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# IMPACT OF SUBSTANCE USE IN SOCIAL NETWORKS ON ANTIRETROVIRAL THERAPY ADHERENCE FOR HIV-POSITIVE YOUNGER MEN WHO HAVE SEX WITH MEN

NATASCHA DEL VECCHIO

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IMPACT OF SUBSTANCE USE IN SOCIAL NETWORKS ON ANTIRETROVIRAL  
THERAPY ADHERENCE FOR HIV-POSITIVE YOUNGER MEN WHO HAVE  
SEX WITH MEN

by

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2020

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THERAPY ADHERENCE FOR HIV-POSITIVE YOUNGER MEN WHO HAVE  
SEX WITH MEN

by

NATASCHA DEL VECCHIO  
BS, University of Texas at Austin, 2018

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SCHOOL OF PUBLIC HEALTH  
Houston, Texas  
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# IMPACT OF SUBSTANCE USE IN SOCIAL NETWORKS ON ANTIRETROVIRAL THERAPY ADHERENCE FOR HIV-POSITIVE YOUNGER MEN WHO HAVE SEX WITH MEN

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The community of young men who have sex with men (YMSM) has higher rates of substance use than the general population and the use of alcohol, cannabis, and illicit drugs has been shown to have a negative impact on the HIV care continuum. Our first aim was to understand the prevalence of substance use in the community through the use of self-reported, RDS-II, and RDS-SS estimates. We used multivariable logistic and negative binomial GEE with QIC selection to determine the factors important to having a prescription and staying adherent, respectively. Selected variables were included with a subset of substance use and network factors to understand the role drug use in YMSM networks impact the care continuum using logistic and NB GEE models. Participants for analysis were 755 YMSM from Chicago, IL and Houston, TX in 2014 – 2016. All prevalence estimates were similar in the two cities. The prevalence of illicit drugs in both cities was about 54% based on self-report, but RDS estimates were closer to 40%. The prevalence of cannabis and alcohol use was 85% and 96% in Chicago, respectively; the prevalence in Houston was 80% and 96%, respectively. Multivariable GEE showed black YMSM were found to be 96% less likely to have a prescription than their counterparts, and low trust in treatment providers was associated with lower odds of having a prescription (OR 0.19, 95% CI 0.04, 0.82). Having insurance was the most important protective factor with missing fewer doses (OR 0.43 95% CI 0.23, 0.91). Cannabis use (OR 1.31 95% CI 1.07, 1.62) during sex

and use of illegal drugs were significant in the outcome of staying adherent (OR 1.80 95% CI 1.0, 3.24). Venue exposures and drug use in YMSM networks were not significantly related. These analyses show that prevalence of drug use in the YMSM community is high and is an important factor to consider during treatment of HIV, particularly if use is associated with sex. Reducing the racial disparities in the HIV care continuum, however, continues to be of the highest importance.

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# **1 Introduction**

## **Background**

### **1.1.1 ART for PWHIV**

Antiretroviral therapy, or ART, is the treatment given to human immunodeficiency virus (HIV) positive individuals to suppress viral loads [1]. In 2015, there were 1,122,900 adults and adolescents living with HIV in the United States; of these, 63% received some care but only 49% were in continuous care [2]. Continuous care is defined in four steps: diagnosis, linkage to care (visiting a provider within 30 days of an HIV diagnosis), received care or retained in care (retained is defined as two or more viral load or CD4 tests within three months), and viral suppression (less than 200 copies/mL) [3]. Continuous care aims to make people living with HIV (PLWHIV) less or not infectious and prevents the virus from progressing to AIDS by reducing the viral loads through medication. Of the adults and adolescents living with HIV in 2015, only 51% were viral suppressed during the year [2]. There have been significant strides in reducing the incidence of HIV due to medications such as PrEP, PEP, and ART [4]. In particular, ART is important for both the health of PLWHIV and to prevent incidence of new HIV infections.

The subpopulation at highest risk for HIV infection is that of men who have sex with men (MSM), particularly men less than 30 years of age. MSM made up 70% of all new HIV diagnoses in the US in 2017 [5] despite only being estimated to represent 3.9% of the US population [6]. Of particular concern, one study showed that only 45% of MSM had good adherence [7]. This group is of particular importance in reducing the spread of HIV, and could largely benefit from interventions for testing and treatment.

However, both getting PLWHIV into care and keeping individuals adherent are significant challenges. These challenges include health insurance coverage, depression, low trust

in healthcare providers, and stigmas surrounding HIV [7]. While adherence cannot be pinned to only one set of factors, the influential factors have previously been categorized into sociodemographic, condition-related, treatment-related, patient-related, and interpersonal factors [8]. Due to the intersection of sociodemographic and interpersonal factors (e.g. discrimination due to race, sexuality, or sex), these categories become blurred. However, as this study was focused on a specific population of YMSM we can assume these factors were consistent across individuals.

### **1.1.2 Drug Use Prevalence in the YMSM Community**

The National Survey on Drug Use and Health found that sexual minority adults of any age had at least double the prevalence or use of illicit drugs compared to the heterosexual population [9]. However, according to the NSDUH [9], the prevalence of alcohol drinking among sexual minorities is higher but the prevalence of high alcohol drinkers was similar. In comparison, another study found alcohol use/abuse to be prominent in the MSM population, with more than double the prevalence compared to the general population [10], indicating a high risk for MSM living with HIV to fall out of care engagement due to alcohol or drug use.

A study reported using an adjusted respondent-driven sampling (RDS) method in Chicago of YMSM in 2009 showed 75.3% having alcohol use, 56% having cannabis use, and 14% with use of cocaine, methamphetamine, prescription pain killers, heroin, or ecstasy use [11]. These estimates are quite lower than those from NSDUH for illicit drug use but higher for alcohol and ecstasy use, which could indicate differences in the sexual minority population as a whole and the YMSM population. The uConnect sample, an RDS sample of participants in Chicago with some overlap with YMAP participants, showed high rates of alcohol (87%) and marijuana (73.1%) use [12]. It is important to examine the drug use prevalence in YMSM to

understand the unique risk factors that they face, and how much these may impact care for HIV management. Moreover, as prevalence of drug use is higher in the YMSM community, it is important to examine the influence that social ties have on management of HIV.

### **1.1.3 Drug Use and HIV Management**

Two of the important patient-related factors that can affect adherence are depression and drug usage. Previous studies on this have shown that low adherence is strongly linked to depression and substance use [13, 14, 15, 16]. In particular, these studies indicate a cyclical nature to depression and substance use, leading to apathy in managing their HIV care. For HIV positive MSM, a multicenter study involving multiple clinical sites found that more than 50% of the participants had used an illegal drug in the past month [17]. High usage of marijuana and opioids are also shown to be associated with suboptimal adherence [18]. A systematic review examining the extent to which marijuana use impacts HIV continuum of care outcomes found inconclusive results [19], while another showed that marijuana use was not associated with lower rates of viral suppression but depressive symptoms and other illegal drug use was linked [20].

A meta-analysis conducted in 2009 found that people living with HIV who possibly have alcohol use disorder were 50-60% less likely to be adherent to ART [14]. Another meta-analysis published in 2015 regarding the impact of alcohol use disorder on the HIV continuum of care showed that alcohol use disorder does appear to be linked to lower care outcomes, but there is difficulty in defining these links due to inconsistent measurements and reporting of results. Though most of the studies did find alcohol use disorder to be negatively linked to the HIV care continuum, there were eight studies that showed no effect [21]. In particular, it was of interest to examine the extent to which drug use disorders (as defined by ASSIST in our study) impacts a participant either initializing their care or being retained (having a prescription) and staying

adherent to their medication. Examining these two parts of the HIV care continuum could help guide interventions for these specific areas of the continuum.

#### **1.1.4 Influence of social networks on HIV Management**

Social, sexual, and venue networks may impact engagement in riskier behavior. A meta-analysis found that approximately one in three MSM sampled from venues that served alcohol did not use condoms when engaging in anal sex [22]. Conversely, they also showed that there are protective effects of a social network if this network practices safe sex practices (i.e. condom use) [23]. Latkin et al. reviewed the evidence that social networks can act as a protective factor for adherence, wherein a supportive network can assist an individual with attending appointments and other ways of managing their care [24]. Social networks have been shown to perpetuate certain behavioral and sexual behaviors, as MSM largely maintain homophilic (similar attributes to others in the network) networks based on race and behavior [25]. Furthermore, studies in various high-risk populations have shown that social interventions on reducing behavior that could lead to HIV transmission have been successful [25]. These studies indicate that an individual's network can have a strong influence on their behavior, which could lead to either positive or negative management outcomes. This study aimed to understand at which level is risky behavior in a person's network associated with low adherence or poor care management.

These previous studies conducted to examine the impact of substance abuse on ART adherence indicate negative effects of use on adherence. However, most of these studies focused only on the substance abuse of an individual rather than focusing on substance use within an individual's network to understand the interpersonal factors or contextual factors (spaces/places) that may impact individuals' behavior regarding receiving and staying in care. Other studies

focused on the impact of network effects on an individual's adherence were limited to heterosexual and needle-use populations rather than MSM or were concerned with transmission risks of HIV. Lastly, little research has specifically been done to understand the risk associations with social and sexual partners, and to what extent they influence low adherence outcomes. This thesis examined whether these network factors (interpersonal and contextual), particularly those related to substance use/abuse, influence if a PLWHIV is taking HIV medication or staying adherent while controlling for the important factor of depression among MSM by using existing data from a cohort study called the Young Men's Affiliation Project (YMAP).

#### **1.1.5 YMAP Study**

The YMAP study was a cohort study focused on young men who have sex with men (YMSM) aged 16-29 conducted in Chicago and Houston. The study had two phases: (1) Phase I focused on venues where YMSM congregate, categorized as social (sex establishments or bars) or health (sport clubs, college LGBTQ social clubs, clinics, testing centers). Survey data were collected by interviewing venue representatives using an informant-driven sampling method. Phase II focused on participant-level survey data by conducting survey interviews and lab tests using site-specific testing algorithm for HIV and syphilis infection [26]. YMAP participants were recruited and sampled using respondent-driven sampling (RDS) method, which is commonly used to recruit hard-to-reach population, by purposefully selecting initial respondents (i.e., seeds) who were given up to four coupons to give to their peers to participate in YMAP study (i.e., sprouts). This recruitment process reached several waves to achieve targeted sample size for each city (N=378 in Houston, N=377 in Chicago). Eligibility criteria for both seed and sprout participants were: between 16-29 years of age at baseline, living in Houston or Chicago

from 2014 to 2016, assigned male at birth and self-identified as male, English-speaking, and had an oral or anal sex partner that was male within a year of the start of the study [27].

Phase II was conducted over two waves (2014-2016 for baseline, and 2015-2017 for follow-up), with follow-up occurring a year later and up to a year and a half (1-1.5 year) from baseline. Survey data included various information, including sociodemographic (age, race/ethnicity, sexual orientation, socioeconomic status, etc.), behavioral (both risk and protective), and partner-level data (information on sexual and social partners). This study will use the information collected on drug use (tobacco, alcohol, marijuana, cocaine, ecstasy, methamphetamine, sedatives, painkillers, opioids, hallucinogens, steroids, and inhalants), medication use (ART if HIV positive), drug dependence, depression, demographics, and variables related to clinical care.

As for the collection of partner-level/interpersonal data, participants were also asked to name up to five social and sex partners, and then asked for each partner, their experience with drug use with partners, condom use, perceived HIV status of partners, and characteristics of partners. Laboratory tests were conducted to determine HIV serostatus of participants.

As for constructing venue affiliation network data, participants were provided a list of social and health venues separately and were then asked to name venues they had attended over the past twelve months and the frequency of attendance (1 – once in the past year to 7 – every day) [27].

#### **1.1.6 Ego-centric network measures and definitions**

An ego is defined as any one actor, or node, in a network; alters are the nodes tied to another ego via a tie. Ties, or edges, can define a variety of relationships – friendships, parental



figures, sexual partners, etc. from one node to another. In the case of YMAP, egos are respondents of the survey and alters are named partners, who occasionally were identified as other participants in the study through entity resolution. The ties, or edges, are defined as referral, social, or sexual. Ego-centric is defined as information specifically pertaining to one ego, such as the number of other nodes they are connected to who have some attribute. Ego-centric network information enables us to assess how interpersonal relationships can positively and negatively impact behavior of an ego (respondent). For example, previous studies have shown that PrEP usage is linked to knowing two or more other PrEP users [28]. Network effects on ART adherence among HIV-positive individuals were assessed by using information on the number of sex partners with certain behavior/attributes in one's egocentric network.

#### **1.1.7 Two-mode venue affiliation network measures**

In social network analysis, any social networks are composed of a set of a kind of nodes, or "mode." A one-mode network is composed of a single set of nodes, such as a set of students, a set of organizations, etc. On the other hand, a two-mode network is composed of sets of two different kinds of nodes, such as a set of students form the first set of nodes (i.e., 1<sup>st</sup> mode) who affiliate with a set of spaces that form the second set of nodes (i.e., 2<sup>nd</sup> mode). Thus, two-mode venue affiliation matrices represent the existence of affiliation tie between an individual and a unique space, location, or venue. In the case of YMAP data, our ties for two-mode matrices were composed of the first set of nodes, individuals or participants (1<sup>st</sup> mode) and the second set of nodes, venues (2<sup>nd</sup> mode). This type of data can be used to create affiliation exposure models (AEMs) [29]. Ego-centric network data allows us to assess if sex partners in one's sexual network may influence an ego's behavior, while AEM's provide insight on the extent to which co-attendance with peers with certain behavior/attributes may influence an ego's behavior [29].

Thus, AEM enable us to assess broader influence through network contexts by going beyond directly connected sex partners (interpersonal relationship).

The YMAP data lends itself to utilizing network data structures by providing venue attendance information and interpersonal/sexual partnership data. We applied ego-centric network and affiliation network analyses to understand the influence of: the number of sex partners an individual has used drugs with, the number of partners perceived as positive or unknown, and the percentage of social venues where co-attendees use the same drugs.

## **1.2 Public Health Significance**

There has been ample research examining drug use in the YMSM community and its impact on HIV outcomes from national surveys to respondent driven samples of YMSM through various time periods. In particular, though this study does not have data available from when the time period Illinois made marijuana use legal (January 2020), it provided some additional information for drug use prevalence in two US cities in the 2014-2016 time period. Furthermore, visualizations of the network helped us understand the connectivity of certain participants, their drug use, and some of their HIV continuum outcomes.

As adherence to ARTs keeps viral loads low or undetectable (and hence not transmissible), dually protecting partners from infection and from the virus progressing to AIDS, it is important to understand the socio-behavioral and network factors that may negatively impact adherence to inform designing and developing interventions and guide patient care. The YMSM population faces unique challenges with adherence compared to the general population and the age group 18-35 also has the highest incidence [30]. This paper will focus on the population of YMSM to understand the limiting factors in receiving care and staying adherent to ART, and

examining the extent to which substance use is prevalent in the YMSM community and its effect on HIV management.

This study also aims to examine whether attending venues where high-risk behavior such as alcohol and drug use may be more prevalent is an important factor in adherence. Conversely, this study will also examine the protective effects of attending venues associated with mental and physical wellbeing, such as gyms, religious organizations, and LGBTQ clubs. Investigating what barriers exist for HIV positive individuals to be taking medication at all and then which factors relate to their adherence can help guide future studies and inform treatment teams on how best to intervene with this population. In particular, we investigated the extent to which social and sexual networks impact behavior and whether an intervention utilizing network structures could be appropriate.

### **1.3 Specific Aims**

#### **1.3.1 Determine the prevalence of drug use in the YMSM community using RDS Estimates**

We aimed to understand the prevalence of substance use in the YMSM community and, more specifically, how substance use differs between HIV-negative and HIV-positive individuals. Moreover, we examined the network of participants to visualize the possible impact of substance use (cannabis, alcohol, or illicit drugs) of various relationships (referral, social, or sexual) on their management of HIV.

Prevalence of cannabis, alcohol, and illicit drug use in the three months prior to the baseline interview were estimated using self-reported information, RDS-II estimates, and RDS-SS estimates. Network graphs of participants connected via referral, social, and sexual ties were created to examine the relationships between participants, their HIV status and management, and substance use.

