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Contingency Management for College Student Smokers: The Role of Drinking as a Moderator and Mediator of Smoking Abstinence during Treatment

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Abstract

Introduction—Contingency management (CM) is effective for promoting smoking abstinence; however, moderators and mediators of CM treatment efficacy in young adult populations are under-explored. We leveraged fine-grained data from a large randomized controlled trial: 1) to determine whether early attainment of sustained abstinence mediated the effect of treatment on abstinence; 2) to test whether heavy drinking moderated the effect of treatment on abstinence; and 3) to test a serial mediation model of the effects of drinking during early treatment on sustained smoking abstinence.

Methods—College student smokers (N=110) were randomized to receive either CM treatment or noncontingent reinforcement (NR) over a 21-day treatment period. All participants received \$5 for providing twice-daily breath carbon monoxide (CO) samples. In CM, additional money was provided for samples that indicated smoking reduction (Initial Phase; first 7 days), and for samples 5ppm (Abstinence Phase; following 14 days).

Results—CM treatment led to greater sustained abstinence relative to NR. Longer sustained abstinence in the Initial Phase partially mediated the effect of treatment on sustained abstinence in the Abstinence Phase. Heavier pretreatment drinkers had shorter periods of sustained abstinence in the Abstinence Phase; this effect was greater in CM. A serial mediation model determined that

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DECLARATION OF INTERESTS

The authors have no financial conflicts of interest to disclose.

Contributors

RC analyzed the data and wrote the first draft of the paper. KJ consulted on statistical analysis and provided critical input to data analytic strategy. PM, SC and JT conceived the primary study. TT collected data. DR, NB and MM provided critical revisions to the manuscript. All authors approved the final manuscript.

Conflict of Interest

The authors have not conflicts of interest to report.

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increased drinking during the Initial Phase led to decreased sustained abstinence, which then led to decreased sustained abstinence in the Abstinence Phase.

Conclusions—These data provide a greater understanding of how heavy drinking and early sustained abstinence may affect success during treatment in young adults undergoing contingency management treatment for smoking.

Keywords

college students; smoking; contingency management; alcohol

1. INTRODUCTION

Smoking remains the leading cause of preventable death, and young adults (age 18–24) smoke at the highest rates of any age group in the United States¹. Tobacco companies specifically target young adult and college populations², and recent data indicate that the most common period of smoking uptake is now between the ages of 19–20, when many young adults are in college^{3,4}. Despite the relatively short history of smoking, by the end of college, smokers are more likely than their peers to experience adverse health effects such as increased sick days⁵. As smoking at this stage may be more malleable than later in life⁶, and because many of these young smokers will continue to smoke into adulthood⁷, targeted intervention in this population is key to reduce the burden of disease across the life course⁸.

One of the most effective interventions for reducing smoking in adults is contingency management (CM;^{9–11}). CM directly reinforces abstinence from smoking by providing monetary or other incentives contingent on evidence of abstaining from smoking¹². Although CM is known to be successful for reducing smoking in adults, it has rarely been studied in young adults or college students¹³. The neuroplasticity of young adulthood, combined with a heightened focus on immediate rewards, suggests that this developmental period may be particularly well-suited for CM intervention^{14,15}. CM for smoking in college students was shown to be efficacious at reducing smoking while contingencies were in place in a single prior study¹⁶. Overall, however, young adults are vastly under-studied in reference to contingency management protocols for smoking, and very little is known about how to optimize CM interventions for the unique environment of college.

Tevyaw et al.¹⁷ tested the efficacy of CM in a large, randomized controlled trial in a college student sample (CM versus a noncontingent reinforcement control group, NR). During the first week of the 3-week study, participants in the CM group were asked to reduce their smoking and were differentially reinforced for samples which showed a reduction in smoking (Initial Phase). During the second two weeks, participants in the CM group were reinforced for samples indicating abstinence (Abstinence Phase). Participants in the NR group were paid a set amount for providing samples, independent of the sample value. In that study, CM was significantly favored over NR for longest consecutive abstinence period, percent of abstinent readings, and lower average carbon monoxide (CO). Findings thus indicated that CM can be efficacious for abstinence from smoking in this population. However, within-person patterns of abstinence achievement and mediators of treatment success have not been explored.

