



# Pre-exposure Prophylaxis (PrEP) Awareness and Use Within High HIV Transmission Networks

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## Abstract

Improved implementation of pre-exposure prophylaxis (PrEP) should be a valuable tool within communities experiencing high HIV incidence, such as black men who have sex with men (MSM). Using baseline data from the Chicago arm of the Transmission Reduction Intervention Project (TRIP), we examined awareness and use of PrEP within HIV potential transmission networks. Transmission Reduction Intervention Project recruited participants ages 18–69 (N = 218) during 2014–2016 from networks originating from recently and chronically HIV-infected MSM and transgender persons. In total, 53.2% of participants had heard of PrEP, while 8 (6.5%) HIV-negative participants reported ever using PrEP. In multivariable regression, PrEP awareness was associated with identifying as gay, attending some college or higher, having an HIV test in the previous 6 months, and experiencing HIV-related social support. PrEP awareness was not associated with experiencing or observing HIV-related stigma. PrEP use was associated with participants knowing two or more other PrEP-users. These findings demonstrate moderate awareness, but low uptake of PrEP within HIV potential transmission networks in Chicago. Future research should explore how to increase PrEP use in these networks and investigate the social dynamics behind our finding that PrEP users are more likely to know other PrEP users.

**Keywords** Human immunodeficiency virus (HIV) · Pre-exposure prophylaxis (PrEP) · Men who have sex with men (MSM) · Network analysis · African American · Black

## Introduction

The incidence of HIV infection in the United States has declined in recent years, however this trend has not been shared by all communities. In 2015, diagnoses among gay and bisexual men accounted for 82% of new HIV diagnoses in men aged 13 and over, largely driven by high incidence rates among young black men who have sex with men (MSM) [1]. Black Americans accounted for 45% of new HIV diagnoses in 2015, while only representing 12% of the population [2]. Furthermore, incidence rates for black MSM were estimated to be six times that of white MSM [3]. These trends are exaggerated in young black MSM under 30, who are increasingly bearing the brunt of the HIV epidemic in the United States [2, 4].

Though most recently the rate of new HIV infections among black MSM has stabilized nationally in the United States [2], improved implementation of efficacious HIV prevention strategies, including pre-exposure prophylaxis (PrEP), are needed in epidemic hot-spots such as Chicago.

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Chicago is the site of this study, where “Getting to Zero” efforts are already underway that aim to achieve HIV elimination consistent with programs in many jurisdictions nationally [5, 6]. PrEP is over 95% effective for MSM if taken daily [7]. Since its approval by the US Food and Drug Administration (FDA) in 2012, the uptake of PrEP among MSM has remained low. Studies from a number of diverse settings and populations have found PrEP uptake among MSM to be between 2 and 12% [4, 8–11]. Unfortunately, most research has demonstrated significantly lower awareness [12–14], and uptake of PrEP [4, 10, 15] among racial and ethnic minority MSM, though this trend may be reversing in some large cities [12, 16]. This underscores the need to improve uptake in this population which faces outsized risk of HIV infection.

Barriers thought to limit PrEP use include low awareness of PrEP, financial barriers, negative attitudes about PrEP including concerns about side effects and stigma, and perception of low HIV risk [13, 14, 17–22]. For instance, research on attitudes about PrEP has demonstrated that black MSM, as compared to white MSM, are more likely to have stigma-related concerns about using PrEP, more likely to endorse conspiracy beliefs about PrEP, and less likely to believe that PrEP is efficacious at preventing HIV infection [23–25]. Though the common assumption is that HIV-related stigma would deter individuals from seeking out and using PrEP for fear of being mistaken as HIV-positive, research has so far shown a mixed picture on the relationship between perception of stigma and awareness of PrEP [25–27]. There are also concerns about stigma that are more directly related to PrEP use, such as PrEP use being seen as a marker of promiscuity and a “less honorable” form of prevention compared to using condoms or abstaining from high-risk behavior [28].