### **1.3.2 Determine which features are differentially related to having ART medication prescribed compared to staying adherent with the medication**

This study included sociodemographic, patient-related, and interpersonal factors that may impact receiving ART. This study aimed to identify the differences, or if any exist, between the factors that determine staying adherent to ART. Furthermore, this study included covariates related to network structured data to examine the importance of interpersonal behavior on adherence. Using the Phase II YMAP data will help determine which drugs, relationships and characteristics of alters, and other sociodemographic and behavioral variables impact (1) having a current HIV medication prescription and (2) staying adherent for YMSM HIV positive individuals.

All models were fit using generalized estimating equations (GEEs). The first point of interest determining which features are relevant for the binary outcome of whether a patient had a current prescription for HIV medication was chosen partially using QIC of the logistic GEE [31]. Adherence is measured as a self-report of the number of days a participant missed at least one dose of medication. Negative binomial GEE models selected using QIC and field knowledge to find the variables that were related to adherence.

We hypothesized that depression would be selected for the logistic model, but not for the NB model. Furthermore, we expected that an ego's marijuana and alcohol use negatively affect both receiving medication and taking it daily, though it will more strongly be linked to the latter.

### **1.3.3 Understand the relationship between an ego's personal drug use and/or drug use within one's social network on care management**

Due to the established relationships between drug use and low adherence, a selection of variables related to drug usage were included to understand which drugs and which type of

social connections affect: (1) having a current HIV medication prescription, and (2) staying adherent for YMSM HIV positive individuals. When controlling for other variables such as black race, insurance, and the study site, we expected to find that substance use was related more strongly to staying adherent than to having a current HIV prescription. However, we hypothesized that substance use/abuse in an ego's social network negatively impact both having a prescription and the number of days a patient missed at least one dose. Variables related to an ego's drug use, drug use during sex with partners, and the level of exposure to co-attendees who report the same drug use as an ego at venues were included for consideration in GEE models. Baseline measures determining whether a patient required a drug intervention using ASSIST guidelines were included for consideration. Multiply imputed Logistic and Poisson GEE models were fit again to meet this second aim, including other covariates determined from the results of Aim 1.

## **2 Methods**

### **2.1 Study Design**

This is a secondary data analysis of the YMAP project, with data collected and led by Dr. Fujimoto. This study used survey information from both baseline and follow-up of the survey data from Phase II of the YMAP project.

### **2.2 Study Subjects**

The young men in this study must have met all requirements to be included in YMAP and considered to be HIV positive during either Wave 1 or Wave 2 to be included for this analysis. The criteria for YMAP required men to be between 16 – 35 years of age, English-speaking, male at birth, male-identifying, had a male oral or anal sex partner in the year prior to the start of the

study, and living in Houston/Chicago from 2014 – 2016 [27]. There were 755 individuals enrolled into YMAP at baseline and 265 participants (35.1%) were self-reported HIV positive during either Wave I or Wave II in Houston and Chicago combined. Only self-reported HIV positive individuals were considered for analysis because those with negative or unknown self-reported status were not asked questions related to medication use and/or adherence.

HIV determinations were made using the CDC recommended testing algorithm by taking blood samples for testing [32]. Briefly, samples were first tested using a rapid test. If this came back positive, results were confirmed. If participants self-reported as positive and testing was inconclusive or unavailable, they were imputed to be positive. However, if participants self-reported as negative the HIV determination was undetermined. All participants newly diagnosed as HIV positive were referred to clinics for care.

## **2.3 Measures**

There are two outcomes that were examined: (i) whether a PLWHIV had a current HIV prescription for HIV medication, and (ii) a count measure of how many days a PLWHIV missed at least one dose of their medication in the past month prior to the survey.

The level of intervention need was determined per drug of use at baseline according to the Alcohol, Smoking and Substance Involvement Screening Test (ASSIST) guidelines, ranging from low risk of intervention to high risk of intervention [33]. The questions asked participants how frequently they had strong urges to use, how often they failed at expected tasks due to the drug, how often the drug has led to problems, whether someone close to them has expressed concern about their drug use, and whether they have tried and failed to control their use. Frequency responses were measured on a Likert scale from never to daily. Drugs included for this analysis were: alcohol, methamphetamine, ecstasy, cocaine, opiates, sedatives, pain killers,

and marijuana. For modelling, drugs were be consolidated into groups based on their frequency of use in the general population while maintaining cell counts. ASSIST scores were calculated for the following drug groups: (1) alcohol, (2) marijuana, and (3) certain other illegal drugs (cocaine, meth, ecstasy, opiates, sedatives and pain killers). Finally, the scores were categorized based on ASSIST guidelines into low risk and moderate/high risk with alcohol having a higher range of values to be considered low risk than other substances. For those that were consolidated, the highest score of the drugs were taken for the whole group.

The 10-item CES-D (Center for Epidemiological Studies Depression Scale) variables were consolidated into one variable. The binary variable indicating whether a participant was depressed was based on a cutoff score greater or equal to ten [34].

Ego-centric network measures related to the attributes of the alters for each ego were computed as well. These network variables are: the number of sex partners who were HIV-negative, positive, or of unknown HIV status; the number of sex partners that have a medium-high risk of alcohol, marijuana, or illicit drug use; and the number of sex partners where ego has had receptive anal intercourse without using a condom with an alter of unknown, positive, or negative HIV status. As for the venue affiliation measures, variables include the number of health venues and the number of social venues that an ego attended in the year prior to the interview. Lastly, we computed affiliation exposure measures using a converted/projected co-affiliation matrix from the original venue-person two-mode affiliation network. The affiliation exposure model allows us to assess the degree to which an individual is exposed to co-attendees with the same characteristics/behaviors at venues, by measuring the percentage of venues attended with other attendees with certain characteristics/behaviors (for example other attendees with high risk of marijuana usage).

Other control variables included for analysis were: race, city of recruitment, trust in treatment team (a self-reported indicator from not at all to completely), whether a participant had health insurance, and consistency of condom use (inconsistent, consistent). For participants that had insurance, they listed which type of insurance they had from: Public assistance (Medicaid, CountyCare, or Medicare), Veteran's Administration, private or work insurance, school-based, and COBRA, and other.

## **2.4 Statistical Analysis**

Estimates of the prevalence of drug use (cannabis, alcohol, or illicit drugs) were estimated using self-reported, RDS-II (Volz-Heckathorn), and RDS-SS (Giles' Sequential Sampling) estimates at Wave 1 for Houston and Chicago separately [35]. Estimates were completed for the overall YMSM population, HIV-positive YMSM, and HIV-negative YMSM.

For analysis of the factors relating to adherence, participants were excluded if they did not self-report being HIV positive at either Wave 1 or at Wave 2. Descriptive statistics for each covariate considered for analysis were assessed with chi-square or Fisher exact tests for categorical variables and Wilcoxon rank sum or t-tests for numerical variables. RDS weights were calculated using the Volz-Heckathorn (V-H/RDS-II) weights to account for the respondent driven sampling recruitment strategy [36]. The affiliation exposure measure terms were standardized to account for their small values for all GEE analyses. Missing data was determined not to be MCAR, so multiple imputation was performed to achieve unbiased estimates. The imputation was conducted in STATA 14.2 using MICE, which accommodated non-normally distributed data [37]. Thirty imputed datasets were created to impute the values of follow-up covariates and some baseline covariates. The baseline covariates that were imputed were the number of partners of positive, unknown, or negative HIV status with which a participant had



condomless receptive anal sex, insurance, homelessness, number of nominated partners at baseline, and depression. The imputation was conducted on the full sample, with conditional statements for variables only asked for self-reported HIV positive participants. All imputations controlled for city, black race, age at baseline, the number of social and health venues attended, the number of sex partners named, and ASSIST scores; the model also adjusted for the V-H weights.

Two different models that will be described in more detail below were used: (1) a multivariate logistic GEE model and a (2) multivariate Negative Binomial GEE model. Both models used robust standard errors and exchangeable correlation matrices, and adjusted for the sampling weight. There is little information on model selection methods post-imputation, but methods such as LRT or QIC are unavailable on pooled data. Due to these reasons, model selection was completed by first examining the results of univariable regressions. Once a baseline model was established, random samples of fifteen multiply imputed datasets were extracted and the QICs (quasilikelihood under the independence model criterion) were assessed when adding/removing variables for each iteration, a method described more thoroughly in Wood et al. [38]. QIC estimates for GEEs were calculated using the package “qui” in STATA 14.2 by James Cui, PhD [28]. Variables selected for each model were recorded, and those that were selected in ten or more of the iterations were kept. For Aim 2, a selection of variables related to substance use were re-entered into the models along with those selected based on the sampling method described above. Both models were estimated on the pooled data using the STATA with binomial family and logit links and negative binomial family with log links, respectively, while accounting for the Volz-Heckathorn sampling weights.

#### **2.4.1 Prevalence Estimates**

Respondent-driven sampling has been in large use for studying hard-to-reach populations since its inception in the late 1990s to account for the non-random sampling of the participants in the study [39]. As described previously, the process is to recruit “seeds” who then recruit a set number of other participants using coupons, who can then recruit more participants themselves. Hereafter, these types of ties will be called “referral ties.”

To determine the proportion of a characteristic present in a population, we can use estimators. Briefly, the first estimator proposed was the RDS-I estimator; due to its underperformance in comparison to RDS-II we will not discuss it in depth [39]. The RDS-II estimator, also known as the Volz-Heckathorn or V-H estimator, was introduced in 2008. It estimates the proportion of some characteristic  $a$  in the population using the form:

$$\hat{P}_a = \frac{\sum_{i \in S} a \frac{1}{d_i}}{\sum_{i \in S} \frac{1}{d_i}} \quad [39]$$

Here,  $S$  is the respondent-driven sample,  $S_a$  is the subgroup of the sample with the characteristic  $a$  and  $d_i$  is the reported number of other YMSM a person knows in their city, which captures a pseudo-degree. This estimator is unbiased under stringent assumptions; a few of these include that all individuals can be reached from any one node, each participant only recruited one other participant, and the number of “waves” or sets of recruitment are large. These assumptions are rarely met in practice. In particular, this can underestimate the proportion of a certain group if there was underselection due to homophily of the seeds [39]. To handle particularly the bias related to homophily, Gile et al. created the Gile’s Sequential Sampling estimator of the form:

$$\hat{P}_a = \frac{\sum_{i \in S} a \frac{1}{\hat{\pi}(d_i)}}{\sum_{i \in S} \frac{1}{\hat{\pi}(d_i)}} \quad [35]$$

Here,  $\hat{\pi}$  is now a function that maps the degree of a node to its inclusion probability [35]. These weights allow the assumption of sampling with replacement present in the V-H estimator to be ignored [35, 40].

We will use these two estimators along with the proportion based on self-report to determine the prevalence of marijuana, alcohol, and illicit (ecstasy, cocaine, meth, opioids, sedatives, and pain killers) drugs in the three months prior to the baseline interview.

#### 2.4.2 Network Measures

We considered the following ego-centric, and affiliation network measures: (1) the number of health/social venues an ego attends, (2) the number of sex partners an ego had anal sex with where he believes the alter was HIV positive/unknown/negative, (3) the number of sex partners that an ego has used drugs with (calculated per drug), and (4) the measure of assessing social venue co-attendees that have the same substance usage.

To calculate (1), the number of health/social venues an ego attends, we used the two-mode person-venue affiliation matrices,  $\mathbf{A}$ , to find the number of health or social venues that an ego has attended within the past year. The two-mode person-venue affiliation matrix has the following form:

$$\mathbf{A} = \{a_{i,m}\} = \begin{bmatrix} i = 1 & m = 1 & \dots & m = M \\ & a_{1,1} & \dots & a_{1,M} \\ \vdots & \vdots & \ddots & \vdots \\ i = N & a_{N,1} & \dots & a_{N,M} \end{bmatrix} \quad [29]$$

where  $i = 1, \dots, N, m = 1, \dots, M$

This matrix is created separately for health venues and for social venues in Chicago and Houston. To find the number of each type of venue attended, the row sums are taken for each participant  $i = 1, \dots, N$ :

$$\# \text{ health/social venues} = \sum_{m=1}^M a_{i,m}$$

For (2) and (3), the survey asked participants about their perception of their sex partner's HIV status and which drugs they have used with these partners. Thus, we counted the number of named sex partners who: (1) a participant believes is HIV positive, (2) a participant is unsure of the partner's status, and (3) used a group of drugs (marijuana, alcohol, depressants, or stimulants) with the ego.

Finally, to calculate (4), we begin with the two-mode venue affiliation matrix  $\mathbf{A}$  used to calculate (1). To first find the number of shared venues each pair of participants have attended we multiply matrix  $\mathbf{A}$  by its transpose ( $\mathbf{A}\mathbf{A}'$ ). This generates into a one-mode actor-by-actor  $N \times N$  adjacency matrix  $\mathbf{C}$ , where off-diagonal entries index the number of shared venues each pair of participants co-attended and on-diagonal entries index the total number of venues each participant has attended. Thus,  $\mathbf{C}$  is a valued adjacency matrix that is projected/converted by the original two-mode affiliation matrix  $\mathbf{A}$ , and this co-membership matrix  $\mathbf{C}$  (with replacing on-diagonal values with zeros but include the original on-diagonal values as a vector as one of the covariates in the subsequent regression analysis to control for the total number of social/health venues attended by each respondent) will be used to compute affiliation exposure measure.

$$\mathbf{A}\mathbf{A}' = \mathbf{C} = \{c_{i,j}\} = \begin{bmatrix} & j=1 & \dots & j=N \\ i=1 & c_{1,1} & \dots & c_{1,N} \\ \vdots & \vdots & \ddots & \vdots \\ i=N & c_{N,1} & \dots & c_{N,N} \end{bmatrix} \quad [29]$$

$$\text{where } i, j = 1, \dots, N, i \neq j$$

To then find the number of these pairs that have the same attributes, we multiply  $\mathbf{C}$  times a vector of the values of the selected attribute of interest,  $y$  of  $j$ , for each participant  $i$ :

$$\mathbf{F} = \{c_{i,j}\} = \begin{bmatrix} & j=1 & j=2 & \dots & j=N \\ i=1 & c_{1,1} & c_{1,2} & \dots & c_{1,n} \\ i=2 & c_{2,1} & c_{2,2} & \dots & c_{2,n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ i=N & c_{n,1} & c_{n,2} & \dots & c_{2,n} \end{bmatrix} \begin{bmatrix} \mathcal{Y}_{j=1} \\ \vdots \\ \mathcal{Y}_{j=n} \end{bmatrix}$$

where  $i, j = 1, \dots, N, i \neq j$

This end result, vector  $\mathbf{F}$ , gives us a scalar value for each participant which states the number of venues that have co-attended with other attendees with the same characteristics/behaviors with an ego at venues. The resulting vector  $\mathbf{F}$  will be divided by the row sum of  $\mathbf{C}$  for normalization that generates the affiliation exposure vector for each participant [29].

Each of these exposure calculations and on-diagonal vector (i.e., the total number of values each participant attended) end in a single scalar value for each participant and can thus were added into models as covariates.