The current study aims to provide a fine-grained analysis of patterns of abstinence achievement and explore mediators of treatment success during the Abstinence Phase of the intervention in the clinical trial reported by Tevyaw et al¹⁶. Long-term abstinence from smoking is achieved through attaining short-term smoking milestones: initiation of abstinence, and short-term abstinence¹⁸. Abstinence early in smoking treatment has also been associated with a greater likelihood of later, long-term abstinence among substance-dependent smokers¹⁹. In these analyses, we aim to capitalize on a study with an ideal design for examining within-person processes of change as we have data across 3 weeks, including abstinence initiation and maintenance during treatment.

One behavior that may undermine the initiation of abstinence and short-term maintenance of early abstinence is heavy alcohol use. In older adults, heavy alcohol use has proximal effects on treatment: higher pretreatment drinking levels are predictive of lower rates of abstinence among smokers enrolled in cessation trials^{20,21}. Alcohol may also directly undermine smoking cessation, as laboratory data show that drinking acutely increases smoking²²; thus, our fine-grained data gave us an opportunity to explore this possibility. In young adults in particular, drinking is closely associated with smoking, and college students often drink conjointly with smoking^{23–25}. Drinking can increase the likelihood of smoking on a particular occasion in this population, as well as the number of cigarettes smoked²⁶, and heavier drinking students may find it harder to be successful in smoking treatment²⁷. Binge drinking in particular is related to higher rates of smoking and dependence in this population²⁸, and problematic alcohol use is associated with greater nicotine dependence^{29,30}.

However, the extent to which degree of alcohol involvement may interact with contingency management treatment for smoking in college students has not been examined. Given the close links between smoking and drinking, it is likely that alcohol involvement may negatively affect treatment success, as adult alcohol-dependent individuals have more trouble quitting in CM trials relative to non-alcohol dependent smokers and lower quit rates overall relative to non-alcoholic smokers in contingency management treatment^{31,32}. This may be due to alcohol's negative effect on abstinence initiation and early maintenance of sustained abstinence. We tested this directly in this sample first by testing a simple mediation model in which treatment effect was hypothesized to be mediated by attainment of longer periods of abstinence in the Initial Phase. Then, we examined whether heavy pretreatment alcohol use at baseline moderated the effect of treatment (CM or NR) on sustained abstinence in the Abstinence Phase. Finally, we explored whether drinking during the Initial Phase directly mediated the effect of treatment condition on sustained abstinence during the Initial Phase and thus affected sustained abstinence in the Abstinence Phase in a serial mediation model.

2. METHODS

As the study methods have been described previously¹⁶, they are only briefly described here, but with greater detail for the relevant measures and procedures for the present study.

2.1. Participants

110 college students (38.2% female, 77.3% white) were randomized to treatment. To be included, participants had to be daily smokers and have an expired alveolar CO level at baseline of 10 ppm or greater, and be currently enrolled in college. Participants were on average 19.7 years old ($SD=1.3$), had an average CO of 18.8 parts per million (ppm; $SD=8.7$), and smoked on average 11.6 cigarettes per day ($SD=4.9$).

2.2. Study Design

The parent study used a 2×2 factorial design to investigate the effects of contingency management (CM) versus a non-contingent reinforcement (NR) control, crossed with a counseling component comparing three one-hour sessions of motivational interviewing versus a time-matched relaxation control across 3 weeks. Further details on the counseling interventions can be found in Tevyaw et al¹⁶. In this study, because there was no effect of MET during CM treatment, we collapsed across intervention conditions and focused on the CM and NR group interventions. Across all three weeks of the intervention, participants in both groups submitted breath CO samples twice daily.

2.3. Procedures

After completing informed consent procedures, participants completed baseline measures of individual differences and submitted a breath CO sample to determine eligibility. Eligible participants were randomized to either a CM or NR group. The participants were informed that a study staff member would meet with them twice each day for the duration of the study to test their CO, with a minimum of 6 hours between sample readings.

2.4. Study Interventions

The study took place across three weeks: A one-week Initial Phase, followed immediately by a two-week Abstinence Phase.

2.4.1. Initial Phase—During the initial study week, participants in the CM group were given \$5 per sample submitted. In addition, participants in the CM group were also given monetary reinforcement contingent on a percentage reduction in their CO from their baseline CO level³³. A reduction of more than 75% (or any CO level ≤ 5 ppm) earned the participants \$3 per sample, a 50–74% reduction earned \$2, and a 25–49% reduction earned \$1. Participants in the NR group earned \$5 per sample submitted regardless of the CO level. Payments were made in cash at the time of each sample reading.

