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Association of current substance use treatment with future reduced methamphetamine use in an observational cohort of men who have sex with men in Los Angeles

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Abstract

Introduction: Methamphetamine use is highly prevalent among men who have sex with men (MSM), but knowledge of the long-term dynamics, and how they are affected by substance use treatment, is limited. This study aimed to describe trajectories of methamphetamine use among MSM, and to evaluate the impact of treatment for any kind of substance use on frequency of methamphetamine use.

Methods: This analysis used data from a cohort of MSM in Los Angeles, CA who participated in semi-annual study visits from 2014–2022. Trajectories of methamphetamine use were characterized using a continuous time multistate Markov model with three states. States were defined using self-reported frequency of methamphetamine use in the past six months: frequent (daily), occasional (weekly or less), and never. The model estimated the association between receiving treatment for any kind of substance use and changes in state of frequency of methamphetamine use.

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Declaration of Competing Interest

The authors have no competing interests to declare.

CRediT Authorship Statement

Allison D. Rosen: Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Visualization. **Marjan Javanbakht:** Methodology, Formal analysis, Data Curation, Writing - Review & Editing. **Steven J. Shoptaw:** Conceptualization, Resources, Writing - Review & Editing, Supervision, Funding acquisition. **Marissa J. Seamans:** Methodology, Formal analysis, Writing - Review & Editing. **James O. Lloyd-Smith:** Conceptualization, Methodology, Formal analysis, Writing - Review & Editing, Supervision. **Pamina M. Gorbach:** Conceptualization, Resources, Writing - Review & Editing, Supervision, Funding acquisition

Results: This analysis included 2348 study visits among 285 individuals who were followed up for an average of 4.4 years. Among participants who were in the frequent use state, 65% (n=26) of those who were receiving any kind of substance use treatment at a study visit had reduced their methamphetamine use at their next visit, compared to 33% (n=95) of those who were not receiving treatment. Controlling for age, race/ethnicity, and HIV-status, those who reported receiving current treatment for substance use were more likely to transition from occasional to no use (HR: 1.63, 95% CI: 1.10 – 2.42) and frequent to occasional use (HR: 4.25, 95% CI: 2.11 – 8.59) in comparison to those who did not report receiving current treatment for substance use.

Conclusions: Findings from this dynamic modeling study provide a new method for assessing longitudinal methamphetamine use outcomes and add important evidence outside of clinical trials that substance use treatment may reduce methamphetamine use.

Keywords

methamphetamine; substance use treatment; multistate models; men who have sex with men

1. Introduction

Methamphetamine use is a significant public health problem that affects both mental and physical health. Between 2015 and 2019, the proportion of American adults who reported more than 100 days of methamphetamine use in the past year increased by 66%, and methamphetamine-involved overdose deaths increased by 180% (Han et al., 2021). Further, methamphetamine use disproportionately affects men who have sex with men (MSM), people living with HIV (PLWH), and especially MSM living with HIV (Rivera et al., 2021; Wohl et al., 2008). Methamphetamine may be used to enable sexual behaviors not common for MSM when not using the drug; its inhibition of judgement increases the likelihood of engaging in risky sexual behaviors such as condomless anal intercourse, which in turn increases the risk of HIV acquisition (Buchacz et al., 2005; Halkitis et al., 2009; Molitor et al., 1998; Reback et al., 2004). Methamphetamine use has also been linked to poor treatment outcomes and accelerated disease progression for MSM living with HIV; this may be explained by increased inflammation and viral replication caused by methamphetamine as well as the association between methamphetamine use and interference with and poor adherence to antiretroviral therapy (Brown et al., 2018; Carrico et al., 2019; Carrico, Shoptaw, et al., 2014; Lai et al., 2020; Passaro et al., 2015).