### 2.4.3 Logistic GEE Model

Due to the repeated measures in the study and the presence of missing data from both waves, a GEE with MI, Huber-White robust standard errors, and an exchangeable correlation matrix were fit. A GEE allows missing values of the outcome to exist in both waves, unlike a repeated measures ANOVA. This model allows for more data to be used while still controlling for the extra covariance due to the repeated measures of the same individuals by using a sandwich variance estimator. Additionally, as we were interested in understanding general population level effects of covariates rather than specific variance in participants, a GEE was more appropriate than a mixed effects model. To understand the binary outcome of whether and individual is currently prescribed HIV medication versus not, the model will have the form:

$$g(\mu_{ij}) = \mathbf{X}_r^T \boldsymbol{\beta}_r + \boldsymbol{\gamma}_w^T \boldsymbol{\beta}_w + \epsilon \quad (\text{Eq. 1})$$

Here,  $\mathbf{X}_r$  is a  $N \times p$  matrix of all fixed predictors besides network affiliation terms;  $\beta_r$  is the  $p \times 1$  vector of unknown coefficients of the  $p$  predictors;  $\gamma_w$  is the matrix of calculated affiliation exposure variables;  $\beta_w$  is the vector of unknown coefficients of the affiliation exposure predictors; and  $\epsilon$  is the random error term, where  $N$  is twice the number of subjects,  $p$  is the number of predictors, and  $r$  is the number of subjects. In the logistic framework, the link function  $g(\mu) = \log\left(\frac{\mu_{ij}}{1 - \mu_{ij}}\right) = \eta$ , where  $\mu_{ij} = E(Y_{ij} | x_{ij})$ . GEEs account for the non-independence of the data through the use of working correlation, which iteratively refits the model. A benefit of this model is that the covariance structure is very robust against misspecifications of the correlation matrix. For our case, we assume an exchangeable correlation structure, which has the form:

$$R(\alpha) = \begin{bmatrix} 1 & \alpha \\ \alpha & 1 \end{bmatrix}$$

As described previously, pooled univariable GEE models were fit to determine some baseline covariates. The significant variables, along with other control variables, were fit to a random selection of fifteen multiply imputed datasets and the model was fit using QIC criteria. However, if a variable was important based on field knowledge, it was kept in the model. Fixed covariates that were considered were demographic information, number of health/social venues attended, depression, sexual behavior such as condom use, and drug use. To meet Aim 2, a selection of variables related to the baseline measure of intervention need per drug and the number of partners an ego uses drugs with were added back into the model.

#### 2.4.4 Negative Binomial GEE Model

To answer which factors impact the level of adherence, defined by the number of days that a participant has missed a dose of their medication in the past month, we used the same

formula as (Eq. 1). However, our outcome is now overdispersed count data so our link function was  $g(\mu) = \log(\mu_{ij})$ . We fit a negative binomial on only the complete cases of Wave 1 data with sampling weights to determine the appropriate  $\alpha$  of the model. We further confirmed that  $\alpha \pm 0.15$  range yielded similar results.

## **2.5 IRB Approval**

I was added to the IRB for the project “YMAP: Young Men's Affiliation Project of HIV Risk and Prevention Venues & iMAN: integrated Molecular & Affiliation Network Analysis of HIV Transmission” (YMAP) for the purpose of this project at The University of Texas Health Science Center School of Public Health. This data was previously collected from the YMAP study. The data was only analyzed on a UTHHealth approved network to maintain the privacy and security of participants secure. I did not come in contact with any of the individuals included in this study or with any animals. The protocol was approved by University of Texas Health Science Center at Houston IRB (HSC-SPH-12-0830).

## **3 Results**

### **3.1 Descriptive Statistics**

#### **3.1.1 Summary of demographic and egocentric predictors of having a current ART prescription at baseline**

Table 2 provides demographic, behavioral, and network characteristics for the YMSM who reported being HIV positive at Wave 1. There were a total of 217 people who self-reported as living with HIV at baseline, and who provided information about whether they had a current prescription. The majority (164, 75.6%) of participants did have a current prescription for

managing their HIV. A total of 103 (47.5%) participants were recruited in Chicago and 114 (52.5%) were recruited in Houston; there was not a significant association with having a current prescription and the city of residence. The ethnic distribution of PLWHIV was 13 Hispanic (6%), 9 NH White (4.1%), 188 NH Black (86.6%), and 7 other (3.2%). There was not a significant association with having a current prescription and ethnicity. However, cell counts were low in non-black groups, so these were aggregated for later analyses. The average age of the subgroup was 24.7 years.

Structural and systematic factors related to a current prescription were having insurance and having a history of incarceration. Of the participants living with HIV and those without there were 119 (72.6%) with insurance and 45 (27.4%) without insurance and 29 (54.7%) with insurance and 23 (43.4%) without insurance, respectively. About half of the participants ( $n = 108$ , 49.8%) reported a history of incarceration. In particular, of participants without a current prescription, 33 (62.3%) were jailed compared to 20 (37.7%) without a prescription who were not jailed. Homelessness was not associated with having a current prescription.

Clinical information related to having a current prescription was depression ( $p < 0.05$ ). Of participants with a prescription, 104 (63.4%) were not depressed compared to 54 (32.9%) who were depressed. Having a history of syphilis and trust in the doctor treating their HIV were not significant factors in having a prescription.

Drug use factors related to having a prescription were any illegal drug use (excluding cannabis) and having a moderate to high need of intervention for cannabis use and illegal drug use (excluding cannabis) based on ASSIST guidelines. There were 126 (58.1%) participants living with HIV who reported having used illegal drugs that are not cannabis. Of participants who did not have a prescription, there were 37 (69.8%) who reported having ever used illegal



drugs compared to 16 (30.2%) who did not. Concerning participants who did have a prescription, 89 (54.3%) used illegal drugs compared to 75 (45.7%) who did not. There were 53 (24.4%) participants were at a moderate to high risk of intervention based on their illegal drug use; of the group that had a prescription, 131 (79.9%) had low to no need for intervention based on their illegal drug use while 33 (20.1%) did have a need. Lastly, a sizeable portion of 135 (62.2%) of participants had a moderate to high need of intervention based on their marijuana use. Out of the participants without a prescription, 39 (73.6%) were participants with a moderate-to-high level of marijuana use. Of the participants with a prescription 96 (58.5%) were also at moderate to high risk compared to 68 (41.5%) who were not.

Inconsistent condom use was one of the sexual behavioral factors linked to having a prescription. Of participants with a prescription, 69 (42.1%) did use condoms in all sexual encounters and 84 (51.2%) did not. Conversely, 83 (38.2%) of participants who did not have a prescription used condoms consistently compared to 118 (54.4%) who did not. The number of partners of unknown HIV status a participant had sex with and, specifically, had condomless receptive anal sex with were significantly associated with having a current prescription ( $p < 0.05$ ).

Social and sexual partner drug behavior was largely not found to be associated with having a current prescription. However, drug use with a partner during sex was found to be associated. The number of partners a participant used alcohol and/or cannabis with during sex was significantly associated with having a current prescription. Affiliation exposure measures were also not found to be significant.

### **3.1.2 Summary of demographic, egocentric, and network predictors of the number of missed doses of ART at baseline**

Participants without a prescription were excluded from analysis related to doses missed in the month prior to the interview, leaving a total of 164 participants who were self-reported HIV positive at Wave 1 and had information on ART medication available. All results are described in detail in Table 3. A majority ( $n = 164$ , 54.9%) of the participants reported that they missed zero to one doses of their medication in the prior month, 63 (38.4%) reported they missed 2-7 doses, and 11 (6.7%) missed more than 7 doses. Race was significantly related to how many doses were missed in the last month ( $p < 0.05$ ). The ethnic distribution of participants who had a current prescription was 12 Hispanic (7.3%), 9 NH White (5.5%), 138 NH Black (84.1%), and 5 (3.0%) other.

A history of incarceration was also significantly associated with the number of missed doses in the prior month ( $p < 0.05$ ). Of participants living with HIV and who had a prescription for their HIV, 75 (45.7%) had a history of incarceration compared to 89 (54.4%). Of this group who missed more than 7 doses, 8 (72.7%) had been jailed compared to 3 (27.3%) who had not been jailed previously. Other structural and community factors were not found to be associated with missing doses of medication.

Illegal drug use (excluding cannabis) was associated with having missed doses of medication, but cannabis and alcohol were not found to be significantly related. There were 89 (54.3%) participants who had a current prescription and reported illegal drug use in their lifetime and 75 (45.7%) who did not. Of those who missed more than seven doses of their medication, 7 (63.6%) had reported illegal drug use compared to 4 (36.4%) who did not report illegal drug use. There were not any sexual behavior or venue affiliation exposure variables related to missing doses of medication.

### **3.2 Aim 1**

### 3.2.1 Prevalence Estimates of Substance Use

The estimated prevalence of cannabis and alcohol were similar across the different estimates, as shown in Table 1 and Figure 1. The estimate of illicit drugs, however, was underestimated by both RDS estimators. Both RDS estimators reported similar results, with the RDS-SS estimate having a slightly higher variance than the RDS-II estimator for all estimations. The reported marijuana use was higher in Chicago (85%) than in Houston (79%), but alcohol use among YMSM was higher in Houston (95%) than in Chicago (92%).

There were a few differences between the cities and the differences in the estimated prevalence for HIV positive participants compared to those who were HIV negative. In Chicago, illicit drug use was reportedly marginally more prevalent for participants living with HIV at baseline (55%) than those who were HIV-negative (53%); cannabis use was also marginally more common among HIV-negative participants (87%). In Houston, illicit drug use was fairly constant across HIV-status according to the self-reported prevalence of 54%. However, the RDS estimates indicate that illicit drug use is more common among YMSM living with HIV with a prevalence of 51% compared to 38% for HIV-negative YMSM. However, for all of these estimates the confidence intervals are still overlapping so these are not significant trends.

Figures 2 and 3 show the Chicago and Houston networks based on referral, sexual, and social ties, with each panel within the figures indicating a different drug group (alcohol, cannabis, or illicit). The sexual and social ties included were only the ones that were linked to other participants in the study, so this is not fully representative of the characteristics of participants' entire network; they may have more or fewer sexual and social ties with certain drug use characteristics who were not participants. Due to the high prevalence of cannabis and alcohol use, there are few ties for any participants with a link to someone who does not use either

substance. Looking at the network with illicit drug use, we see that participants who do not have a prescription are mostly linked to others with illicit drug use. Interestingly, in Houston there appears to be a small socially-connected cluster of participants who do not have medication. In comparison, there appears to be homophily with participants who are HIV-positive and are on medication, indicating a possibly protective factor.

### **3.3 Aim 2**

#### **3.3.1 Univariable logistic GEE models for ART Prescription**

All results from the pooled univariable logistic GEEs are presented in Table 5. Logistic GEE were fit one predictor at a time using the pooled results from the thirty iterations of multiple imputation with exchangeable correlation matrices, robust standard errors, and sampling weights. This model allowed for participants who self-reported living with HIV and had data information on their ART prescription available in either Wave 1 or Wave 2, expanding the sample size to 262 participants and 426 observations compared to 217 just at baseline. Cell counts in several of the categorical variables (trust in HIV provider, feeling a part of the gay community, and race) were small, so they were collapsed into binary groups. All affiliation exposure measure variables were normalized. The city of recruitment was significantly associated with having a prescription when looking at the univariable model ( $p < 0.05$ ). YMSM with HIV were 0.35 times as likely to have a prescription for HIV medication as those living in Chicago.

The only structural factor significantly related to having a prescription was having insurance ( $p < 0.05$ ). YMSM with HIV who had insurance were 4.69 times as likely to have a current prescription as those who did not have insurance. Young MSM with HIV and their immediate network's drug use was not significantly related to having medication, and neither was the percentage of venues attended where there were participants with drug use. The number

of perceived HIV negative partners was significantly associated. For every one HIV negative sex partner YMSM had, they were 50% more likely to have a current prescription. There were not any venue-related factors which were significantly associated with having a prescription.

### **3.3.2 Logistic GEE model selected by QIC Selection for ART Prescribed**

Variables with a p-value less than 0.20 were included for consideration for building the multivariable logistic GEE. As goodness-of-fit statistics are unavailable and unreliable on pooled data, a subset of fifteen randomly selected datasets were extracted to test model fit based on QIC. The variables selected in ten out of the fifteen subsets were used in the pooled multivariate logistic GEE model with sample weights. We confirmed that the exchangeable correlation matrix was appropriate compared to a one-period autoregressive correlation for each iteration. The exchangeable correlation matrix always had a smaller QIC, and doubly made the model more parsimonious. Variable selection was largely consistent across all fifteen imputed datasets with similar QICs and identical models chosen.

The variables selected were black race, having insurance, trust in their HIV provider, having a history of syphilis infection, the number of partners a participant used illegal drugs with during sex, the number of sexual partners a participant had condomless anal sex with of positive HIV status, the number of HIV-negative sex partners, and the standardized percentage of health venues attended by an ego that other HIV positive people.. To account for the variance in the number of participants who named partners where information was asked, the total number of named sex partners was added back to the model; similarly, the number of health venues attended was added to account for the percentage variable. All results are available in Table 6.

Variables related to whether YMSM with HIV were likely to have a prescription were largely related to clinical and structural reasons. The multivariable GEE shows that YMSM

living with HIV who are black are 95% less likely to have a current prescription for managing their HIV when controlling for all other variables. Insurance is also significantly associated, with YMSM living with HIV being 4.45 times more likely to have had a current prescription than those who did not. Lastly, YMSM with HIV who have no trust to only somewhat trust in their providers in treating their HIV were 84% less likely to have a current prescription compared to YMSM with HIV who mostly to completely trusted their providers in managing their care.

Compared to the univariable models, there were fewer variables found to be significant when controlling for others in the multivariable model. In particular, the number of HIV-partners and the number of health venues attended became insignificant when controlling for other variables in the model. City of residence was ultimately determined to be unimportant when considering other factors, and was not included in the model at all. Black race and trust in a provider did become significant when controlling for other variables, though. Insurance was significant in both the univariable and multivariable model, supporting the assumption that insurance is strongly linked to engagement in YMSM's engagement in care.

The Monte Carlo errors for coefficients, standard errors, and p-values all confirmed that there was minimal error associated with the repeated iterations of multiple imputation. Per the guidelines by White et al, all Monte Carlo error estimates of the coefficients were less than 10% of the standard errors of the coefficients and Monte Carlo error estimates of the p-values followed a similarly appropriate relationship [35].

### **3.3.3 Univariable negative binomial GEE models for ART Missed**

All results from the pooled univariable negative binomial GEEs are presented in Table 5. The negative binomial GEE models were fit one predictor at a time using the pooled results from the thirty iterations of multiple imputation. As previously mentioned, goodness of fit tests are

unreliable for pooled, imputed data. To test whether a negative binomial GEE was appropriate compared to a Poisson, we used the non-imputed dataset and fit a complete case negative binomial regression on the first wave of data. A negative binomial distribution was determined to be ideal, and the  $\alpha$  estimate was 1.36, which was used for defining the distribution in the univariable and multivariable negative binomial models. Based on various variables in this model, the  $\alpha$  changed within a range of [1.21, 1.41]. We confirmed that conclusions and results at these boundaries were similar to those when using an  $\alpha$  of 1.36 or when not specified ( $\alpha = 1$ ).

Black race and insurance were non-drug related factors significantly related to how many doses of ART medication YMSM with HIV missed. The models show that the expected count of the number of missed pills for black YMSM with HIV is 0.45 times than the expected count for YMSM with HIV of other races. Having insurance also appears to act in a protective factor as YMSM who have insurance had an expected count of missed pills 0.40 times than those without insurance. In terms of variables related to an ego's drug use, YMSM with HIV who had illegal drug use of any kind (OR 3.03, 95% CI 1.68-5.46) and moderate-to-high risk use of cannabis (OR 2.11, 95% CI 1.23-3.63) or illegal drugs (OR 2.94, 95% CI 1.71-5.04) tended to miss more pills than those without drug use.

Drug use in YMSM living with HIV's social and sexual networks was also linked to more missed doses of medication in a month. For every one partner YMSM used cannabis with during sex, the expected number of missed pills increases by a factor of 1.45 ( $p < 0.05$ ). Similarly, for every one social or sexual partner who YMSM know that used alcohol or cannabis, their expected number of missed pills increase by a factor of 1.29 and 1.24, respectively. Venue affiliation exposure terms were also linked to larger doses of medication missed in the last month. For every social venue YMSM living with HIV attend, they miss an expected 1.06 times

more pills. Attending venues that other YMSM with moderate-to-high risk of alcohol (OR 1.52, 95% CI 1.17-1.97) was linked to more missed pills, but co-attendance with other participants who use cannabis was linked to fewer missed pills or cannabis use (OR 0.71, 95% CI 0.52-0.95).