2.4.2. Abstinence Phase—Immediately following the Initial Phase, participants in the CM group were asked to abstain from smoking, and payments in addition to the \$5 payment per sample submitted were contingent on evidence of abstinence (CO ≤ 5 ppm). An escalating schedule of reinforcement with reset was used, with payments beginning at \$3 and increasing by \$0.50 for each consecutive negative sample; a bonus of \$1 was given for two negative samples in a row³⁴. Missed or positive samples received no payment, and the first negative sample after a positive or missed sample was reset to \$3. Four consecutive negative samples following a reset would bring the payment value back to its value prior to

the reset. In the NR group, as in the initial week, participants earned \$5 per sample. The Abstinence Phase lasted two weeks.

2.5. Measures

2.5.1. Demographics—At baseline, participants reported their age, gender and other demographic characteristics.

2.5.2. Timeline Follow Back—This calendar-assisted interview is a validated method for determining recent smoking, alcohol and/or other drug use³⁵. From this measure, administered at baseline, average number of cigarettes per day over the last month and number of heavy drinking days (5 drinks for men, 4 drinks for women) in the last month were calculated.

2.5.3. Modified Fagerström Tolerance Questionnaire (mFTQ)—At baseline, participants completed this 7-item measure of nicotine dependence, which has been validated for use in young people ages 14–20^{36,37}. Total scores reflect baseline level of nicotine dependence, with 0–2 indicating no dependence, 3–5 indicating moderate dependence, and 6–9 indicating substantial dependence.

2.5.4. Carbon Monoxide samples—Samples were coded as abstinent during the initial and abstinence phase if the CO sample met the 5ppm criterion. Longest sustained abstinence in the Initial Phase and Abstinence Phase was calculated as the largest number of consecutive samples that were coded as abstinent. Missed samples were included in the abstinence analyses as positive samples, and missed samples did not result in payment in either group; missed samples are shown as missed in Figure 2.

2.6. Data Analysis

We dichotomized treatment as NR (0) or CM (1). To examine overall treatment effects, daily CO sample outcomes were plotted and examined visually for patterns in the data across groups³⁸. We also examined bivariate correlations between the outcome variable (longest sustained abstinent samples submitted during treatment) and relevant baseline characteristics (age, sex), to determine whether particular variables warranted inclusion as covariates.

2.6.1. Simple mediation—We conducted a simple mediation model examining whether the effect of treatment on sustained abstinence in the Abstinence Phase was mediated by longer periods of sustained abstinence in the Initial Phase. Baseline dependence was included in the model as a covariate.

2.6.2. Simple moderation—Moderation analyses were conducted to determine whether number of heavy drinking days in the previous month moderated the effect of treatment (CM=1, NR=0) on the longest period of sustained abstinence during the abstinence phase, controlling for dependence, age and gender³⁹. Age and gender were not significantly associated with the outcome and inclusion of these variables did not alter the pattern of results; thus, these variables were removed from this and subsequent models.

2.6.3. Serial multiple mediation model—In order to test whether drinking during the first week impacted early abstinence and later abstinence during treatment, we combined the two models described above to create the serial multiple mediation model depicted in Figure 1⁴⁰. The model hypothesizes that the effect of treatment is mediated via drinking days during the Initial Phase, which impacts the longest period of sustained abstinence during the Initial Phase, which in turn impacts sustained abstinence during the Abstinence Phase. All analyses were conducted with SPSS version 24 for Windows (IBM) and moderation and mediation analyses were conducted using the PROCESS macro for SPSS (³⁹) and all significance tests were considered significant at $\alpha=.05$.

3. RESULTS

3.1. Effect of treatment group on abstinence

The mean CO value during the Abstinence Phase was 6.2 ppm (SD=4.44) for the CM group and 11.94 ppm (SD=7.2) for the NR group. The mean percent of abstinence samples submitted during the Abstinence Phase was 55.22% (SD=36.49) for the CM group and 18.01% (SD=26.22) for the NR group. Figure 2 plots each sample submitted by each participant over the course of the entire 3-week trial as a function of group membership³⁸. Overall, participants in the CM group submitted more abstinent samples, and missed fewer samples, relative to the NR group. The average longest period of sustained abstinence for the Initial and Abstinence Phases, respectively, (measured in number of samples) was 1.4 and 2.0 in the NR group and 3.98 and 10.0 in the CM group. In the NR group, 1 participant was abstinent throughout the entire Initial Phase, and no participants were abstinent throughout the entire abstinence phase; in the CM group, 4 participants were abstinent throughout the entire Initial Phase and 4 participants were abstinent throughout the entire Abstinence Phase.