For many who use methamphetamine regularly, methamphetamine use is a highly dynamic behavior that involves changing patterns of use as well as periods of non-use, or methamphetamine abstinence. Among MSM, those who use methamphetamine can often be split into two groups, those who use frequently and those who use occasionally (weekend warriors) (Shoptaw et al., 2022). While frequency of methamphetamine use can range from daily to less than weekly among people who use the drug regularly, there appears to be some benefit in reducing the frequency of use, both in terms of negative social and physical health consequences including reductions in mental health conditions, cardiovascular issues, risk of overdose, and HIV/STI incidence (Aguilar & Sen, 2013; Halkitis et al., 2005; Javanbakht et al., 2020; Jones et al., 2022; Shoptaw et al., 2022). In order to better

understand methamphetamine use, its determinants, and potential targets for intervention, it is advantageous to conceptualize its use as chronic and measure it longitudinally.

Trajectories of methamphetamine use over time, and of substance use in general, are understudied (Fuller et al., 2002; Hadland et al., 2017; Lloyd-Smith et al., 2009; Reddon et al., 2018). Latent class analyses have been used to describe stages of the substance use trajectory, but fail to consider the dynamic nature of this behavior (Genberg et al., 2011; McCarty-Caplan et al., 2014; Tobin et al., 2016). In fact, analyses that determine factors associated with group membership assume that group membership does not change over time. A study of the stability of latent classes in a population of MSM found that 26% of participants transitioned between classes over a period of 2.5 years (Card et al., 2018). While the authors of this study concluded that this suggests relative stability of latent classes for substance use trajectories, the limited follow-up period and substantial fraction of participants that transitioned suggest that further study is needed. In addition, the authors note that classes may be less stable in populations where substance use patterns are determined by fluctuating extrinsic factors such as income, housing, drug supply, and access to substance use treatment (Card et al., 2018).

The extent to which substance use treatment may change trajectories of methamphetamine use is poorly understood and is rarely considered in analyses that explore trajectories of substance use. There are few treatment options for methamphetamine use, and there is currently no FDA-approved medication (Brown & DeFulio, 2020; Cook et al., 2017; Courtney & Ray, 2014; Paulus & Stewart, 2020; Siefried et al., 2020). Recent clinical trials reported that Mirtazapine and combined Bupropion and extended-release Naltrexone reduced methamphetamine use over placebo, though access to these treatments remains limited (Coffin et al., 2020; Trivedi et al., 2021). Contingency management, which uses monetary and other incentives to encourage reductions in use, is currently the most effective treatment for methamphetamine use disorder; when patients complete a course of contingency management, return to use of methamphetamine can occur, which underscores the chronic nature of this disorder and underscores need for continued involvement in non-drug behaviors after the end of the treatment to maintain these reductions (Brown & DeFulio, 2020). Residential rehabilitation has been shown to reduce methamphetamine use in the first three months following detoxification, but the association was not sustained long term (McKetin et al., 2012). In addition, the availability and efficacy of 12-step programs and sponsorship is limited for stimulant use disorders (Donovan & Wells, 2007; Hatch-Maillette et al., 2016; Wendt et al., 2017).

There has been minimal research on longitudinal trajectories of substance use, and no specific studies of methamphetamine use trajectories to our knowledge. Analyses that account for the long-term, dynamic nature of methamphetamine use among MSM over time have potential to characterize methamphetamine use trajectories and the ways in which substance use treatment may change them. This study aims to describe trajectories of methamphetamine use in a cohort of MSM in Los Angeles, and to determine the association between reporting treatment for substance use and changes in these trajectories.

2. Materials and Methods

2.1 Study Population

The present analysis used data from mSTUDY, a National Institute on Drug Abuse (NIDA)-funded cohort in Los Angeles, CA. mSTUDY began enrolling participants in 2014. Participants were recruited using direct outreach including flyers and advertising on social media; study visits took place at two sites including a community-based organization providing services to the lesbian, gay, bisexual, and transgender community, and a university-based research clinic. Follow-up is ongoing. Inclusion criteria for mSTUDY include being between age 18 and 45 at baseline, assigned male sex at birth, ability to provide informed consent, and willingness to return for follow-up visits. Participants include those people living with HIV and those who reported high risk for HIV acquisition (condomless anal intercourse with a male partner in the past six months). The present analysis was restricted to the 285 participants (51% of the parent cohort) who reported methamphetamine use at one or more study visits and includes follow-up data collected through February 2022.