Individuals most at risk of becoming HIV positive are HIV negative persons who are in sexual or other risk networks with individuals recently or acutely infected with HIV, because this increases the risk of active HIV transmission [29]. Research suggests that individuals connected both sexually or socially share common attitudes and risk behaviors, meaning that within a network of connected individuals there is a common risk environment shared by members that heightens the risk of HIV transmission [30–32]. In addition, sexual networks are fluid and dynamic, with social network members often becoming sex partners or being previous sex partners [33]. The optimal public health strategy is thus identifying these sexual and social networks in which active transmission is occurring and leveraging them to both detect and treat HIV positive individuals unaware of their status as well as encourage PrEP uptake among their HIV-negative members. Current research does not provide a clear picture as to whether those most at risk of acquiring HIV are using PrEP. Several studies have examined the relationship

between individuals’ demographic or behavioral factors and PrEP use and awareness [4, 8–10, 15, 16, 18, 34–37]. Studies have found that some behaviors, including participation in condomless anal sex or group sex, and having a history of syphilis or herpes, are associated with increased likelihood of PrEP use [4, 7, 8], but no research has directly investigated whether people socially and sexually connected to individuals who are infected with HIV are aware of PrEP or using PrEP.

Network influences are also an important factor in the dissemination of information and attitudes, thus social- or sexual-network norms and attitudes about PrEP may play a significant role in determining whether a person hears about PrEP and in shaping a person’s willingness or motivation to use PrEP [29, 32, 38, 39]. Given these influences, the effort to increase PrEP use in networks with high potential for HIV transmission could benefit from a better understanding of attitudes about PrEP in these networks within black MSM communities. The aims of this analysis are: (1) to characterize HIV-positive index participants and the members of their potential transmission networks in Chicago’s black MSM community, hereafter called “transmission networks”; and (2) to understand how behavioral factors, PrEP use within networks, and experiences of stigma and community support are associated with awareness and use of PrEP among transmission network members. Understanding the factors that impact PrEP use within transmission networks in black MSM communities will be useful in developing tailored mechanisms to improve uptake of PrEP in this critically important population.

## Methods

### Study Sample

We conducted an analysis of baseline survey data collected between 2014 and 2016 in the Chicago arm of the Transmission Reduction Intervention Project (TRIP) [40]. TRIP was a multi-site study that focused on preventing HIV transmission in vulnerable populations, and in Chicago focused on transmission networks originating from HIV-positive men who have sex with men (MSM) and transgender persons ages 18–69. Initial participants—or index participants—who were referred from HIV testing programs in Chicago were classified as (1) recently infected (“recents”) if they had seroconversion within 9 months or were acutely infected or (2) chronically infected (“chronic”) if they had a longer-term HIV infection over 9 months in duration [40]. These HIV-positive index participants were then asked to provide the names of their social, sexual, and drug-injection contacts and the venues at which they engage in social, sexual, and drug-injection activities. These contacts, as well as persons

at venues named by participants, were considered part of the index participant's transmission network and efforts were made to recruit them to the study and test them for HIV. Index participants that tested negative for HIV were considered part of an HIV-negative control group. Participants were included in the study if they were at least 18 years old, able to answer the questionnaire, and were an index participant or a member of an HIV-positive index participant's potential transmission network.

## Data Collection & Measures

Data were collected using questionnaires administered in person by trained interviewers. The questionnaire protocol contained items about socio-demographics, HIV testing history, transmission behaviors, substance use, PrEP, knowledge about HIV infection, and experience of HIV-related stigma. Laboratory testing was also conducted, as described below in the HIV Status section.

## Primary Outcomes

The primary outcomes of interest included PrEP awareness and PrEP use, measured by the questions “Before today, have you ever heard of PrEP” and “Have you ever used PrEP,” respectively. Prior to answering these questions, participants were read the following statement explaining PrEP: “PrEP (pre-exposure prophylaxis) is when a person is given medicine before being exposed to HIV (like when they expect that they will be having unprotected sex with an infected partner) to prevent them from becoming infected.”