3.2. Sample characteristics and correlations among model variables

Across both groups, participants were on average 19.7 years old (SD=1.5). Participants were 38.2% female, had an average mFTQ score of 3.6 (SD=1.6), the average number of heavy drinking days at baseline was 6.9 (SD= 5.6), and the average longest period of sustained abstinent samples during the Initial Phase was 2.7 samples (SD=3.5). Pearson's correlations between the outcome variable (longest period of sustained abstinence during the Abstinence Phase) and all independent variables (heavy drinking at baseline, longest sustained abstinence in Initial Phase, and treatment group assignment) and covariates (age, sex) in both groups (N=110) were assessed. Longest period of sustained abstinence during the Abstinence Phase was significantly correlated with all variables except gender (all p 's <.05), which justified initial inclusion of these variables as covariates in the tested models.

3.3. Mediation of treatment effect by longest period of sustained abstinence in Initial Phase

The analysis revealed that the total effect of treatment group on longest sustained abstinent samples submitted during the Abstinence Phase was significant ($\beta=7.68$, $p<.000$). A positive a path coefficient suggests that participants in the contingency management group had longer periods of sustained abstinence in the Initial Phase ($\beta=2.35$, $p<.000$), which in turn led to greater sustained abstinence in the Abstinence Phase (b path coefficient $\beta=1.06$, $p<.000$). The indirect effect of treatment group on sustained abstinence in the Abstinence Phase

(*ab* path product) was judged to be significant based on a bias-corrected bootstrap confidence interval estimate which did not include zero (95% CI=1.1 to 4.3). The direct effect remained significant when accounting for mediation by longest period of sustained abstinence in the Initial Phase (*c'* path, $\beta=5.18$, $p<.000$) suggesting a partial mediation effect.

3.4. Moderation of treatment group effect by heavy drinking at baseline

The overall model was significant, and results indicated that number of heavy drinking days reported at baseline significantly moderated the effect of treatment group on longest period of sustained abstinence during the Abstinence Phase (treatment x heavy drinking interaction $\beta=-0.61$, $p=.005$). A graphical depiction of the moderation effect is shown in Figure 3, with heavy drinking days trichotomized as the mean number of heavy drinking days out of the last 30 days and one standard deviation above and below the mean. The moderation effect indicates that having a greater number of heavy drinking days at baseline was associated with shorter periods of sustained abstinence for individuals in the CM group.

3.5. Serial multiple mediation model

A descriptive depiction of the effect of Initial phase drinking on sustained abstinence in the Initial Phase is shown in Figure 4. The direct effect of treatment on sustained abstinence during the Abstinence Phase remained significant (*c'* path, $\beta=5.5$, $p<.000$), and the analysis confirmed that findings of the simple mediation model that the effect of treatment on sustained abstinence in the abstinence phase was mediated by greater sustained abstinence in the Initial Phase. The analysis revealed that the indirect effect of treatment through serial mediation of Initial phase drinking's effect on sustained abstinence during the initial phase was judged to be significant based on a bootstrap CI that did not include zero (.09 – 0.68). The negative coefficient for the path from drinking during the Initial Phase to sustained abstinence during the Initial Phase ($\beta=-.21$) indicates that greater Initial Phase drinking reduced the average length of sustained abstinence. The same model was run with the temporal location of the two mediators reversed; however, in this case the indirect effect of serial mediation was not significant: in other words, while greater drinking was associated with reduced sustained abstinence in the Initial Phase, the reverse was not significant. This indicates that greater drinking led to failure to sustain abstinence gains, and not the reverse. The indirect effect of treatment on sustained abstinence during the Abstinence phase via drinking in the Initial Phase was not significant (CI includes zero), further indicating that the effect of early drinking on later sustained abstinence was mediated through sustained abstinence in the Initial Phase.