2.2 Data Collection and Measures

At each of the semi-annual visits, participants completed a self-administered, computer-based questionnaire which was available in both English and Spanish. As part of the questionnaire, participants reported on recent (past six months) substance use. Frequency of methamphetamine use was measured using the Alcohol, Smoking and Substance Involvement Screening Test (ASSIST) that was adapted to capture substance use in the past six months (Humeniuk et al., 2010). Participants reported frequency of use as daily, weekly, monthly, less than monthly, once, or never; weekly use was defined as at least one time per week, monthly use was defined as at least one time per month and less than monthly use was defined as less than once per month but more than once in the past six months. For this analysis, frequent use was defined as daily use and occasional use was defined as weekly or less. Substance use treatment was based on an affirmative response to the questions that asked, “are you currently receiving treatment for substance use, including alcohol?” HIV status was based on laboratory testing and every six months, blood samples were collected for HIV testing among those not living with HIV. Due to the COVID-19 pandemic, between March 2020 and June 2021, in-person research activities were curtailed and precluded the collection of blood for HIV testing.

All participants were scheduled to return every six months and the study procedures were repeated at each visit. Visits typically lasted 60–90 minutes and participants were compensated between \$70 and \$90 depending on the visit. The University of California, Los Angeles Institutional Review Board approved the study, and all participants provided written informed consent.

2.3 Model Description

Trajectories of methamphetamine use were characterized using a continuous time Markov Chain, a probabilistic mathematical model that assumes that the future state of the system depends only on the current state of the system (Grimmett & Stirzaker, 2001). The model

tracks the state S of an individual at time t . The ways an individual may move through the states of the model are defined by transition intensities, which represent the instantaneous risk of transition between two states.

Trajectories of methamphetamine use were defined using three states of frequency: none, occasional, and frequent. The model did not include an absorbing state for loss to follow-up or death; since mSTUDY began, 93% of participants remain enrolled and there has been less than 1% mortality.

The model was designed with seven possible transitions, as represented by the arrows in Figure 1. Participants could increase frequency of methamphetamine use from none to occasional or occasional to frequent, decrease frequency from frequent to occasional or occasional to none, or they could remain in each of the three respective states. It was assumed that model parameters do not change over time, and that there were no transitions between non-adjacent states in the model. Participants who reported non-adjacent transitions at consecutive study visits were assumed to have traveled through the adjacent state during the intervening 6 months.

Parameter estimation was performed using the *msm* package in R (Jackson, 2011). Using the observed state of each participant at each study visit, maximum likelihood estimation was used to estimate the transition intensities. The estimation method assumed that the observed data were panel data from a time-homogeneous process. Panel data are data collected on a continuous time process that is observed periodically; the time of observation does not influence the observed value or the transition intensities. This is a reasonable assumption, as mSTUDY participants are observed biannually, and the timing of study visits do not influence frequency of methamphetamine use.

2.4 Analytic Strategy

Before modeling trajectories of methamphetamine use, univariate and bivariate analyses were conducted to describe the study sample. Baseline methamphetamine use, age, race/ethnicity, and HIV-status were compared for those who did and did not report receiving current treatment for substance use. In addition, the number of observed transitions among those who did and did not report receiving current treatment for substance use was computed by tabulating participants' frequency of methamphetamine use at visit $t-1$ and visit t .

Three increasingly complex multistate models were analyzed. The first model estimated trajectories of methamphetamine use without covariates. The second model compared trajectories of methamphetamine use for those who did and did not report receiving current treatment for substance use. The third model built upon the second model by controlling for age, race/ethnicity, and HIV-status. All covariates except race/ethnicity were time-varying, and it was assumed that they were constant between study visits, and that the estimated transition intensity was dependent upon the value of the covariate at visit $t-1$ (Jackson, 2011).

The estimated transition intensities from each model were used to present more intuitive parameterizations: the mean sojourn time and the probability that the next transition is to

state S. Mean sojourn time was defined as the amount of time in years that individuals spend in each state before transitioning to another state.³¹

To compare transition rates for those who did and did not report receiving current treatment for substance use, hazard ratios for the association of reporting current treatment for substance use and transition between states of methamphetamine frequency were computed. Model fit was assessed by using likelihood ratio tests to compare each of the three models.

