on observable characteristics within a behavioral phenotype. This study also provides actionable results that may guide future programs designed to prevent the development of chronic obstructive pulmonary disease and other smoking-related disorders. More than 80% of large employers use financial incentives to promote employee health (39), and this practice will only expand because the Affordable Care Act now allows employers to use larger payments to change employees' behaviors and health outcomes (7). Our data suggest that in comparison with the one-size-fits-all approach currently used by employers, greater success may be obtained by targeting different incentive programs to different types of employees. Although it is premature to target specific groups of patients with different incentive programs in practice, the present data suggest the need for future trials that assess the feasibility and incremental cost-effectiveness of "individualized" incentive programs compared with uniform approaches. ■

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