4. DISCUSSION

The current study used simple mediation and serial multiple mediation models to examine how alcohol use prior to and during treatment and initial achievement of sustained abstinence affected sustained abstinence during a CM intervention in a sample of college student smokers. While group-average data have been published previously¹⁵, this is the first time individual-level data have been presented on young adults in a CM treatment for smoking. Fine-grained data such as these are important for understanding behavioral

mechanisms at work in promoting smoking abstinence and underscore how powerful CM can be for generating abstinence, even in difficult-to-treat populations. The individual-level data show that sustained abstinence did occur at high rates in this population, and highlights the potential for contingency management interventions to have great impact on smoking abstinence initiation in young adults. Overall, large differences were seen in the achievement of sustained abstinence between CM and NR.

The treatment included an Initial Phase for participants in the CM group in which reductions in CO from baseline levels were differentially reinforced, followed by an Abstinence Phase in which only abstinence samples were reinforced. The data indicated that sustained success in the Abstinence Phase was partially mediated by the longest period of abstinence achieved in the Initial Phase. The attainment of longer periods of abstinence in the CM group indicate that shaping can be helpful for initiating abstinence in young adults, and contributes to the literature indicating that by promoting early and frequent contact with contingency-based reinforcement, reduction-based schedules facilitate better outcomes in contingency management treatment⁴¹. Thus, these data are consistent with prior research in this area, but is novel in its extension to this population. Further, these data underscore the importance of early initiation of sustained abstinence in achieving longer-term abstinence.

We also found that pretreatment heavy drinking levels moderated treatment group effect, such that among CM participants, heavy drinking attenuated the positive effects that were observed in participants with fewer heavy drinking days at baseline. Heavier drinking participants had fewer abstinent samples during CM treatment; however, CM was still relatively more successful than NR even among heavier drinkers. We further explored whether drinking during the Initial Phase undermined the achievement of sustained smoking abstinence during the Initial Phase, and we found that drinking did affect initial abstinence. These data show that not only did pre-treatment drinking moderate treatment effect, but that participants who drank more during the Initial Phase week were less likely to achieve sustained smoking abstinence in the Initial Phase, and this lack of success continued to affect their treatment response in the Abstinence Phase. Conversely, participants in the CM group who drank less during the Initial Phase were notably more successful at achieving sustained abstinence. These data underscore how alcohol use can interfere with smoking treatment in this population, even in the context of a relatively powerful intervention.

Both drinking and smoking behaviors frequently occur together among college students, and these behaviors occur often in social situations where peer influence is strong⁴². Indeed, young adults who identify as ‘social smokers’ are both more likely to co-use alcohol and tobacco and less likely to make quit attempts⁴³. Recent interventions with college students have begun to integrate interventions for both smoking and alcohol with success^{44,45}. Related research showed that alternative reinforcers that complement smoking behavior, such as alcohol and reinforcement from social sources in this population, can undermine cessation with nicotine patches; but substitute behaviors that compete with smoking, such as exercise, can be protective⁴⁶. The relative strength of CM as an intervention provides a promising avenue for treatments that attempt to overcome these powerful alternative social reinforcers by providing a strong immediate incentive to abstain, rather than assistance in overcoming withdrawal symptoms; however, it is clear that further research is necessary to

optimize CM treatment in this population. Future research should consider addressing smoking and drinking behavior jointly by providing incentives contingent on evidence of reduction in use or abstinence from both substances.

The study does have limitations. First, smokers in the sample needed to smoke at least daily to be included; however, many college student smokers smoke less than daily⁶. Thus, the results of this study may not generalize to intermittent- or lighter-smoking college students. This study also did not include non-college attending youth, who show higher rates of smoking and face different social contexts for substance use; therefore, these results may not generalize to such a population⁴⁷. Further, cessation rates were low overall at 6 month follow up (3.8% overall), with no significant difference across conditions; these low overall quit rates precluded analysis of predictors of post-treatment sustained abstinence. This may have been due to the relatively short duration of the intervention, as research has shown that longer-duration CM contributes to greater rates of post-treatment abstinence in other populations^{48,49}. Future studies should explore methods for increase rates of post-treatment cessation by implementing longer-term CM interventions, and particularly by exploring methods for increasing generalization of treatment gains by thinning reinforcement schedules rather than abruptly removing contingencies- e.g., gradually increasing the number of abstinent samples required for reinforcement in order to gradually phase out reinforcement. Future studies should also explore whether reinforcing alcohol abstinence in addition to tobacco abstinence might increase and prolong the effects of CM, as our results suggest that alcohol-using individuals who do not initiate sustained smoking abstinence early in treatment are less likely to benefit longer treatment durations more intensive intervention. While the current study was not designed to test a mechanism of change⁵⁰, future research can use this investigation as a starting point for understanding what mechanisms are at work in participants who are able to curb their drinking in response to initiation of smoking treatment, as perhaps these individuals show high self-efficacy with respect to quitting, or are engaging in behavioral coping strategies which may enhance future cessation trials. The strengths of the study include the relatively large sample, and relatively high proportion of participants who were able to achieve abstinence in the contingency management groups, allowing us to look a range of variables that may affect abstinence during treatment.