3. Results

This analysis included 285 unique individuals who reported methamphetamine use on at least one visit, of whom 15.8% (n=45) reported receiving current treatment for substance use at baseline. At baseline, 23.5% (n=67) of participants reported no methamphetamine use in the past six months, 57.5% (n=164) reported occasional use, and 18.9% (n=54) reported frequent use. The mean baseline age was 32.5 years old, and 40.8% (n=116) identified as Black/African American, 36.6% (n=104) identified as Hispanic/Latinx/Spanish, 15.5% (n=44) identified as white, and 7.0% (n=20) identified as another race or ethnicity. The proportion of participants who identified as Black/African American was higher among those who reported not receiving current treatment for substance use, and the proportion of participants who identified as Hispanic/Latinx/Spanish and who were living with HIV was higher among those who reported receiving current treatment for substance use. (Table 1). Among 104 participants who reported receiving treatment for substance use at some point over the course of the study, 53.8% (n=56) reported receiving treatment for substance use at two or more consecutive study visits.

Between August 2014 and February 2022 these individuals had a combined 2,348 study visits and 2,063 observed transitions between states of methamphetamine frequency. On average, participants had 8.2 study visits over the course of 4.4 years. Average follow-up time was comparable for those who reported receiving current treatment for substance use and those who did not.

Comparisons of observed transitions between states of methamphetamine use for those who did and did not report receiving current treatment for substance use at visit t-1 are shown in Figure 2. Of 2,063 observed transitions, 12.0% (n=247) were among participants who reported receiving current treatment for substance use at visit t-1, and 88.0% (n=1816) were among those who did not report receiving current treatment for substance use at visit t-1. Among participants who reported frequent use at visit t-1, 35.0% (n=14) of those who were receiving any kind of substance use treatment remained in the frequent use state at their next visit, compared to 67.5% (n=197) of those who were not receiving treatment. It was most common to remain in the same state between visit t-1 and t, and non-adjacent transitions were relatively rare.

When modeling trajectories of methamphetamine use without covariates, an average of 1.6 years (95% CI: 1.4–1.8) of nonuse elapsed before participants transitioned to occasional use. An average of 1 year (95% CI: 0.9–1.1) of occasional use elapsed before participants transitioned to no use with a probability of 0.64 (95% CI: 0.6–0.7) or frequent use with a

probability of 0.36 (95% CI: 0.3–0.4). An average of 1.2 years (95% CI: 1.0–1.4) of frequent use elapsed before participants transitioned to occasional use (Table 2).

Trajectories of methamphetamine use are compared for those who did and did not report receiving current treatment for substance use in Table 2. Controlling for age, race/ethnicity, and HIV-status, participants who reported receiving current treatment for substance use did not use methamphetamine for an average of 2.1 years (95% CI: 0.8 – 5.4) before transitioning to occasional use. They used methamphetamine occasionally for an average of 0.4 years (95% CI: 0.2 – 0.8) and then had a 0.7 (95% CI: 0.4 – 0.9) probability of transitioning to non-use and a 0.3 (95% CI: 0.1 – 0.6) probability of transitioning to frequent use. They used methamphetamine frequently for an average of 0.2 years (95% CI: 0.1 – 0.7) before transitioning to occasional use.

In comparison, those who did not report receiving current treatment for substance use did not use methamphetamine for an average of 1.9 years (95% CI: 0.9 – 4.2) before transitioning to occasional use. They used methamphetamine occasionally for an average of 0.7 years (95% CI: 0.3 – 1.2) and then had a 0.8 (95% CI: 0.5 – 0.9) probability of transitioning to non-use and a 0.2 (95% CI: 0.1– 0.5) probability of transitioning to frequent use. They used methamphetamine frequently for an average of 0.9 years (95% CI: 0.3 – 2.8) before transitioning to occasional use.