Several sexual behavior factors were significantly related to the number of self-reported doses of HIV medication YMSM missed. For every one named sex partner of unknown HIV status, YMSM missed an expected 1.43 times more doses. YMSM with inconsistent condom use missed an expected count of doses 2.62 times more than that of YMSM with consistent condom use. In particular, condomless anal receptive with a partner of unknown (OR 1.52, 95% CI 1.04-2.23), positive (OR 2.14, 95% CI 1.22-3.76), or negative (OR 1.52, 95% CI 1.24-1.86) HIV status were found to be significantly related to a higher expected count of missed pills.

#### **3.3.4 Final negative binomial GEE model selected by QIC Selection for ART Doses Missed**

Variables with a p-value less than 0.20 were included for consideration for building the multivariable negative binomial GEE. As goodness-of-fit statistics are unavailable and unreliable on pooled data, a subset of fifteen randomly selected datasets were extracted to test model fit based on QIC as before with the logistic model. The variables selected in ten out of the fifteen subsets were used in the pooled multivariable negative binomial GEE model with sample weights, an exchangeable correlation matrix, and robust standard errors. We confirmed that the exchangeable correlation matrix was appropriate compared to a one-period autoregressive correlation for each iteration. As with the logistic model, the exchangeable correlation matrix always had lower QIC. Variable selection was largely consistent across all fifteen imputed datasets with similar QICs and identical models chosen. As before, Monte Carlo errors for coefficients, standard errors, and p-values all confirmed that there was minimal error associated with the repeated iterations of multiple imputation.



The final model selected using QIC after including all variables selected based on a p-value less than 0.20 in the univariable models is presented in Table 5. The final factors selected were city of residence, black race, insurance status, trust in their HIV provider, inconsistent condom use, the number of sexual partners they used cannabis with during sex, the number of sex partners of unknown HIV status, the number of partners who were HIV positive that a participant had anal, condomless receptive sex with, and the standardized percentage of social venues attended by participants with moderate-to-high alcohol risk. The number of named sex partners was added to the model to account for the questions specifically related to sex partners and the number of social venues was added again for the same reason.

When controlling for other factors, YMSM living with HIV with insurance missed an expected count of 0.59 times the doses that YMSM without insurance missed. Sexual behavioral factors were not found to be associated with a higher expected count of missed pills, when controlling for other factors. The only drug-related variable selected was the number partners YMSM used cannabis with during sex. For every one partner YMSM used cannabis with during sex, they missed 45% more expected doses.

The multivariable model excluded most variables related to drug use when compared to the univariable model, when controlling for other factors. The only factor that remained and was significant in both models were insurance. The protective relationship between insurance and adherence was maintained in both models. Insurance had a protective effect with fewer missed pills per month in both models. Inconsistent condom use and the number of sex partners of unknown status both became insignificant when controlling for other factors.

### **3.3.5 Comparison of ART prescribed model selected using QIC and ART missed models selected using QIC**

There were different variables selected and significant between the logistic model examining having a prescription and the negative binomial examining adherence to the medication when using QIC criteria. Table 6 clearly presents the results comparing the models selected. In both models, black race, insurance, trust in HIV provider, and the number of partners living with HIV YMSM had condomless anal receptive sex with were selected to be important to both models. Insurance indicated a protective effect in both models; YMSM with insurance were more likely to be on medication and missed fewer doses of medication. Trust in the provider treating their HIV was only significant for the logistic model. The negative binomial model indicated that cannabis during sex was linked to worse adherence outcomes, though illegal drug use during sex was also selected as important for the logistic model.

Exposure to participants with HIV at health venues, a history of syphilis infection, and the number of negative partners a participant had were selected only by the logistic model but not the negative binomial model. The variables selected in the negative binomial model that were not selected in the logistic model were: city of residence, the number of sex partners of unknown HIV status, inconsistent condom use, and exposure to co-attendees with a moderate-to-high risk need for intervention for alcohol.

The hypothesis that marijuana and/or alcohol use would be associated was not supported. Both models selected a variation of using drugs during sex. Additionally, ASSIST-related variables were also not selected or found to be significant in either model. We hypothesized that depression would be associated with having a prescription, but it was not found to explain an important portion of variance in either model, and was not significant in either model when tested.

### **3.4 Aim 2**

### **3.4.1 Results of multivariable logistic GEE model with selected substance use variables**

Variables related to our hypotheses related to drug use were not always selected. However, due to large collinearity between some of the substance use variables it was not appropriate to add all of them directly back into the model, which could obscure significant relationships. Instead, we again examined the randomly selected set of multiply imputed datasets and added substance use variables back one at a time while inspecting the QIC to maintain parsimony of the model. In particular, many of the substance use variables are highly correlated, so only a selection from each drug type (alcohol, cannabis, illegal) were included. The number of sex partners a participant named was added to the model to control for variables related to the number of sex partners who met some characteristic. Additionally, city of residence was not included in the initial model, so this was added again to control for differences in the populations in Houston and Chicago.

The variables selected were city, black race, insurance, trust in provider, illicit drug use, moderate to high alcohol risk, having a history of syphilis, the number of named sex partners, the number of named HIV-negative partners, the number of partners a participant used illegal drugs with during sex, exposure to others with HIV at health venues, and the number of HIV-positive sex partners an ego had condomless anal receptive sex with. The model was fit with V-H sampling weights, Huber-White robust standard errors, and an exchangeable correlation matrix. All results are presented in detail in Table 6. Individual non-drug related factors related to having a prescription when controlling for other factors were black race and trust in a YMSM's treatment provider for their HIV. Black YMSM with HIV were 96% less likely to have a current prescription, when controlling for other variables. YMSM with low trust in their provider managing their HIV were 81% less likely to have a current prescription.

Overall, sexual behavioral factors were not found to be associated with having a current prescription when controlling for other variables and neither were affiliation exposure or drug use terms. Interestingly, insurance became insignificant when adding other variables into the model.

We confirmed that all Monte Carlo simulation errors for coefficients was less than 10% of the standard errors of the coefficients, and that p-values of the errors also met the threshold of being 5-10% of the coefficient p-values.

### **3.4.2 Results of Negative Binomial GEE model with selected substance use variables**

As described for the logistic GEE, variables related to substance use that were not selected using QIC selection were added for consideration. Along with the control variables of city, black race, and insurance, the other non-drug related variables included for analysis were: trust in the provider managing HIV treatment, inconsistent condom use, and the number of partners an ego had condomless anal receptive sex with who were living with HIV. The same drug variables (moderate-to-high need for intervention for alcohol and illegal drug use) were added for the negative binomial regression as for the logistic described above to make these comparisons more meaningful. We confirmed that these additions did not largely change the model's parsimony by examining the QIC on a selection of extracted datasets. An additional variable considered for the negative binomial was the number of sex partners with which a participant used cannabis with and the standardized percentage of venues that had other attendees with moderate-to-high alcohol intervention need, which were significant in the univariable model. Additionally, the number of nominated social and sexual partners was included to control for the variation between the number of named partners egos named, as well as the number of social venues. The pooled negative binomial GEE included the thirty iterations

of multiple imputation with an alpha set to 1.36, with Huber-White robust standard errors, V-H sampling weights, and an exchangeable correlation matrix.

When controlling for other factors in the model, the only structural factor significantly related to missing doses of medication was having insurance. Insurance again exhibited a protective effect, with YMSM who had insurance missing an expected count 57% less than those of YMSM with HIV without insurance when controlling for other variables.

YMSM living with HIV with drug use appear to be at a higher risk of missing doses of medication. For every one partner YMSM used cannabis with during sex, they missed 1.31 times as many expected doses. Additionally, YMSM with hard drug use were found to be significantly associated with missing more doses of medication (OR 2.07, CI 1.16-3.69). We again confirmed that all Monte Carlo error estimates for coefficients were less than 10% of the standard errors of the coefficients, and that p-values of the errors also met the threshold of being 5-10% of the coefficient p-values.

### **3.4.3 Comparison of ART prescribed and ART missed models with substance use**

A comparison of tables 7 and 8 shows additional differences between the factors related to having a current prescription and staying adherent to the medication. The control factors of city, black race, and insurance were added in both models. Black race was significantly related to having a prescription, but not with maintaining adherence.

Variables that were significantly associated with having prescription but not with adherence were the number of partners YMSM used illegal drugs with during sex and black race. The variables significant in the negative binomial model that were not significant in the logistic model were the number of partners who an ego reported using cannabis with during sex, whether an ego used hard drugs, and insurance.

Our hypothesis that substance use in YMSM's networks would be more strongly related to maintaining adherence was not strongly supported by the two models. An alter's drug use during sex was associated with missing more doses of medication. However, there was not an association between the sexual or confidant partners in an ego's network who used a drug and adherence. Our hypothesis that drug use in a YMSM's network would impact their adherence more than their initial care engagement was not supported by these models. Moreover, attending venues where there are other YMSM with high-risk drug use does not appear to negatively impact adherence.

## **4 Discussion**

The MSM population continues to be the largest group of new HIV infections every year, with the youngest group (25 -3 4 years old) maintaining rising incidence from 2010 – 2016 [36]. There has been varying research on the effects of social networks, drug use, and/or sexual behavior on adherence to medication. However, little research has examined the influence that drug use in one's social or sexual network influences an ego's behavior in regards to retention in care and adherence to the medication. Furthermore, there is conflicting information on the extent to which alcohol and marijuana use impact the HIV care continuum.

According to the self-reported sample, YMSM in Chicago and Houston have high rates of drug use. Estimates of prevalence of illicit drug use among sexual minorities and YMSM specifically have range from 20%-65% [9, 10, 11]; we have found that the estimated prevalence of recent (past three month use) of one of ecstasy, cocaine, meth, opioids, sedatives, or pain killers is around 50% for YMSM. A study examining YMSM from 1994-1998 found similar rates for illicit drug use [43], though cannabis use appeared to be lower at the time. However, this is to be expected as public support and use of cannabis has increased in this time period [44].

The high rates of cannabis and alcohol use were unusual. Most studies estimate marijuana use among YMSM to range from 40-70% [45, 46]. However, the lower bound of the confidence intervals is in a more reasonable range. Some of the high estimates of marijuana use could be related to the majority of this sample being of black race (62%), as marijuana use has been found to be more prevalent among black populations [47, 45]. Other studies have higher estimates of alcohol use prevalence among MSM are at 88% compared to the 90-96% we observed [48, 49]. These studies both focused on overall general MSM populations and not YMSM specifically, though they note that binge drinking was more common among younger MSM. As our study was focused on YMSM in particular, their prevalence may be higher than compared to just the MSM population as a whole cited in other work.

RDS estimates for illicit drug use were often low, particularly when looking at the subgroups of only HIV-negative or HIV-positive participants. Fujimoto et al. (2018) described that this issue is related to the bias of self-reported network sizes [50]. Participants answered the question “How many MSM do you know in this city?” with responses ranging from 0 to 4000 men. Due to the formula for estimation, these extreme values are essentially excluded from adding to the prevalence estimate [50]. An examination of the outliers of this question showed that 66% of the outliers were of participants who stated they used illicit drugs, indicating that there was underestimation from the RDS estimates. Another concern is that the sample size for accurately estimating the prevalence is too low. Assuming a design effect of two and a 95% confidence interval, the expected sample size would need to be at least 300 participants for those who are HIV-negative and HIV-positive in each city [51]. A larger study could be used to examine these effects more thoroughly.

There was little indication that YMSM's cannabis or alcohol use was highly associated with linkage to care and adherence to the care, but the use of illegal drugs does seem to indicate poorer care outcomes. The population of HIV-positive participants in YMAP indicated high rates of drug use compared to other prevalence estimations of drug use [52]. In particular, 83% of participants reported marijuana use in their lifetime. Moreover, a sizeable portion (62.2%) of participants was determined to be in a moderate to high need of an intervention for their cannabis use. The bivariate analysis at baseline did indicate that having a moderate-to-high risk of intervention for cannabis was associated with having a prescription ( $p < 0.05$ ). However, this association did not maintain significance in either the univariable logistic regression model and was not considered an important variable for multivariable analysis. These results support the findings by Sinha et al.; cannabis use does not appear to be associated with the HIV care continuum [20]. However, other studies have indicated that black MSM with heavy use of cannabis are less likely to be aware of their seropositive status [53]. Because we only measured participants who knew of their HIV status, we may be missing the population at the beginning of the HIV care continuum who need regular testing. Continuing research into understanding the impact of cannabis use, particularly in black MSM, on the HIV care continuum is vital to reducing the disparity in health outcomes for black MSM living with HIV.

There is inconclusive evidence that alcohol use is associated with lower care outcomes, though there is indication that binge drinking and alcohol use disorder are associated with lower adherence [21]. Bivariate analyses comparing moderate-to-high risk of intervention based on alcohol use and having a prescription or staying adherent were not found to be significant. It was determined to be an important factor for the multivariable logistic model based on QIC selection. However, it was not significant. It appears that the effect of alcohol use and alcohol use disorder



remains on engagement in care continues to be inconclusive. Future studies with a larger sample size could examine these effects more thoroughly.

Illicit drug use (cocaine, meth, ecstasy, opiates, sedatives and pain killers) was associated with both adherence and having a prescription in some way. Bivariate chi-square analyses examining whether a history illicit drug use was associated with the outcomes of having a prescription and staying adherent were significant. Having a moderate-to-high risk need for intervention based on illicit drug use was only significant for outcome of having a prescription, but not for staying adherent. However, illegal drug use and the need for an intervention were not significant in the univariable analysis for having a prescription. Both, however, were significant in the model examining how many pills an ego missed in the prior month. This supports other studies which have indicated a negative impact of illicit drug use on maintaining adherence to medication. It does not appear to be a barrier in initially receiving care, however.

Despite ample evidence that depression is related to negative linkage to care and retention outcomes, it was not found to be an important variable in any of the models. As described in Gonzales et al., substance use may act as a mediator between depression and engagement in care [17]. Examining these mediating effects may be worthwhile next steps.

An interesting finding was the intersection of drug use and sex. Alcohol use during sex was significant in the bivariate analyses of having a prescription, but not for the analysis of adherence. Furthermore, it was not significant in the univariable or multivariable models. However, the number of partners YMSM used cannabis with during sex was significant in the multivariable models examining staying adherent. Drug use during sex was associated with worse outcomes related to the HIV care continuum. This information could be associated with generally higher sexual risk behavior, which has been previously associated with care outcomes.

In particular, Risher et al. found that people living with HIV who inconsistently used condoms were less likely to be on ART [54]. We found that inconsistent condom use was significant in the univariable analysis examining adherence. These results, however, were not significant in the multivariable analyses, perhaps because of their correlation with one another. We also examined condomless anal receptive sex with partners of negative, positive, or unknown HIV status. In particular, univariable analyses showed that the number of partners with which YMSM had condomless receptive anal sex was not a significant predictor of having a prescription, but it was a predictor of staying adherent to the medication. QIC results showed that these variables were vital to the model, but they were not overall significant in the model.

Few variables related to dyadic information about a partner were significant. Of note, variables related to a sex partner's HIV status were significant. Interestingly, YMSM who had HIV- sex partners were more likely to have a prescription, but there was no association with adherence when considering the number of HIV- partners when examining the univariable analyses. However, the more sex partners of unknown HIV status, the more pills YMSM reportedly missed. This could further indicate higher sexual risk behavior (i.e. casual sex with short term partners) and negative consequences on the HIV care continuum. This also indicates a need for interventions targeting MSM with high sexual risk behavior, particularly if they have sex with persons of unknown HIV status. Future work could be spent analyzing the extent to which there is overlap between drug use during sex, inconsistent condom use, and casual sex to target interventions for possible high transmitters.

Exposure to other YMSM with drug use was not associated with univariable analyses of having a prescription, but the exposure at social venues to other attendees with moderate-to-high alcohol and cannabis intervention needs were significant in the univariable analysis for the

number of doses missed. However, these did not remain to be significant in the multivariable models, though exposure to co-attendees with alcohol use disorder was important to the overall model. This could be due to control variables that also indicate other behaviors that could lead to attending venues with other high-risk individuals.

The most consistent factors related to maintaining a prescription and staying adherent are still systemic, such as race and access to insurance. Having insurance was found to be significant in all models and bivariate analyses for the population of YMSM except for the multivariable model for whether someone had a prescription. A likely reason for this is that this final model controlled for city, which was found to be significantly associated with having insurance. YMSM in Houston were more likely to have insurance than those in Chicago so this relationship masked the effect of insurance in general on having a prescription.