Improving smoking cessation rates in young adults is important for the future health of young smokers. The current data suggest that combining effective elements of contingency management interventions for smoking, including an initial percentile shaping phase, as well as potentially integrating smoking and alcohol treatment, holds promise for this population. Further, such treatments can be delivered more widely when integrated with mobile devices^{51,52}. As quitting smoking before age 35 can almost entirely eliminate risk of death from smoking⁵³, optimizing effective treatment in this population remains a critical area of research.

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HIGHLIGHTS

- Improving smoking cessation rates in young adults is important for the future health of young people
- We found that early sustained abstinence improved later sustained abstinence in contingency management (CM)
- Heavy drinking both before and during CM treatment undermined sustained abstinence
- CM holds promise for young smokers, but drinking needs to be addressed concurrently

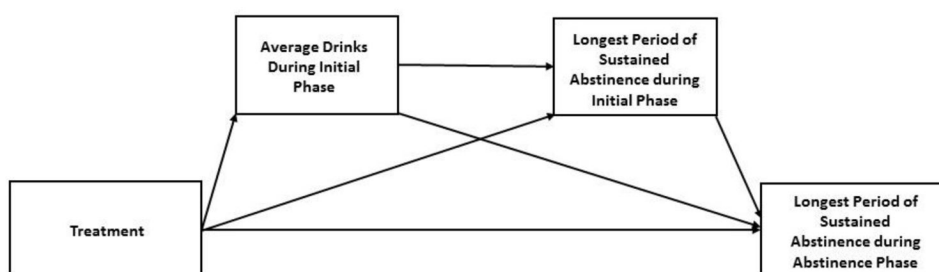


Figure 1.
Path diagram of the serial multiple mediation model. Baseline dependence (modified Fagerström Tolerance Questionnaire score) was included as a covariate.