Controlling for age, race/ethnicity, and HIV-status, those who reported receiving current treatment for substance use were more likely to transition from occasional to no use (HR: 1.6, 95% CI: 1.1 – 2.4) and from frequent to occasional use (HR: 4.3, 95% CI: 2.1 – 8.6) in comparison to those who did not report receiving current treatment for substance use (Table 3). Receiving current treatment for substance use was not associated with transition from no to occasional use or occasional to frequent use.

Likelihood ratio tests revealed that the bivariate model improved model fit over the model without covariates ($p<0.001$), and that the fully adjusted model also improved model fit over the bivariate model ($p<0.001$).

4. Discussion

In this study, a continuous-time multistate Markov model provided insight into trajectories of methamphetamine use in a population of MSM living with or at high risk of acquiring HIV. Receiving current treatment for substance use was associated with both transition from frequent to occasional use states and transition from occasional to no use states, suggesting that treatment for substance use may lead to reduced frequency of methamphetamine use.

Additionally, those who reported receiving current treatment for substance use did not report significant increases in frequency of methamphetamine use. While we have no data to detail whether substance use treatment was specific to methamphetamine, these findings suggest that MSM who report involvement with substance use treatment behave in ways that reduce the cumulative reported frequency of their methamphetamine use. This finding is supported by other data which suggest that people in substance use treatment engage in behavioral self-monitoring independent of treatment type (Foxx & Brown, 1979). It is possible that

being in substance use treatment sensitizes the individuals to pay attention to the frequency of one's use of methamphetamine. Whatever the mechanism, the signal that substance use treatment produces downward influences on trajectories of methamphetamine use in this group provides evidence for harm reduction strategies that incorporate these ideas.

Consistent with these findings, those who report receiving current treatment for substance use have longer periods of abstinence and shorter periods of occasional and frequent use of methamphetamine than their peers who do not report receiving current treatment for substance use. This finding, taken together with the strong association between receiving treatment for substance use and transition from frequent down to occasional use, highlights the importance of treatment programs that focus on reducing use, rather than requiring commitment to and achievement of complete abstinence. In fact, prior work has shown that reductions in frequency of methamphetamine use, independent of involvement in substance use treatment, may decrease the likelihood of many of the harmful physical effects of methamphetamine such as psychosis, cardiovascular complications, infectious disease acquisition, overdose, and death as well as improve social relationship status, economic status, and mental health status (Carrico, Flentje, et al., 2014; Corsi et al., 2019; Prakash et al., 2017; Shoptaw et al., 2022).

By considering multiple transitions, rather than just cessation, this model highlights substance use treatment outcomes related to both reduction in use and abstinence. It is well-established that treatment options for methamphetamine use are limited, especially for those who report frequent use (Coffin et al., 2020; Cook et al., 2017; Siefried et al., 2020; Trivedi et al., 2021). While our study made the important observation that substance use treatment may reduce frequency of methamphetamine use in an observational cohort of MSM, further research is needed to better understand how methamphetamine use trajectories may differ depending on the type of substance use treatment (e.g., contingency management, medication, residential rehabilitation) that a patient is receiving as well as whether they sought treatment on their own or if it was court-ordered. Such studies could employ the novel conceptualization of longitudinal methamphetamine use presented in this analysis to provide important insight into the long-term efficacy of specific modalities used to treat methamphetamine use and how self-motivation to enter treatment may influence efficacy. Additionally, future models should explore trajectories of methamphetamine use following discontinuation or completion of substance use treatment in order to determine if reductions in use persist beyond the treatment period.

Further work must also consider interventions that could increase not only the rate of transition from occasional use to abstinence, but also the rate of transition from frequent to occasional use. Future studies would benefit from more extensive data sources with larger sample sizes to consider how additional time-varying background factors as well as different types of treatment work together to influence changes in frequency of methamphetamine use over long periods of time.

The multistate Markov model used in this study provides important insight into the rates at which MSM transition between states of frequency of methamphetamine use, and reveals key observations that would not have been visible under a conventional static

risk factor analysis. Multistate Markov models are widely used in public health research to study chronic disease progression, but they have rarely been applied to studies of substance use. One previous modeling study focused on transition from cannabis use to illicit substance use, and another considered transitions from onset to regular use of alcohol and tobacco among adolescents (Mayet et al., 2011; Mayet et al., 2012). However, multistate Markov models have not been previously used to study multiple transitions within a methamphetamine use trajectory, and they have not been used to study substance use treatment.