Moreover, low trust in a provider's care was also negatively associated with having a prescription. Future analyses could examine the reasons for YMSM to have low trust in their provider. These findings are similar to others and identify an urgent need to uncover the reasons behind low trust in a provider. Saha et al. concluded that low trust in the provider managing their HIV was a factor in racial disparities among African Americans living with HIV [55]. Identifying the cause of low trust is an important next step in closing the disparity in health outcomes between African Americans and white HIV patients in the US.

There were several limitations to this study. We focused on a self-report of the number of doses of medication missed rather than viral loads. Though self-reports are a good proxy for adherence, there is a tendency for individuals to underreport the number of missed doses [56]. However, using adherence can also be problematic due to some strands of HIV being particularly difficult to treat; moreover, some participants reported low adherence but still maintained low

viral counts. In an ideal scenario, participants would be followed over time and any leftover pills would be counted at follow-up visits. However, this process is expensive and not always manageable.

Similarly, one of the other limitations is that there was no data collected on the type medication a participant was taking or whether they experienced any side effects. Certain drug combinations could cause side effects that make a participant less likely to take their medication [57]. Moreover, difficulty in finding the right combination of drugs could lead to apathy in continuing care and contribute to low provider trust as well. In particular, YMAP was not focused specifically on only HIV+ individuals, and, as such, there is a relatively small sample size and few questions specifically related to HIV management. However, compared to mixed effect models, GEE are able to detect effects at smaller sample sizes [58].

There are simply limitations due the self-reported nature of the variables presented. Network members were not interviewed, so characteristics may be missing or unknown for the variables related to a network member's drug use or HIV status. However, the data presented is similar to other studies based on network analyses wherein information about others was collected through a participant [59].

Lastly, venue affiliation exposure measures were dependent on the classification of venues into health (LGBTQ organizations, clinics, or gyms) and social (bars, clubs, sex clubs). However, the classification of gyms in particular can be problematic as they are a site of cruising for some of the MSM community [60], so they may not be as appropriately defined as health venues. However, these only compromised of about four venues out of the health venues in each city, so they should have minimal impact on the general findings.

Despite the limitations, there were useful results from this paper in guiding future analyses. Overall, substance use in a YMSM's social and sexual network was not associated with poor HIV continuum outcomes. However, direct engagement in drug use, particularly illicit drugs, can lead to poor adherence to HIV medication. In particular, the intersection of drug use and sex could warrant future analysis as to the extent to which it is linked with other high-risk sexual behavior. Of particular concern, research should be focused on whether YMSM who engage in drug use during sex also do not use condoms consistently. This population may be an appropriate target of HIV transmission interventions. Lastly, this study confirmed that insurance and trust in their provider are two of the most important factors related to HIV continuum outcomes. Additional research focused on the reasons why patients do not trust their provider could assist in reducing the HIV care outcome disparity between African Americans and other ethnicities in the US.

## 5 Tables

Table 1. Baseline Prior 3 Months Drug Use Prevalence (n = 377 in Chicago, 378 in Houston)  
(YMAP, 2014 - 2016)

City	Drug Use	HIV Status	Sample <sup>1</sup>	RDS- II <sup>2</sup>	RDS-SS <sup>3</sup>
Chicago	Illicit <sup>4</sup> Drugs	HIV+	0.55 (0.45,0.64)	0.37 (0.22,0.51)	0.37 (0.22,0.53)
		HIV-	0.53 (0.48,0.58)	0.41 (0.31,0.50)	0.41 (0.31,0.51)
		Overall	0.53 (0.48,0.58)	0.39 (0.31,0.47)	0.40 (0.32,0.48)
	Cannabis	HIV+	0.83 (0.75,0.90)	0.75 (0.64,0.87)	0.76 (0.63,0.88)
		HIV-	0.87 (0.83,0.91)	0.84 (0.79,0.90)	0.84 (0.79,0.90)
		Overall	0.85 (0.81,0.88)	0.82 (0.76,0.87)	0.82 (0.77,0.87)
	Alcohol	HIV+	0.91 (0.86,0.97)	0.84 (0.76,0.93)	0.85 (0.76,0.94)
		HIV-	0.94 (0.91,0.97)	0.87 (0.8,0.93)	0.87 (0.80,0.94)
		Overall	0.92 (0.89,0.95)	0.86 (0.81,0.91)	0.86 (0.80,0.92)
Houston	Illicit <sup>4</sup> Drugs	HIV+	0.54 (0.45,0.63)	0.51 (0.36,0.66)	0.51 (0.35,0.67)
		HIV-	0.54 (0.48,0.61)	0.38 (0.28,0.48)	0.39 (0.29,0.49)
		Overall	0.54 (0.49,0.59)	0.42 (0.34,0.51)	0.43 (0.34,0.52)
	Cannabis	HIV+	0.81 (0.74,0.88)	0.78 (0.66,0.90)	0.78 (0.66,0.91)
		HIV-	0.79 (0.74,0.84)	0.72 (0.63,0.81)	0.72 (0.63,0.82)
		Overall	0.79 (0.75,0.83)	0.74 (0.67,0.81)	0.74 (0.67,0.82)
	Alcohol	HIV+	0.97 (0.93,1.00)	0.97 (0.94,1.00)	0.97 (0.95,1.00)
		HIV-	0.97 (0.95,0.99)	0.94 (0.89,0.98)	0.94 (0.89,0.99)
		Overall	0.96 (0.94,0.98)	0.95 (0.91,0.98)	0.95 (0.91,0.98)

1 Unadjusted sample estimates

2 RDS-II is the Volz-Heckathorn estimator

3 RDS-SS is the Gile's Sequential Sampling estimator

4 Illicit drugs were use of any one of: ecstasys, cocaine, meth, opioids, sedatives, or pain killers

Table 2. Individual and network characteristics among self-reported HIV+ young men who have sex with men by ART prescription at baseline (n = 217) (YMAP, 2014 - 2016)

	Total (n = 217)	Current ART Prescription		p value
	n (%)	No (n = 53) n (%)	Yes (n = 164) n (%)	
Respondent's Characteristics				
City				0.96
Chicago	103 (47.5%)	25 (47.2%)	78 (47.6%)	
Houston	114 (52.5%)	28 (52.8%)	86 (52.4%)	
Race				0.14
Hispanic	13 (6.0%)	1 (1.9%)	12 (7.3%)	
NH White	9 (4.1%)	0 (0.0%)	9 (5.5%)	
Black	188 (86.6%)	50 (94.3%)	138 (84.1%)	
Mixed/Other	7 (3.2%)	2 (3.8%)	5 (3.0%)	
Age, mean (sd)	24.7 (2.8)	24.7 (2.7)	24.7 (2.8)	0.99
Insurance				0.023*
No	68 (31.3%)	23 (43.4%)	45 (27.4%)	
Yes	148 (68.2%)	29 (54.7%)	119 (72.6%)	
Missing	1 (0.5%)	1 (1.9%)	0 (0.0%)	
Ever Jailed				0.036*
No	109 (50.2%)	20 (37.7%)	89 (54.3%)	
Yes	108 (49.8%)	33 (62.3%)	75 (45.7%)	
Homeless Past 12 months				0.25
No	152 (70.0%)	34 (64.2%)	118 (72.0%)	
Yes	64 (29.5%)	19 (35.8%)	45 (27.4%)	
Missing	1 (0.5%)	0 (0.0%)	1 (0.6%)	
Depressed <sup>1</sup>				0.036*
No	127 (58.5%)	23 (43.4%)	104 (63.4%)	
Yes	78 (35.9%)	24 (45.3%)	54 (32.9%)	
Missing	12 (5.5%)	6 (11.3%)	6 (3.7%)	
Trust in HIV Provider				0.075
Completely	118 (54.4%)	15 (28.3%)	103 (62.8%)	
Mostly	25 (11.5%)	9 (17.0%)	16 (9.8%)	
Somewhat	26 (12.0%)	5 (9.4%)	21 (12.8%)	
A little	4 (1.8%)	1 (1.9%)	3 (1.8%)	
Not at all	3 (1.4%)	1 (1.9%)	2 (1.2%)	
Missing	41 (18.9%)	22 (41.5%)	19 (11.6%)	
Illegal Drug Use <sup>2</sup>				0.046*
Yes	91 (41.9%)	16 (30.2%)	75 (45.7%)	
No	126 (58.1%)	37 (69.8%)	89 (54.3%)	
Alcohol ASSIST Risk				0.60
Low	162 (74.7%)	41 (77.4%)	121 (73.8%)	
Mod/High	55 (25.3%)	12 (22.6%)	43 (26.2%)	
Cannabis ASSIST Risk				0.049*
Low	82 (37.8%)	14 (26.4%)	68 (41.5%)	
Mod/High	135 (62.2%)	39 (73.6%)	96 (58.5%)	
Illegal ASSIST Risk				0.009*
Low	164 (75.6%)	33 (62.3%)	131 (79.9%)	
Mod/High	53 (24.4%)	20 (37.7%)	33 (20.1%)	
Gay Community				0.86
Very much a part of	91 (41.9%)	22 (41.5%)	69 (42.1%)	
Somewhat a part of	69 (31.8%)	16 (30.2%)	53 (32.3%)	
Not very much a part of	45 (20.7%)	13 (24.5%)	32 (19.5%)	
Not at all a part of	12 (5.5%)	2 (3.8%)	10 (6.1%)	
Syphilis				0.61
No	59 (27.2%)	12 (22.6%)	47 (28.7%)	
Yes	122 (56.2%)	29 (54.7%)	93 (56.7%)	
Missing	36 (16.6%)	12 (22.6%)	24 (14.6%)	

Inconsistent Condom Use <sup>3</sup>				
No	83 (38.2%)	14 (26.4%)	69 (42.1%)	0.05*
Yes	118 (54.4%)	34 (64.2%)	84 (51.2%)	
Missing	16 (7.4%)	5 (9.4%)	11 (6.7%)	
Number of HIV+ Named Sex Partners	1 (0-1)	1 (0-1)	1 (0-1)	0.63
Number of Named HIV Unk Partners, median (IQR)	0 (0-1)	0 (0-2)	0 (0-1)	<0.001*
Number of Named HIV- Partners, median (IQR)	1 (0-2)	0 (0-2)	1 (0-2)	0.19
<b>Dyadic Sexual Network Characteristics median (IQR)</b>				
Number of Partners Used Alcohol W/ During Sex	0 (0-1)	0 (0-1)	0 (0-1)	0.035*
Number of Partners Used Cannabis W/ During Sex	0 (0-1)	0 (0-2)	0 (0-1)	0.093*
Number of Social/Sexual Partner Use Illegal Drugs	0 (0-0)	0 (0-0)	0 (0-0)	0.16
Number of Social/Sexual Partner Use Alcohol	1 (0-3)	1 (0-3)	1 (0-3)	0.70
Number of Social/Sexual Partner Use Cannabis	2 (0-3)	1 (0-4)	2 (.5-3)	0.93
Number of Social/Sexual Partner Use Illegal Drugs	0 (0-0)	0 (0-0)	0 (0-0)	0.16
Number of Unknown Status Partners Had				0.029*
Condomless Receptive Anal Sex With	0 (0-0)	0 (0-0)	0 (0-0)	
Number of HIV+ Partners Had				0.30
Condomless Receptive Anal Sex With	0 (0-0)	0 (0-0)	0 (0-0)	
Number of HIV- Partners Had				0.68
Receptive Condomless Anal Sex With	0 (0-0)	0 (0-0)	0 (0-0)	
<b>Venue and Co-Attendee Characteristics median (IQR)<sup>4</sup></b>				
Number of Health Venues Attended	2 (1-4)	2 (1-4)	2 (1-4)	0.86
Number of Social Venues Attended	4 (2-8)	5 (2-9)	4 (2-8)	0.95
Exposure to HIV at Health Venues	22 (15.3-28)	19.7 (10-23.8)	22.5 (16.3-29)	0.032*
Exposure to HIV at Social Venues	0.49 (0.34-0.61)	0.46 (0.33-0.53)	0.51 (0.34-0.61)	0.11
Exposure to High-Risk Alcohol Use	0.35 (0.29-0.40)	0.34 (0.29-0.39)	0.35 (0.29-0.40)	0.79
Exposure to High-Risk Cannabis Use	0.33 (0.32-0.35)	0.33 (0.32-0.34)	0.33 (0.31-0.36)	0.75
Exposure to High-Risk Illegal Drug Use	0.56 (0.49-0.61)	0.57 (0.49-0.60)	0.55 (0.49-0.62)	0.84

1 Determined based on the CES-D Depression Inventory. Participants with a score  $\geq 10$  were considered depressed.

2 Use of either cocaine/crack, methamphetamine, ecstasy, opioids, sedatives, or painkillers.

3 Defined as reporting no condom use in any sexual encounter.

4 All exposure terms were normalized over the number of health/social venues attended.



Table 3. Individual and network characteristics among self-reported HIV+ young men who have sex with men by categorized missed ART doses at baseline (n = 164) (YMAP, 2014 - 2016)

	Total N=164	# Missed ART Doses in Prior Month			p value
	n (%)	0-1 (n = 90) n (%)	2-7 (n = 63) n(%)	> 7 (n = 11) n(%)	
Respondent's Characteristics					
City					0.32
Chicago	78 (47.6%)	38 (42.2%)	34 (54.0%)	6 (54.5%)	
Houston	86 (52.4%)	52 (57.8%)	29 (46.0%)	5 (45.5%)	
Race					0.004*
Hispanic	12 (7.3%)	5 (5.6%)	3 (4.8%)	4 (36.4%)	
NH White	9 (5.5%)	5 (5.6%)	4 (6.3%)	0 (0.0%)	
Black	138 (84.1%)	75 (83.3%)	56 (88.9%)	7 (63.6%)	
Mixed/Other	5 (3.0%)	5 (5.6%)	0 (0.0%)	0 (0.0%)	
Age, mean (sd)	24.7 (2.8)	24.4 (2.8)	25.2 (2.8)	24.3 (2.6)	0.17
Insurance					0.58
No	45 (27.4%)	22 (24.4%)	19 (30.2%)	4 (36.4%)	
Yes	119 (72.6%)	68 (75.6%)	44 (69.8%)	7 (63.6%)	
Syphilis					0.14
No	47 (28.7%)	20 (22.2%)	23 (36.5%)	4 (36.4%)	
Yes	93 (56.7%)	56 (62.2%)	32 (50.8%)	5 (45.5%)	
Missing	24 (14.6%)	14 (15.6%)	8 (12.7%)	2 (18.2%)	
Inconsistent Condom Use					0.42
No	69 (42.1%)	41 (45.6%)	26 (41.3%)	2 (18.2%)	
Yes	84 (51.2%)	44 (48.9%)	34 (54.0%)	6 (54.5%)	
Missing	11 (6.7%)	5 (5.6%)	3 (4.8%)	3 (27.3%)	
Ever Jailed					0.019*
No	89 (54.3%)	57 (63.3%)	29 (46.0%)	3 (27.3%)	
Yes	75 (45.7%)	33 (36.7%)	34 (54.0%)	8 (72.7%)	
Homeless Past 12 months					0.10
No	118 (72.0%)	70 (77.8%)	39 (61.9%)	9 (81.8%)	
Yes	45 (27.4%)	20 (22.2%)	23 (36.5%)	2 (18.2%)	
Missing	1 (0.6%)	0 (0.0%)	1 (1.6%)	0 (0.0%)	
Depressed					0.70
No	104 (63.4%)	58 (64.4%)	39 (61.9%)	7 (63.6%)	
Yes	54 (32.9%)	27 (30.0%)	24 (38.1%)	3 (27.3%)	
Missing	6 (3.7%)	5 (5.6%)	0 (0.0%)	1 (9.1%)	
Trust in HIV Provider					0.45
Completely	103 (62.8%)	58 (64.4%)	39 (61.9%)	6 (54.5%)	
Mostly	16 (9.8%)	6 (6.7%)	8 (12.7%)	2 (18.2%)	
Somewhat	21 (12.8%)	12 (13.3%)	9 (14.3%)	0 (0.0%)	
A little	3 (1.8%)	1 (1.1%)	1 (1.6%)	1 (9.1%)	
Not at all	2 (1.2%)	1 (1.1%)	1 (1.6%)	0 (0.0%)	
Missing	19 (11.6%)	12 (13.3%)	5 (7.9%)	2 (18.2%)	
Illegal Drug Use					0.047*
Yes	75 (45.7%)	49 (54.4%)	22 (34.9%)	4 (36.4%)	
No	89 (54.3%)	41 (45.6%)	41 (65.1%)	7 (63.6%)	
Alcohol ASSIST Risk					0.78
Low	121 (73.8%)	65 (72.2%)	47 (74.6%)	9 (81.8%)	
Mod/High	43 (26.2%)	25 (27.8%)	16 (25.4%)	2 (18.2%)	
Cannabis ASSIST Risk					0.69
Low	68 (41.5%)	40 (44.4%)	24 (38.1%)	4 (36.4%)	
Mod/High	96 (58.5%)	50 (55.6%)	39 (61.9%)	7 (63.6%)	
Illegal ASSIST Risk					0.099
Low	131 (79.9%)	77 (85.6%)	45 (71.4%)	9 (81.8%)	
Mod/High	33 (20.1%)	13 (14.4%)	18 (28.6%)	2 (18.2%)	
Inconsistent Condom Use					0.42
No	69 (42.1%)	41 (45.6%)	26 (41.3%)	2 (18.2%)	
Yes	84 (51.2%)	44 (48.9%)	34 (54.0%)	6 (54.5%)	