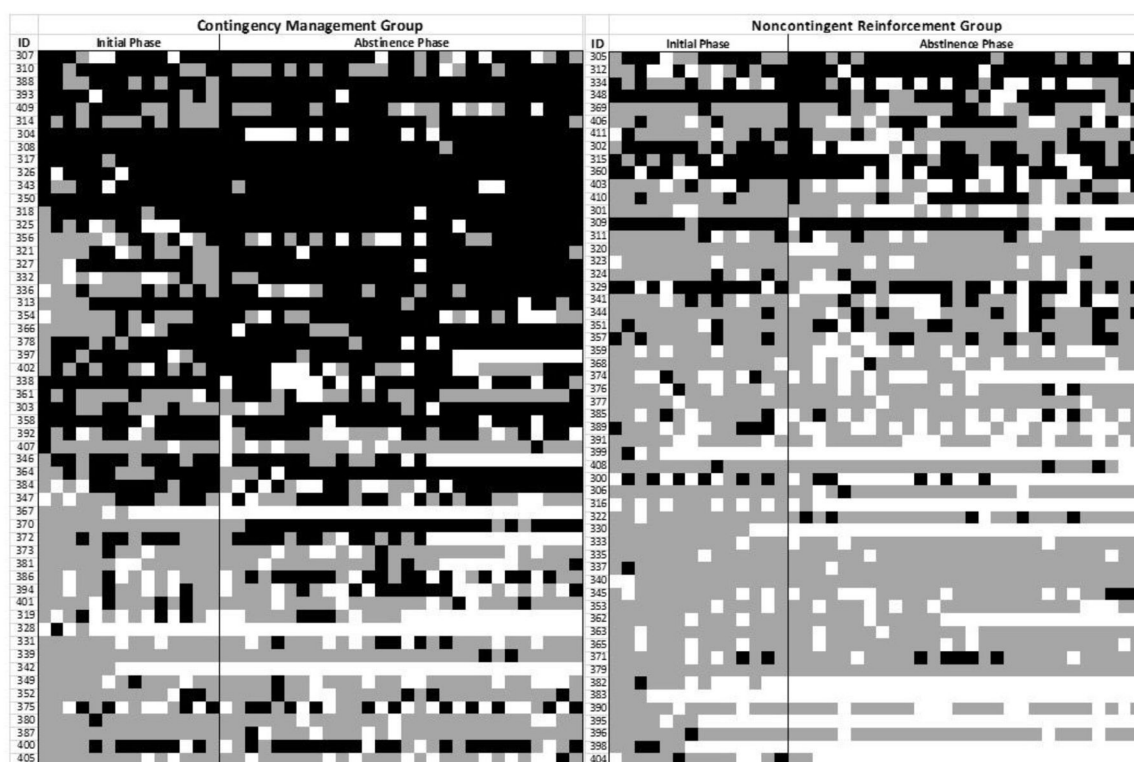


Figure 2.

Individual sample status as a function of treatment day and group assignment. Each row represents a participant in each group, and each square represents a sample. Black squares represent negative samples. Gray squares are positive samples, and white squares are missed samples.

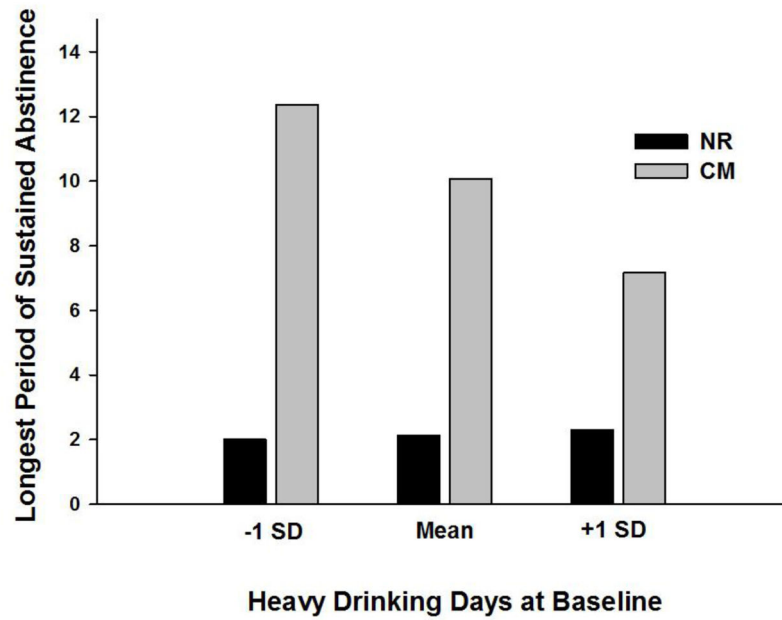


Figure 3.

Effect of baseline heavy drinking days (at 2, 6, and 11 days out of the past 30) on sustained abstinence during the abstinence phase across group assignment. CM refers to the Contingency Management treatment group; NR refers to the Noncontingent Reinforcement group.

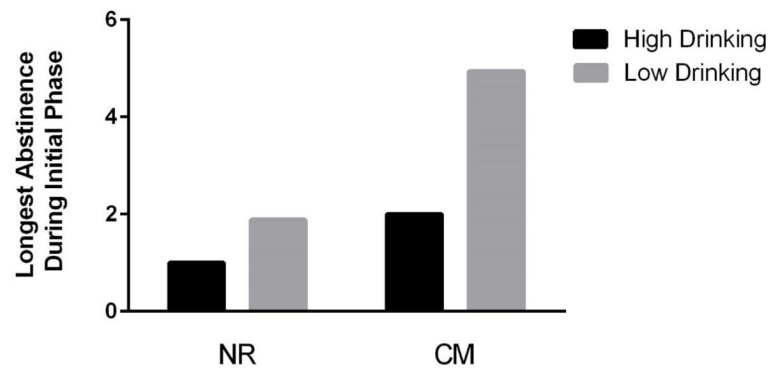


Figure 4. Effect of drinking during the Initial Phase on longest abstinence during the Initial Phase across group assignment. High and Low drinking are defined as above or below mean drinking days during the Initial Phase.