4.1 Limitations

It is important to keep in mind the limitations of this study. First, nearly all of the data for this analysis was collected by self-report. Social desirability bias is particularly likely when collecting data about sensitive behaviors such as substance use, where participants are likely to underreport these behaviors. However, the use of computer-assisted self-interviewing (CASI) rather than face-to-face interviews, helps to minimize this bias.

The model used in this analysis makes strong assumptions that must be considered. First, the model assumes that all parameter values are constant over time and that all observed non-adjacent transitions occurred via travel through adjacent states. In addition, Markov models assume that the future state of the system depends only on the current state of the system; it is likely that the system is not entirely memory-less and that previous methamphetamine use has some amount of influence on transition between states. Lastly, participants were observed biannually, so if the true sojourn time for a particular state is less than six months, that could be missed by the data collection process and hence not captured by the model.

This study is also limited by its sample size. Sparse data limited the number of covariates that could be included in the fully adjusted model; additional factors, including use of other substances, mental health, and housing likely confound this association as well as mask additional heterogeneity in the estimated transition intensities. Of particular note, most mSTUDY participants use multiple substances; the decreases in methamphetamine use observed in this study may be associated with changes in use of other substances, which the model does not capture.

Lastly, the results of this study should be generalized with caution. mSTUDY is a convenience sample that may not be representative of all MSM in Los Angeles or people who use methamphetamine in other settings or locations. mSTUDY provides connections to healthcare and other services for participants, so those who choose to remain enrolled may be more motivated to change substance use behaviors or have better access to treatment. In particular, people living in Los Angeles who seek treatment for methamphetamine use have access to an unusually extensive array of options including in-person- and agency-based harm reduction programs, outpatient treatment programs that feature contingency management and culturally tailored cognitive behavioral therapy, and clinical trials of new/emerging behavioral and medical treatments for methamphetamine use disorder. Additionally, the mSTUDY cohort is by purpose designed to over-recruit MSM who hold minority racial and ethnic identities in order to enrich the sample with participants who have disproportionate risks for HIV incidence in Los Angeles; thus the high prevalence of

engagement with substance use treatment reported by participants who identify as Hispanic or Latinx could be spurious and/or relate to the lack of similar sized White and Asian MSM that might provide a fair comparator to the observed correlation.

5. Conclusions

Findings from this study are important in that they provide a new model for measuring outcomes from methamphetamine use longitudinally. Consequences to methamphetamine use for most users accrue gradually, so viewing methamphetamine use in terms of periods of use frequency (“sojourns”), which can increase, decrease, or remain static, offers a novel way of understanding the cumulative impacts of those consequences. Findings from these kinds of analyses may point to events or to opportunities that might be pivotal in shifting the duration of “sojourns” of methamphetamine use to avoid negative consequences that are less intensive than formal drug treatment episodes.

This study highlights the utility of multistate Markov models in substance abuse research, and future studies should consider using this method to further delve into trajectories of methamphetamine use. The present analysis focused on frequency, an important characteristic of one’s methamphetamine use. However, there are other relevant markers of use including craving, interference with responsibilities, and mode of administration (Hasin et al., 2013; Koob & Le Moal, 2001). In the future, a questionnaire that assesses multiple dimensions of methamphetamine use (such as the ASSIST) could be used to characterize low, moderate, and high severity. These categories could define the states of a multistate Markov model that provides new insight into the dynamic nature of methamphetamine use (Humeniuk et al., 2010).