Missing	11 (6.7%)	5 (5.6%)	3 (4.8%)	3 (27.3%)	
Gay Community					
Very much a part of	69 (42.1%)	33 (36.7%)	31 (49.2%)	5 (45.5%)	0.082
Somewhat a part of	53 (32.3%)	25 (27.8%)	24 (38.1%)	4 (36.4%)	
Not very much a part of	32 (19.5%)	24 (26.7%)	6 (9.5%)	2 (18.2%)	
Not at all a part of	10 (6.1%)	8 (8.9%)	2 (3.2%)	0 (0.0%)	
Number of HIV+ Partners	1 (0-1)	1 (0-1)	1 (0-1)	0 (0-1)	0.34
Number of Named HIV- Partners	1 (0-2)	1 (0-2)	1 (0-2)	0 (0-3)	0.78
Number of Named HIV Unk Partners	0 (0-1)	0 (0-1)	0 (0-0)	0 (0-1)	0.49
<b>Dyadic Sexual Network Characteristics median (IQR)</b>					
Number of Partners Used Alcohol W/ During Sex	0 (0-1)	0 (0-1)	0 (0-0)	0 (0-1)	0.70
Number of Partners Used Cannabis W/ During Sex	0 (0-1)	0 (0-1)	0 (0-1)	0 (0-1)	0.14
Number of Social/Sexual Partner Use Illegal Drugs	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.35
Number of Social/Sexual Partner Use Alcohol	1 (0-3)	1 (0-3)	1 (0-3)	1 (0-3)	0.65
Number of Social/Sexual Partner Use Cannabis	2 (.5-3)	2 (0-3)	2 (1-4)	1 (0-3)	0.55
Number of Social/Sexual Partner Use Illegal Drugs	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.35
Number of Unknown Status Partners Had Condomless Receptive Anal Sex With	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.16
Number of HIV+ Partners Had Condomless Receptive Anal Sex With	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.089
Number of HIV- Partners Had Receptive Condomless Anal Sex With	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.41
<b>Venue and Co-attendee Characteristics median (IQR)</b>					
Number of Health Venues Attended	2 (1-4)	2 (1-4)	2 (1-3)	1 (1-3)	0.50
Number of Social Venues Attended	4 (2-8)	4 (2-8)	5 (1-9)	4 (1-9)	0.94
Exposure to HIV at Health Venues	0.51 (0.34-0.61)	0.50 (0.32-0.61)	0.53 (0.35-0.61)	0.48 (0.35-0.58)	0.66
Exposure to HIV at Social Venues	0.35 (0.29-0.40)	0.35 (0.29-0.40)	0.33 (0.29-0.40)	0.34 (0.29-0.43)	0.85
Exposure to High-Risk Alcohol Use	0.33 (0.31-0.36)	0.33 (0.32-0.35)	0.34 (0.31-0.36)	0.33 (0.31-0.36)	0.48
Exposure to High-Risk Cannabis Use	0.55 (0.49-0.62)	0.53 (0.48-0.60)	0.56 (0.50-0.62)	0.58 (0.52-0.63)	0.51
Exposure to High-Risk Illegal Drug Use	0.22 (0.20-0.23)	0.21 (0.20-0.23)	0.22 (0.21-0.23)	0.22 (0.19-0.23)	0.25

1 Determined based on the CES-D Depression Inventory. Participants with a score  $\geq 10$  were considered depressed.

2 Use of either cocaine/crack, methamphetamine, ecstasy, opioids, sedatives, or painkillers.

3 Defined as reporting no condom use in any sexual encounter.

4 All exposure terms were normalized over the number of other individuals who attended the same venues.

Table 4. Univariable pooled weighted logistic GEE results examining whether subject had a current ART prescription (n = 262) (YMAP, 2014 - 2016)

Characteristics	OR (95% CI)	p value
City		0.015*
Chicago	REF	
Houston	0.35 (0.15, 0.82)	
Black	0.38 (0.10, 1.44)	0.154
Age	1.04 (0.89, 1.22)	0.598
Insurance		0.001*
No	REF	
Yes	4.69 (1.85, 11.90)	
Homeless Past 12 months		
No	REF	0.768
Yes	1.13 (0.49, 2.60)	
Ever Jailed		0.438
No	REF	
Yes	0.69 (0.28, 1.74)	
Depressed <sup>1</sup>		
No	REF	0.331
Yes	0.65 (0.27, 1.55)	
Gay Community		0.838
Very much a part of	REF	
Not at all a part of - Somewhat a part of	1.10 (0.44, 2.75)	
Trust in HIV Provider		0.075
Mostly - Completely	REF	
Not at all - Somewhat	0.31 (0.09, 1.12)	
Illegal Drug Use <sup>2</sup>		
No	REF	0.155
Yes	0.51 (0.20, 1.29)	
Alcohol ASSIST Risk		0.877
Low	REF	
Mod/High	0.91 (0.29, 2.90)	
Cannabis ASSIST Risk		0.410
Low	REF	
Mod/High	0.65 (0.23, 1.82)	
Illegal Drugs ASSIST Risk		
Low	REF	0.172
Mod/High	0.49 (0.18, 1.36)	
Inconsistent Condom Use <sup>3</sup>		0.744
No	REF	
Yes	0.85 (0.31, 2.30)	
Syphilis Infection		0.075
No	REF	
Yes	0.34 (0.10, 1.12)	
Number of Named HIV- Partners	1.50 (1.03, 2.21)	0.036*
Number of Named HIV Unk Partners	0.97 (0.67, 1.39)	0.854
Number of Named HIV+ Partners	1.25 (0.61, 2.53)	0.542

<b>Dyadic Sexual Network Characteristics</b>		
Number of Partners Used Alcohol W/ During Sex	0.98 (0.67, 1.43)	0.905
Number of Partners Used Cannabis W/ During Sex	0.90 (0.65, 1.24)	0.517
Number of Partners Used Illegal Drugs W/ During Sex	0.71 (0.40, 1.25)	0.234
Number of Social/Sexual Partner Use Alcohol	0.86 (0.69, 1.08)	0.202
Number of Social/Sexual Partner Use Cannabis	0.98 (0.76, 1.26)	0.859
Number of Social/Sexual Partner Use Illegal Drugs	unestimable	
Number of Unknown Status Partners Had Condomless Receptive Anal Sex With	0.93 (0.54, 1.62)	0.803
Number of HIV+ Partners Had Condomless Receptive Anal Sex With	1.04 (0.40, 2.74)	0.936
Number of HIV- Partners Had Receptive Condomless Anal Sex With	1.53 (0.65, 3.58)	0.331
<b>Venue and Co-attendee Characteristics<sup>4</sup></b>		
Number of Health Venues Attended	1.28 (0.98, 1.69)	0.072
Number of Social Venues Attended	1.06 (0.96, 1.16)	0.251
Exposure to HIV at Health Venues	1.14 (0.73, 1.77)	0.558
Exposure to HIV at Social Venues	0.63 (0.37, 1.08)	0.093
Exposure to High-Risk Alcohol Use	1.21 (0.76, 1.92)	0.432
Exposure to High-Risk Cannabis Use	1.31 (0.82, 2.11)	0.259
Exposure to High-Risk Illegal Drug Use	0.91 (0.48, 1.71)	0.767

1 Determined based on the CES-D Depression Inventory. Participants with a score  $\geq 10$  were considered depressed.

2 Use of either cocaine/crack, methamphetamine, ecstasy, opioids, sedatives, or painkillers.

3 Defined as reporting no condom use in any sexual encounter.

4 All exposure terms are the percentage of venues attended where there were attendees with a particular characteristic

Table 5. Univariable pooled weighted negative binomial (alpha = 1.36) GEE results examining covariates on missed doses of ART (n = 230) (YMAP, 2014 - 2016)

Characteristics	OR (95% CI)	p value
City		
Chicago	REF	0.382
Houston	1.32 (0.71, 2.48)	
Black	0.45 (0.23, 0.87)	0.019*
Age	1.08 (0.97, 1.21)	0.169
Insurance		
No	REF	0.024*
Yes	0.40 (0.18, 0.88)	
Homeless Past 12 months		
No	REF	0.319
Yes	0.73 (0.40, 1.35)	
Ever Jailed		
No	REF	0.538
Yes	1.24 (0.63, 2.44)	
Depressed <sup>1</sup>		
No	REF	0.490
Yes	1.34 (0.59, 3.07)	
Gay Community		
Very much a part of	REF	0.434
Not at all a part of - Somewhat a part of	1.41 (0.60, 3.34)	
Trust in HIV Provider		
Mostly - Completely	REF	0.135
Not at all - Somewhat	1.89 (0.82, 4.38)	
Illegal Drug Use <sup>2</sup>		
No	REF	<0.001*
Yes	3.03 (1.68, 5.46)	
Alcohol ASSIST Risk		
Low	REF	0.071
Mod/High	1.90 (0.95, 3.81)	
Cannabis ASSIST Risk		
Low	REF	0.007*
Mod/High	2.11 (1.23, 3.63)	
Illegal Drugs ASSIST Risk		
Low	REF	<0.001*
Mod/High	2.94 (1.71, 5.04)	
Syphilis Infection		
No	REF	0.803
Yes	1.10 (0.55, 2.17)	

Inconsistent Condom Use <sup>3</sup>		
No	REF	<0.001*
Yes	2.62(1.58, 4.34)	
Number of Named HIV- Partners	1.05 (0.75, 1.47)	0.791
Number of Named HIV Unk Partners	1.43 (1.20, 1.71)	<0.001*
Number of Named HIV+ Partners	0.97 (0.68, 1.38)	0.862
<b>Dyadic Sexual Network Characteristics</b>		
Number of Partners Used Alcohol W/ During Sex	1.31 (0.95, 1.81)	0.094
Number of Partners Used Cannabis W/ During Sex	1.45 (1.17, 1.79)	0.001*
Number of Partners Used Illegal Drugs W/ During Sex	1.42 (0.77, 2.61)	0.256
Number of Social/Sexual Partner Use Alcohol	1.29 (1.04, 1.60)	0.018*
Number of Social/Sexual Partner Use Cannabis	1.24 (1.00, 1.55)	0.050*
Number of Social/Sexual Partner Use Illegal Drugs	0.50 (0.12, 2.12)	0.347
Number of Unknown Status Partners Had Condomless Receptive Anal Sex With	1.52 (1.03, 2.23)	0.033*
Number of HIV+ Partners Had Condomless Receptive Anal Sex With	2.14 (1.22, 3.76)	0.008*
Number of HIV- Partners Had Receptive Condomless Anal Sex With	1.52 (1.24, 1.86)	<0.001*
<b>Venue and Co-attendee Characteristics<sup>4</sup></b>		
Number of Health Venues Attended	0.99 (0.90, 1.08)	0.803
Number of Social Venues Attended	1.06 (1.01, 1.11)	0.015*
Exposure to HIV at Health Venues	1.02 (0.73, 1.43)	0.910
Exposure to HIV at Social Venues	0.76 (0.56, 1.04)	0.082
Exposure to High-Risk Alcohol Use	1.52 (1.17, 1.97)	0.002*
Exposure to High-Risk Cannabis Use	0.71 (0.52, 0.95)	0.024*
Exposure to High-Risk Illegal Drug Use	1.16 (0.80, 1.68)	0.430

1 Determined based on the CES-D Depression Inventory. Participants with a score  $\geq 10$  were considered depressed.

2 Use of either cocaine/crack, methamphetamine, ecstasy, opioids, sedatives, or painkillers.

3 Defined as reporting no condom use in any sexual encounter.

4 All exposure terms were normalized over the number of health/social venues attended.

Table 6. Comparison of the QIC-selected logistic and negative binomial models.

Characteristics	ART Prescribed Logistic Model (n = 253)		ART Missed Negative Binomial Model (n = 221)	
	OR (95% CI)	p value	OR (95% CI)	p value
City				
Chicago			REF	0.191
Houston			0.68 (0.39, 1.21)	
Black	0.05 (0.01, 0.36)	0.003*	0.59 (0.27, 1.29)	0.185
Insurance		0.018*		
No	REF		REF	0.018*
Yes	4.45 (1.29, 15.34)		0.50 (0.28, 0.89)	
Trust in HIV Provider		0.013*		
Mostly - Completely	REF		REF	0.699
Not at all - Somewhat	0.16 (0.04, 0.69)		1.16 (0.55, 2.44)	
Syphilis Infection		0.529		
No	REF			
Yes	0.67 (0.20, 2.30)			
Inconsistent Condom Use				
No			REF	0.370
Yes			1.28 (0.74, 2.22)	
Number of Named Sex Partners	1.67 (0.80, 3.49)	0.173	0.94 (0.74, 1.19)	0.609
Number of Named HIV Unk Partners			1.17 (0.95, 1.44)	0.140
Number of Named HIV - Partners	0.82 (0.42, 1.60)	0.569		
<b>Dyadic Sexual Network Characteristics</b>				
Number of Partners Used Illegal Drugs W/ During Sex	0.41 (0.17, 1.02)	0.056		
Number of Partners Used Cannabis W/ During Sex			1.45 (1.21, 1.73)	< 0.001*
Number of HIV+ Partners Had Condomless Receptive Anal Sex With	1.08 (0.25, 4.67)	0.913	0.82 (0.46, 1.47)	0.510
<b>Venue and Co-attendee Characteristics <sup>1</sup></b>				
Number of Health Venues Attended	1.32 (0.99, 1.76)	0.060		
Number of Social Venues Attended			1.02 (0.97, 1.08)	0.382
Exposure to HIV at Health Venues	1.76 (0.96, 3.23)	0.067		
Exposure to High Risk Alcohol Use			1.31 (0.87, 1.97)	0.204

<sup>1</sup> All exposure terms are the percentage of venues attended where there were attendees with a particular characteristic

Table 7. Multivariable pooled weighted logistic (alpha = 1.36) GEE results on whether subject had a current ART prescription (YMAP, 2014 - 2016)

Characteristics	OR (95% CI)	p value
City		
Chicago	REF	0.260
Houston	0.49 (0.14, 1.68)	
Black	0.04 (0.00, 0.41)	0.010*
Insurance		
No	REF	0.086
Yes	3.3 (0.84, 12.88)	
Trust in HIV Provider		
Mostly - Completely	REF	0.026*
Not at all - Somewhat	0.19 (0.04, 0.82)	
Syphilis		
No	REF	0.530
Yes	0.69 (0.22, 2.19)	
Illegal Drug Use <sup>1</sup>		
No	REF	0.148
Yes	0.48 (0.18, 1.29)	
Alcohol ASSIST Risk		
Low	REF	0.720
Mod/High	1.24 (0.39, 3.98)	
Number of Named Sex Partners	1.79 (0.89, 3.61)	0.104
Number of Named HIV- Partners	0.79 (0.40, 1.54)	0.488
<b>Dyadic Sexual Network Characteristics</b>		
Number of Partners Used Illegal Drugs W/ During Sex	0.47 (0.20, 1.09)	0.079
Number of HIV+ Partners Had Condomless Receptive Anal Sex With	0.97 (0.24, 3.90)	0.966
<b>Venue and Co-attendee Characteristics<sup>2</sup></b>		
Exposure to HIV at Health Venues	1.89 (0.94, 3.78)	0.074
Number of Health Venues Attended	1.29 (0.95, 1.73)	0.099