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Abbreviations:

MSM	men who have sex with men
PLWH	people living with HIV
ASSIST	Alcohol, Smoking and Substance Involvement Screening Test
HR	hazard ratio

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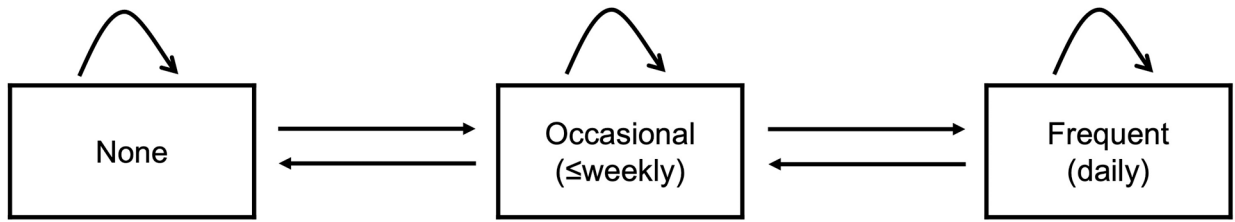


Figure 1.
Trajectories of methamphetamine use model diagram.

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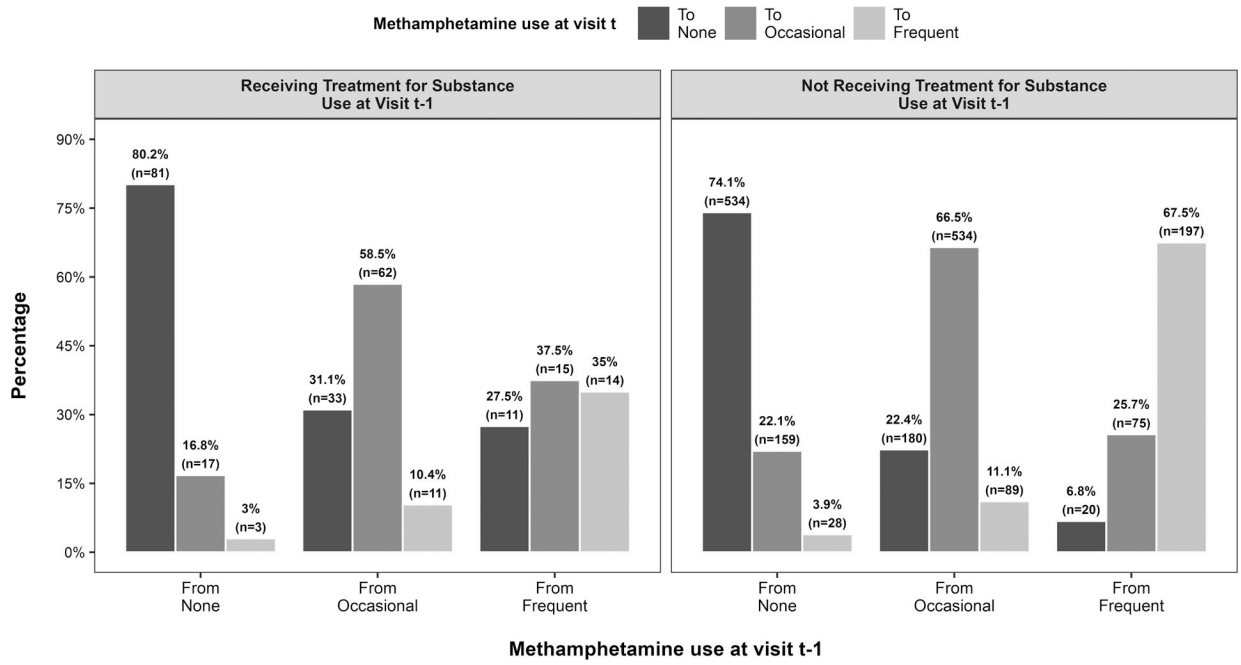


Figure 2. Observed transitions between states of methamphetamine use comparing those who reported receiving substance use treatment at visit t-1 compared to those who did not.

Table 1.