1 Use of either cocaine/crack, methamphetamine, ecstasy, opioids, sedatives, or painkillers.

2 All exposure terms are the percentage of venues attended where there were attendees with a particular characteristic



Table 8. Multivariable pooled weighted negative binomial (alpha = 1.36) GEE results on whether subject had a current ART prescription (YMAP, 2014 - 2016)

Characteristics	OR (95% CI)	p value
City		
Chicago	REF	0.215
Houston	0.68 (0.37, 1.25)	
Black	0.77 (0.40, 1.49)	0.438
Insurance		
No	REF	0.008*
Yes	0.43 (0.23, 0.81)	
Trust in HIV Provider		
Mostly - Completely	REF	0.879
Not at all - Somewhat	1.06 (0.52, 2.13)	
Inconsistent Condom Use <sup>1</sup>		
No	REF	0.726
Yes	1.12 (0.59, 2.15)	
Alcohol ASSIST Risk		
Low	REF	0.217
Mod/High	0.69 (0.39, 1.24)	
Illegal Drug Use <sup>2</sup>		
No	REF	0.013*
Yes	2.07 (1.16, 3.69)	
Number of Nominated Social/Sexual Partners	1.07 (0.95, 1.20)	0.292
Number of Named HIV Unk Partners	1.05 (0.87, 1.27)	0.579
<b>Dyadic Sexual Network Characteristics</b>		
Number of Sexual Partner Use Cannabis	1.31 (1.07, 1.61)	0.009*
Number of HIV+ Partners Had Condomless Receptive Anal Sex With	0.74 (0.44, 1.24)	0.256
<b>Venue and Co-attendee Characteristics<sup>3</sup></b>		
Number of Social Venues Attended	1.01 (0.95, 1.07)	0.743
Exposure to High-Risk Alcohol Use	1.37 (0.88, 2.11)	0.161

1 Defined as reporting no condom use in any sexual encounter.

2 Use of either cocaine/crack, methamphetamine, ecstasy, opioids, sedatives, or painkillers.

3 All exposure terms are the percentage of venues attended where there were attendees with a particular characteristic

## 6 Figures

Figure 1. Boxplots of self-reported, RDS-II, and RDS-SS estimates of drug use prevalence for Chicago and Houston (YMAP, 2014 - 2016)

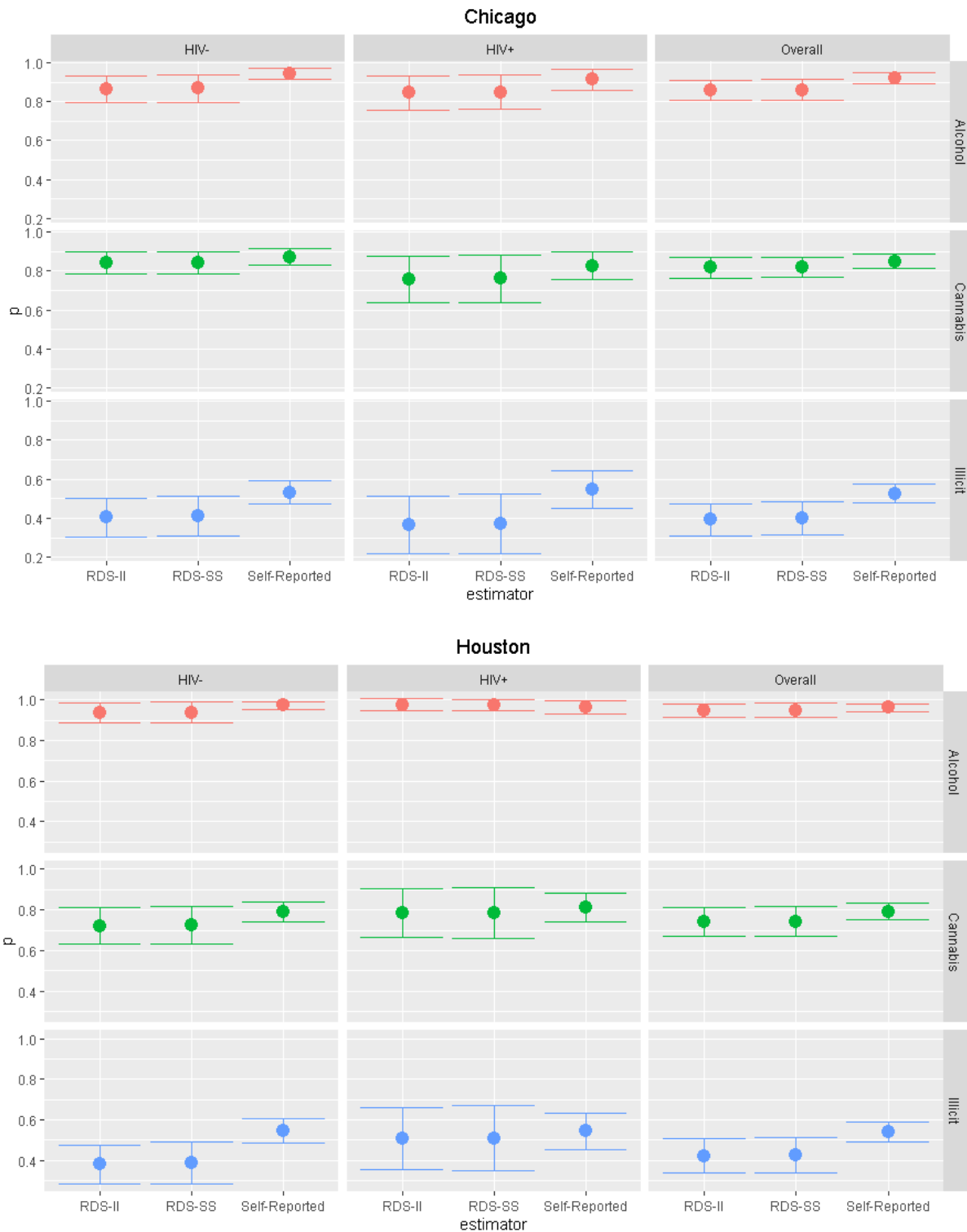
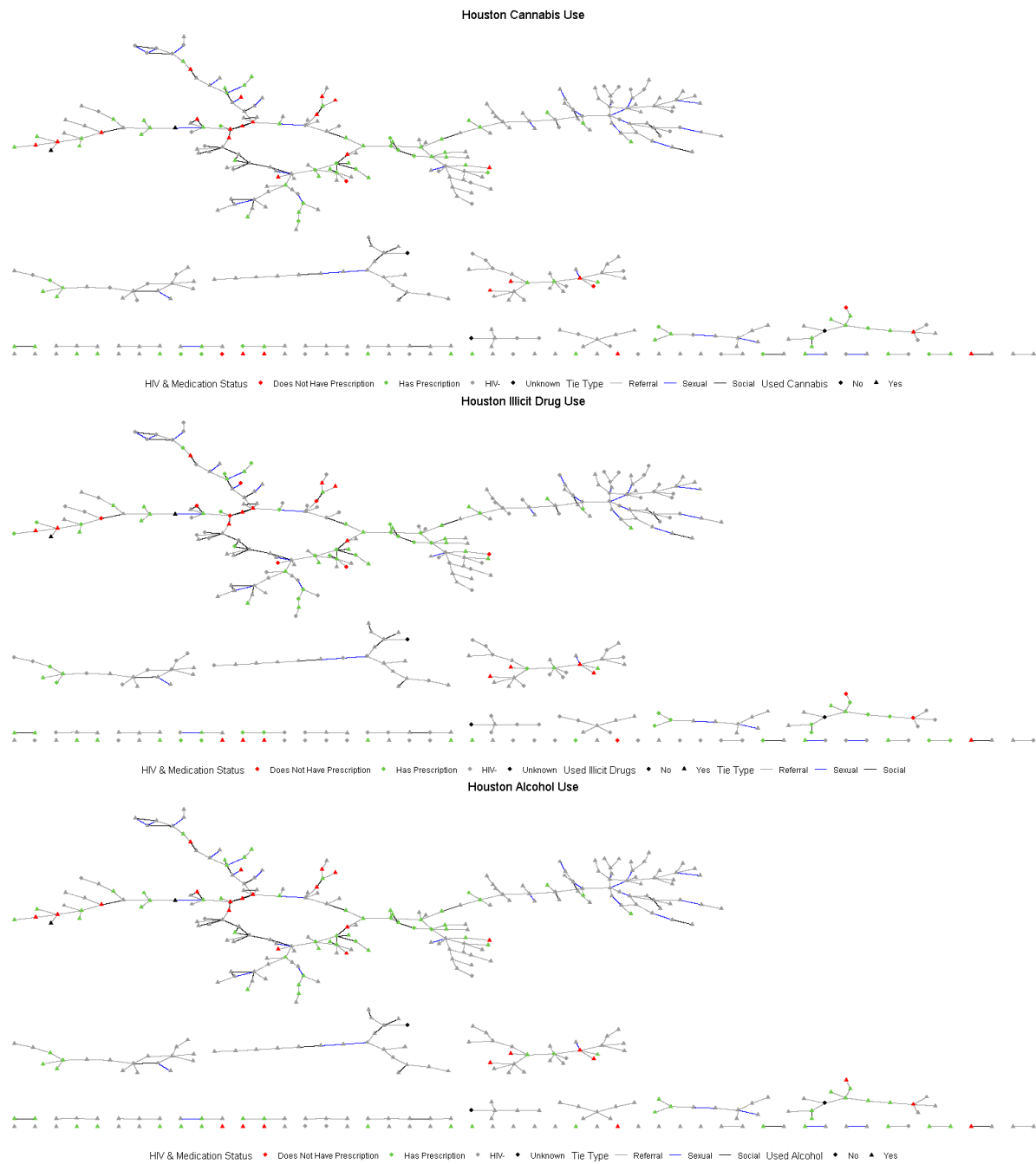
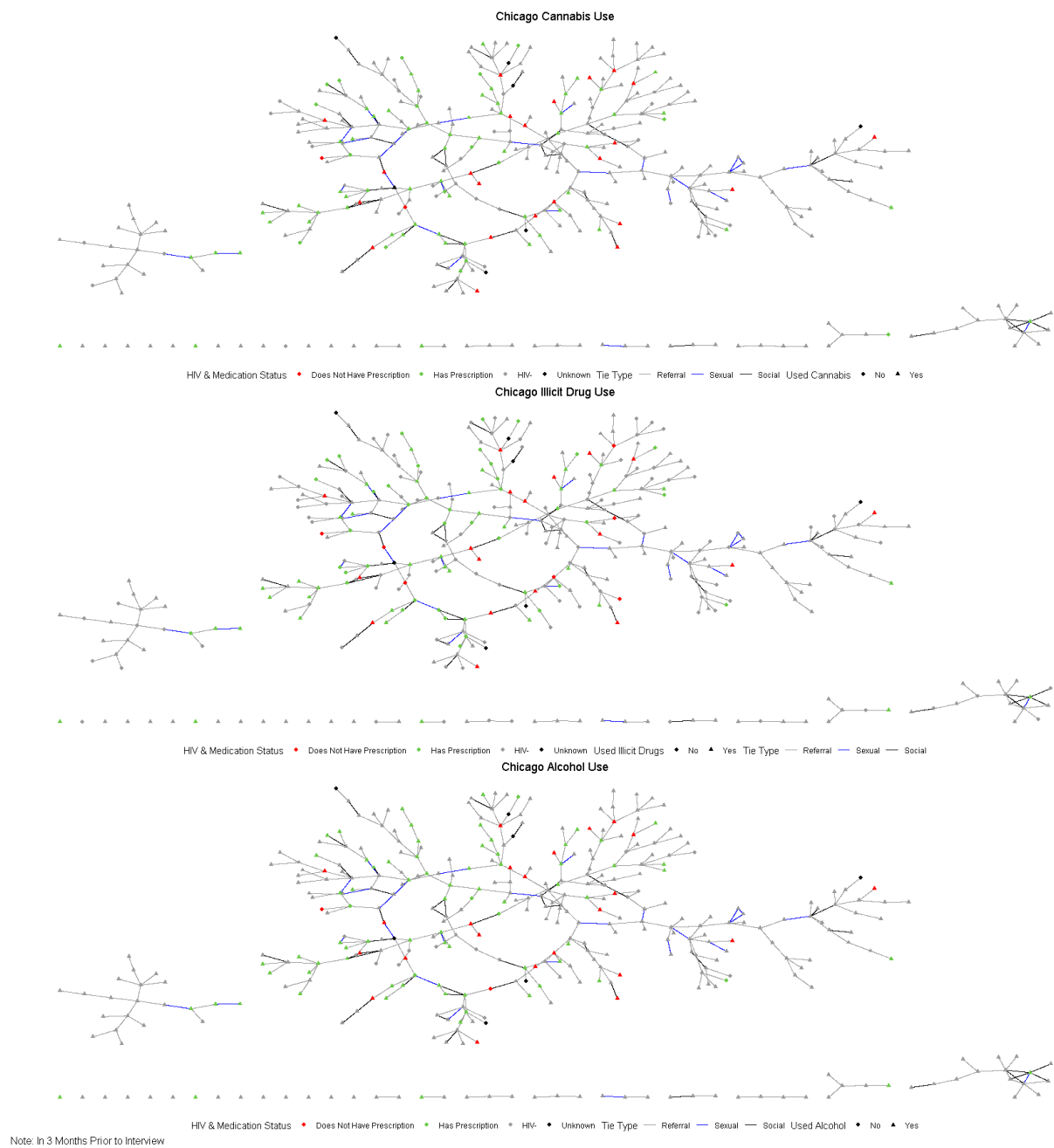


Figure 2. Drug use in the referral, social, and sexual network in Houston (YMAP, 2014 - 2016)



Note: In 3 Months Prior to Interview

Figure 3. Drug use in the referral, social, and sexual network in Chicago (YMAP, 2014 - 2016)



## References

- [1] Hogg, S., R., Heath, V., K., Bangsberg, S. G., D., Yip, S. G., B., Press, S. G., N., O'Shaughnessy, S. G., Michael, et al. (2002). Intermittent use of triple-combination therapy is predictive of mortality at baseline and after 1 year of follow-up. *Aids*, 16(7), 1051-1058.
- [2] Centers for Disease Control U.S. Statistics, 2019. [cited 23 November 2019]. Available from: <https://www.hiv.gov/hiv-basics/overview/data-and-trends/statistics>.
- [3] Centers for Disease Control, 2019. Understanding the HIV Care Continuum [Fact Sheet]. Available from: <https://www.cdc.gov/hiv/pdf/library/factsheets/cdc-hiv-care-continuum.pdf>.
- [4] Bangsberg, S., Perry, E., Charlebois, R., Clark, M., Roberston, A., Zolopa, A., et al. (2001). Non-adherence to highly active antiretroviral therapy predicts progression to AIDS. *Aids*, 15(9), 1181-1183.
- [5] Centers for Disease Control and Prevention HIV Surveillance Report, 2017. [cited 20 November 2019]. Available from: <https://www.cdc.gov/hiv/pdf/library/reports/surveillance/cdc-hiv-surveillance-report-2017-vol-29.pdf>.
- [6] Grey, J. A., Bernstein, K. T., Sullivan, P. S., Purcell, D. W., Chesson, H. W., Gift, T. L., & Rosenberg, E. S. (2016). Estimating the Population Sizes of Men Who Have Sex With Men in US States and Counties Using Data From the American Community Survey. *JMIR Public Health and Surveillance*, 2(1), e14. <https://doi.org/10.2196/publichealth.5365>
- [7] Iacob, S. A., Iacob, D. G., Jugulete, G., & Iacob, S. A. (2017). Improving the adherence to antiretroviral therapy, a difficult but essential task for a successful HIV treatment-clinical points of view and practical considerations. *Frontiers in Pharmacology*, 8, 831-831.
- [8] Langebeek, N., Gisolf, E. H., Reiss, P., Vervoort, S. C., Hafsteinsdottir, T. B., Richter, C., et al. (2014). Predictors and correlates of adherence to combination antiretroviral therapy (ART) for chronic HIV infection: A meta-analysis. *BMC Medicine*, 12(1)
- [9] Medley, G., Lipari, R. N., Bose, J., Cribb, D. S., Kroutil, L. A., & McHenry, G. (2016, October). Sexual orientation and estimates of adult substance use and mental health: Results from the 2015 National Survey on Drug Use and Health. NSDUH Data Review. Retrieved from <https://www.samhsa.gov/data/>
- [10] Galvan, F. H., Bing, E. G., Fleishman, J. A., London, A. S., Caetano, R., Burnam, M. A., et al. (2002). The prevalence of alcohol consumption and heavy drinking among people with HIV in the united states: Results from the HIV cost and services utilization study \*(statistical data included). *Journal of Studies on Alcohol*, 63(2), 179.