Baseline characteristics of mSTUDY participants

	Receiving Treatment for Substance Use		
	Total^a	Yes	No
	(n=285)	(n=45)	(n=240)
	n (%)	n (%)	n (%)
Methamphetamine Use^b			
None	67 (23.5)	12 (26.7)	55 (22.9)
Occasional	164 (57.5)	23 (51.1)	141 (58.8)
Frequent	54 (18.9)	10 (22.2)	44 (18.3)
Age (Mean, SD)	32.5 (6.7)	33.2 (6.0)	32.4 (6.9)
Race/Ethnicity			
Black/African American, NH	116 (40.8)	10 (22.2)	106 (44.4)
Hispanic/Latinx/Spanish	104 (36.6)	25 (55.6)	79 (33.1)
White, NH	44 (15.5)	8 (17.8)	36 (15.1)
Other, NH	20 (7.0)	2 (4.4)	18 (7.5)
HIV-Positive	181 (63.5)	35 (77.8)	146 (60.8)
Number of Visits (Mean, SD)	8.2 (3.7)	8.3 (3.7)	8.2 (3.7)
Years of Follow-Up (Mean, SD)	4.4 (1.9)	4.4 (1.9)	4.4 (1.9)

^aParticipants reported methamphetamine use during one or more visits

^bSelf-reported frequency of use in the past six months (occasional defined as weekly or less, frequent defined as daily).

Abbreviations: NH = Non-Hispanic

Table 2.

Full parameterization of continuous-time multistate Markov model

	Mean Sojourn Time						Probability State S is Next	
	None		Occasional		Frequent		Occasional to Frequent	
	Years (95% CI)	Years (95% CI)	Years (95% CI)	Years (95% CI)	Years (95% CI)	Years (95% CI)	Probability (95% CI)	Probability (95% CI)
No Covariates	1.57 (1.36, 1.83)	0.97 (0.87, 1.09)	1.16 (0.96, 1.41)	0.64 (0.59, 0.70)	0.36 (0.30, 0.41)			
Receiving Treatment for Substance Use (Bivariate)								
Yes	1.82 (1.13, 2.93)	0.61 (0.43, 0.87)	0.38 (0.22, 0.66)	0.62 (0.43, 0.79)	0.38 (0.21, 0.57)			
No	1.55 (1.33, 1.81)	1.04 (0.92, 1.17)	1.37 (1.11, 1.70)	0.64 (0.57, 0.69)	0.36 (0.31, 0.43)			
Receiving Treatment for Substance Use (Adjusted ^a)								
Yes	2.10 (0.82, 5.39)	0.38 (0.19, 0.76)	0.20 (0.06, 0.70)	0.74 (0.39, 0.92)	0.26 (0.08, 0.61)			
No	1.88 (0.85, 4.17)	0.65 (0.34, 1.23)	0.87 (0.27, 2.84)	0.78 (0.50, 0.93)	0.22 (0.07, 0.50)			

^a Adjusted for age, race/ethnicity, and HIV-status

Table 3.

Association of receiving treatment for substance use and transitions between states of frequency of methamphetamine use

	Transition			
	None to Occasional	Occasional to None	Occasional to Frequent	Frequent to Occasional
	HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Bivariate Model				
Receiving Treatment for Substance Use	0.85 (0.52, 1.41)	1.65 (1.13, 2.41)	1.77 (0.85, 3.71)	3.58 (2.00, 6.39)
Adjusted Model				
Receiving Treatment for Substance Use	0.90 (0.54, 1.49)	1.63 (1.10, 2.42)	2.01 (0.84, 4.81)	4.25 (2.11, 8.59)
Age at visit	1.01 (0.98, 1.03)	0.99 (0.97, 1.01)	1.00 (0.97, 1.03)	0.99 (0.96, 1.02)
Race/Ethnicity				
Black/African American	1.43 (1.02, 2.00)	0.98 (0.71, 1.36)	1.18 (0.76, 1.83)	1.01 (0.63, 1.60)
Hispanic/Latinx/Spanish	1.02 (0.62, 1.66)	1.15 (0.74, 1.78)	0.86 (0.46, 1.60)	0.67 (0.34, 1.31)
Other	1.24 (0.70, 2.19)	1.14 (0.63, 2.09)	1.97 (0.93, 4.14)	0.73 (0.33, 1.57)
White	1.00	1.00	1.00	1.00
HIV-Positive	0.67 (0.47, 0.95)	0.55 (0.41, 0.75)	0.93 (0.61, 1.41)	1.09 (0.68, 1.73)

Abbreviations: HR=Hazard Ratio