- [11] Newcomb, M. E., Ryan, D. T., Greene, G. J., Garofalo, R., & Mustanski, B. (2014). Prevalence and patterns of smoking, alcohol use, and illicit drug use in young men who have sex with men. *Drug and Alcohol Dependence*, 141, 65–71. <https://doi.org/10.1016/j.drugalcdep.2014.05.005>
- [12] Morgan, E., Khanna, A. S., Skaathun, B., Michaels, S., Young, L., Duvoisin, R., Chang, M., Voisin, D., Cornwell, B., Coombs, R. W., Friedman, S. R., & Schneider, J. A. (2016). Marijuana Use Among Young Black Men Who Have Sex With Men and the HIV Care Continuum: Findings From the uConnect Cohort. *Substance Use & Misuse*, 51(13), 1751–1759. <https://doi.org/10.1080/10826084.2016.1197265>
- [13] Wagner, G., Goggin, K., Remien, R., Rosen, M., Simoni, J., Bangsberg, D., et al. (2011). A closer look at depression and its relationship to HIV antiretroviral adherence. *Annals of Behavioral Medicine*, 42(3), 352–360.
- [14] Hendershot, S., C., Stoner, A., S., Pantalone, W., D., & Simoni, M., J. (2009). Alcohol use and antiretroviral adherence: Review and meta-analysis. *JAIDS Journal of Acquired Immune Deficiency Syndromes*, 52(2), 180–202.
- [15] White, J. M., Gordon, J. R., & Mimiaga, M. J. (2014). The role of substance use and mental health problems in medication adherence among HIV-infected MSM. *LGBT Health*, 1(4), 319–322.
- [16] Magidson, J., Blashill, A., Safren, S., & Wagner, G. (2015). Depressive symptoms, lifestyle structure, and ART adherence among HIV-infected individuals: A longitudinal mediation analysis. *AIDS and Behavior*, 19(1), 34–40.
- [17] Daskalopoulou, M., Rodger, A., Phillips, A. N., Sherr, L., Speakman, A., Collins, S., et al. (2014). Recreational drug use, polydrug use, and sexual behaviour in HIV-diagnosed men who have sex with men in the UK: Results from the cross-sectional ASTRA study. *The Lancet HIV*, 1(1), e22–e31.
- [18] Gonzalez, A., Barinas, J., & O’Cleirigh, C. (2011). Substance use: Impact on adherence and HIV medical treatment. *Current HIV/AIDS Reports*, 8(4), 223–234.
- [19] Montgomery, L., Bagot, K., Brown, J. L., & Haeny, A. M. (2019). The Association Between Marijuana Use and HIV Continuum of Care Outcomes: a Systematic Review. *Current HIV/AIDS Reports*, 16(1), 17–28. <https://doi.org/10.1007/s11904-019-00422-z>
- [20] Sinha, S., McCaul, M. E., Hutton, H. E., Monroe, A. K., Alvanzo, A., Lesko, C., Lau, B., Keruly, J., Moore, R. D., & Chander, G. (2017). Marijuana use and HIV treatment outcomes among PWH receiving care at an urban HIV clinic. *Journal of Substance Abuse Treatment*, 82, 102–106. <https://doi.org/10.1016/j.jsat.2017.09.009>
- [21] Vagenas, P., Azar, M. M., Copenhaver, M. M., Springer, S. A., Molina, P. E., & Altice, F.

- L. (2015). The Impact of Alcohol Use and Related Disorders on the HIV Continuum of Care: a Systematic Review. *Current HIV/AIDS Reports*, 12(4), 421–436. <https://doi.org/10.1007/s11904-015-0285-5>
- [22] Ghosh, D., Krishnan, A., Gibson, B., Brown, S., Latkin, C., & Altice, F. (2017). Social network strategies to address HIV prevention and treatment continuum of care among at-risk and HIV-infected substance users: A systematic scoping review. *AIDS and Behavior*, 21(4), 1183-1207. doi:10.1007/s10461-016-1413-y
- [23] Nardone, A., Frankis, J. S., Dodds, J. P., Flowers, P. N., Mercey, D. E., & Hart, G. J. (2001). A comparison of highrisk sexual behaviour and HIV testing amongst a bargoing sample of homosexual men in london and edinburgh. *The European Journal of Public Health*, 11(2), 185-189. doi:10.1093/eurpub/11.2.185
- [24] Latkin, C. A., Davey-Rothwell, M. A., Knowlton, A. R., Alexander, K. A., Williams, C. T., & Boodram, B. (2013). Social Network Approaches to Recruitment, HIV Prevention, Medical Care, and Medication Adherence. *JAIDS Journal of Acquired Immune Deficiency Syndromes*, 63, S54–S58. <https://doi.org/10.1097/qai.0b013e3182928e2a>
- [25] Amirkhanian, Y. A. (2014). Social Networks, Sexual Networks and HIV Risk in Men Who Have Sex with Men. *Current HIV/AIDS Reports*, 11(1), 81–92. <https://doi.org/10.1007/s11904-013-0194-4>
- [26] Fujimoto, M., K., Wang, W., P., Kuhns, L., L., Ross, S., M., Williams, O., M., Garofalo, A., R., et al. (2017). Multiplex competition, collaboration, and funding networks among health and social organizations: Toward organization-based HIV interventions for young men who have sex with men. *Medical Care*, 55(2), 102-110.
- [27] Fujimoto, K., Flash, C. A., Kuhns, L. M., Kim, J., & Schneider, J. A. (2018). Social networks as drivers of syphilis and HIV infection among young men who have sex with men *BMJ Publishing Group Ltd*.
- [28] Schueler, K., Ferreira, M., Nikolopoulos, G., Skaathun, B., Paraskevis, D., Hatzakis, A., et al. (2019). Pre-exposure prophylaxis (PrEP) awareness and use within high HIV transmission networks. *AIDS and Behavior*, 23(7), 1893-1903.
- [29] Fujimoto, K., Unger, J. B., & Valente, T. W. (2012). A network method of measuring affiliation-based peer influence: assessing the influences of teammates' smoking on adolescent smoking. *Child development*, 83(2), 442–451. doi:10.1111/j.1467-8624.2011.01729.
- [30] Jones, J., Grey, J. A., Purcell, D. W., Bernstein, K. T., Sullivan, P. S., & Rosenberg, E. S. (2018). Estimating prevalent diagnoses and rates of new diagnoses of HIV at the state level by age group among men who have sex with men in the united states. *Open Forum Infectious Diseases*, 5(6)

- [31] Cui, J., & Qian, G. (2007). Selection of Working Correlation Structure and Best Model in GEE Analyses of Longitudinal Data. *Communications in Statistics - Simulation and Computation*, 36(5), 987–996. <https://doi.org/10.1080/03610910701539617>
- [32] Centers for Disease Control and Prevention Stacks. Recommended laboratory HIV testing algorithm for serum or plasma specimens, 2018 [cited 20 November 2019]. Available from: <https://stacks.cdc.gov/view/cdc/50872>.
- [33] WHO ASSIST Working Group (2002). The Alcohol, Smoking and Substance Involvement Screening Test (ASSIST): development, reliability and feasibility. *Addiction*, 97 (9): 1183-1194.
- [34] Radloff, L. S. (1977). The CES-D Scale. *Applied Psychological Measurement*, 1(3), 385–401. <https://doi.org/10.1177/014662167700100306>
- [35] Gile, K. J. (2011). Improved Inference for Respondent-Driven Sampling Data With Application to HIV Prevalence Estimation. *Journal of the American Statistical Association*, 106(493), 135–146. <https://doi.org/10.1198/jasa.2011.ap09475>
- [36] Volz, E., Heckathorn, D.D., 2008. Probability based estimation theory for respondent driven sampling. *J. Off. Stat.* 24 (1), 79–97.
- [37] StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP.]
- [38] Wood, A. M., White, I. R., & Royston, P. (2008). How should variable selection be performed with multiply imputed data? *Statistics in Medicine*, 27(17), 3227–3246. <https://doi.org/10.1002/sim.3177>
- [39] Léon, L., Des Jarlais, D., Jauffret-Roustide, M., & Le Strat, Y. (2016). Update on respondent-driven sampling: Theory and practical considerations for studies of persons who inject drugs. *Methodological Innovations*, 9, 205979911667287. <https://doi.org/10.1177/2059799116672878>
- [40] Fellows, I. E. (2018). Respondent-driven sampling and the homophily configuration graph. *Statistics in Medicine*, 38(1), 131–150. <https://doi.org/10.1002/sim.7973>
- [41] Royston, P., & White, I. (2011). Multiple Imputation by Chained Equations (MICE): Implementation in Stata. *Journal of Statistical Software*, 45(4). <https://doi.org/10.18637/jss.v045.i04>
- [42] Center for Disease Control (2019). HIV Among Gay and Bisexual Men [Fact sheet]. <https://www.cdc.gov/nchhstp/newsroom/docs/factsheets/cdc-msm-508.pdf>
- [43] Thiede, H., Valleroy, L. A., MacKellar, D. A., Celentano, D. D., Ford, W. L., Hagan, H., Koblin, B. A., LaLota, M., McFarland, W., Shehan, D. A., & Torian, L. V. (2003). Regional Patterns and Correlates of Substance Use Among Young Men Who Have Sex With Men in



- 7 US Urban Areas. *American Journal of Public Health*, 93(11), 1915–1921.  
<https://doi.org/10.2105/ajph.93.11.1915>
- [44] National Academies of Sciences, Engineering, and Medicine. (2017). *The health effects of cannabis and cannabinoids: The current state of evidence and recommendations for research*. Washington, DC: The National Academies Press. doi: 10.17226/24625.
- [45] Knox J et al. Explaining racial disparities in viral suppression among MSM living with HIV. Conference on Retroviruses and Opportunistic Infections, abstract 146, March 2020.
- [46] Newcomb, M. E., Ryan, D. T., Greene, G. J., Garofalo, R., & Mustanski, B. (2014). Prevalence and patterns of smoking, alcohol use, and illicit drug use in young men who have sex with men. *Drug and Alcohol Dependence*, 141, 65–71.  
<https://doi.org/10.1016/j.drugalcdep.2014.05.005>
- [47] Pacek, L. R., Malcolm, R. J., & Martins, S. S. (2012). Race/Ethnicity Differences between Alcohol, Marijuana, and Co-occurring Alcohol and Marijuana Use Disorders and Their Association with Public Health and Social Problems Using a National Sample. *The American Journal on Addictions*, 21(5), 435–444. <https://doi.org/10.1111/j.1521-0391.2012.00249.x>
- [48] Stall, R., Paul, J. P., Greenwood, G., Pollack, L. M., Bein, E., Crosby, G. M., Mills, T. C., Binson, D., Coates, T. J., & Catania, J. A. (2001). Alcohol use, drug use and alcohol-related problems among men who have sex with men: the Urban Men's Health Study. *Addiction*, 96(11), 1589–1601. <https://doi.org/10.1046/j.1360-0443.2001.961115896.x>
- [49] Santos, G., Jin, H. & Raymond, H.F. Pervasive Heavy Alcohol Use and Correlates of Increasing Levels of Binge Drinking among Men Who Have Sex with Men, San Francisco, 2011. *J Urban Health* 92, 687–700 (2015). <https://doi.org/10.1007/s11524-015-9958-z>
- [50] Fujimoto, K., Cao, M., Kuhns, L. M., Li, D., & Schneider, J. A. (2018). Statistical adjustment of network degree in respondent-driven sampling estimators: Venue attendance as a proxy for network size among young MSM. *Social Networks*, 54, 118–131.  
<https://doi.org/10.1016/j.socnet.2018.01.003>
- [51] World Health Organization, Regional Office for the Eastern Mediterranean. (2013). *Introduction to HIV/AIDS and sexually transmitted infection surveillance: module 4: introduction to respondent-driven sampling*. <https://apps.who.int/iris/handle/10665/116864>
- [52] Mackesy-Amiti, M. E., Fendrich, M., & Johnson, T. P. (2008). Prevalence of recent illicit substance use and reporting bias among MSM and other urban males. *Addictive Behaviors*, 33(8), 1055–1060. <https://doi.org/10.1016/j.addbeh.2008.03.003>
- [53] Morgan, E., Khanna, A. S., Skaathun, B., Michaels, S., Young, L., Duvoisin, R., Chang, M., Voisin, D., Cornwell, B., Coombs, R. W., Friedman, S. R., & Schneider, J. A. (2016). *Marijuana Use Among Young Black Men Who Have Sex With Men and the HIV Care*

Continuum: Findings From the uConnect Cohort. *Substance Use & Misuse*, 51(13), 1751–1759. <https://doi.org/10.1080/10826084.2016.1197265>

- [54] Risher, K., Rehle, T., Simbayi, L., Shisana, O., & Celentano, D. D. (2015). Antiretroviral Treatment and Sexual Risk Behavior in South Africa. *AIDS and Behavior*, 20(4), 710–716. <https://doi.org/10.1007/s10461-015-1125-8>
- [55] Saha, S., Jacobs, E. A., Moore, R. D., & Beach, M. C. (2010). Trust in Physicians and Racial Disparities in HIV Care. *AIDS Patient Care and STDs*, 24(7), 415–420. <https://doi.org/10.1089/apc.2009.0288>
- [56] Cunningham, W. E., Nance, R. M., Golin, C. E., Flynn, P., Knight, K., Beckwith, C. G., Kuo, I., Spaulding, A., Taxman, F. S., Altice, F., Delaney, J. A., Crane, H. M., & Springer, S. A. (2019). Self-reported antiretroviral therapy adherence and viral load in criminal justice-involved populations. *BMC Infectious Diseases*, 19(1). <https://doi.org/10.1186/s12879-019-4443-z>
- [57] Guimarães, M. D. C., Rocha, G. M., Campos, L. N., Freitas, F. M. T. de, Gualberto, F. A. S., Teixeira, R. d'Ávila R., & Castilho, F. M. de. (2008). Difficulties reported by hiv-infected patients using antiretroviral therapy in brazil. *Clinics*, 63(2). <https://doi.org/10.1590/s1807-59322008000200003>
- [58] Ma, Y., Mazumdar, M., & Memtsoudis, S. G. (2012). Beyond Repeated-Measures Analysis of Variance. *Regional Anesthesia and Pain Medicine*, 37(1), 99–105. <https://doi.org/10.1097/aap.0b013e31823ebc74>
- [59] Latkin, C. A., & Knowlton, A. R. (2015). Social Network Assessments and Interventions for Health Behavior Change: A Critical Review. *Behavioral Medicine*, 41(3), 90–97. <https://doi.org/10.1080/08964289.2015.1034645>
- [60] Grov, C., Golub, S. A., & Parsons, J. T. (2010). HIV Status Differences in Venues Where Highly Sexually Active Gay and Bisexual Men Meet Sex Partners: Results from a Pilot Study. *AIDS Education and Prevention*, 22(6), 496–508. <https://doi.org/10.1521/aeap.2010.22.6.496>