## Demographic & Behavioral Measures

Demographic factors included in the analysis were age, gender, sexual orientation, race/ethnicity, marital/relationship status, educational attainment, and employment status. To define sexual orientation, participants were asked “Do you consider yourself to be gay, lesbian, straight, bisexual, or something else?” The “lesbian” response was included as part of the “other” category in the analysis due to small numbers identifying as lesbian. Measures were also included to assess health care access (“I am able to get health care whenever I need it” Response options: 5-point Likert scale). Participants who responded “strongly agree” or “somewhat agree” to this question were considered to have “good” care access. Due to a skewed distribution, the responses “strongly disagree”, “somewhat disagree”, and “neither agree nor disagree” were collapsed into a single category we considered “poor” access to care. In addition, we measured knowledge about HIV transmission (“If someone gets infected with HIV and then has unsafe sex or shares syringes with someone, they are more likely to transmit the disease

to their partner...”; Response options: (1) During the first 6 months after they get infected, (2) More than a year after they get infected, and (3) They are equally likely to infect their partner at any time during the first 5 years after they get infected). Finally, we included measures on transmission risk behaviors in the 6 months prior to the interview, including reporting having condomless sex, using a sex drug, or having sex while group sex was taking place.

## HIV Status

HIV status—either HIV positive or HIV negative—was determined via 4th generation HIV Immunoassay (Abbott ARCHITECT HIV Ag/Ab Combo assay) and HIV-1/-2 Ab differentiation (Bio-Rad Multispot HIV-1/-2 Rapid Test). HIV RNA testing using Abbott RealTime HIV-1 Viral Load Assay was also conducted at the time of the baseline interview. Limiting Antigen Avidity (LAG) assay (Sedia™ Biosciences Corporation) was later used to determine recent versus chronic HIV infection [41]. Self-reported HIV status and testing history were used for the 34 participants that did not undergo an HIV test or if results of their test were not available. Four participants were missing HIV status data, and for simplicity the single participant with an indeterminate HIV test result was also considered to have missing HIV status for the analysis.

## Network Membership

We created two variables to define the networks to which participants belong. The transmission network variable represents whether a respondent was in the social or sexual network of: (1) a person with a recent HIV infection or (2) a person who had a chronic HIV infection. A third group of HIV-negative controls was included for comparison. These network classifications were used for generation of the original sample during study recruitment. The second variable, called PrEP-Network membership, was created specifically as part of this analysis to capture participants who were in close proximity to a PrEP user. PrEP-Networks were defined to include PrEP users and all of the contacts in their network, up to two connections away, that had been captured through the recruitment process. This method was used to be consistent with the two-step approach of the TRIP intervention where network members were elicited up to “two-steps” away from a recently infected person [40]. Prior research has demonstrated that observed “two-steps” away may be closer in the actual network if unobserved ties are considered [29]. In addition, prior research suggests that similar HIV related behaviors exist up to three degrees away from an index [42], likely due to social norms, but also due to unobserved ties that may connect individuals in the actual network and thus decrease the degree of separation. As in most network

studies, the networks observed are a sample of the larger network, given the inability to recruit all network members.

### Community Stigma and Support

To determine a person's experience of HIV-related stigma, we created two measures capturing "observed HIV-related stigma" and "experienced HIV-related stigma" based on the measurement guidelines developed by the International Center for Research on Women [43]. For "observed stigma", participants were asked if they had, in the last 6 months, seen their friends or relatives (1) saying negative things about, (2) saying negative things to, or (3) physically acting out against a person thought to have a recent HIV infection. A participant was considered to have observed stigma if he or she reported that they had seen "few," "about half," "most," or "all" of their friends and family carry out any of these three negative behaviors. Participants with "experienced stigma" reported directly experiencing any of these three types of stigmatizing events, due to them having or people thinking they had a recent HIV infection. "Observed support" was measured in a similar manner, representing whether participants had heard or seen any of their family and friends offering an HIV-positive individual (1) concrete assistance like food or money, (2) emotional support, or (3) information about HIV services. "Experienced support" captured whether a participant had any of these three positive behaviors directed at them because people thought they had a recent HIV infection.

### Data Analysis

Statistical analyses included univariate and multivariable logistic regression models. Initially, each independent variable was analyzed in a univariate analysis with the primary outcomes: PrEP awareness, PrEP use, and PrEP-Network membership. Variables found in the univariate analysis to have a significant association with the primary outcome at the  $p \leq 0.10$  level were then included in the initial multivariable regression model. Stepwise model selection was used to determine which variables contributed to a model with the lowest Akaike Information Criterion value [44]. Due to their potential to be important confounders, HIV status and transmission network membership were controlled for in the multivariable models. Gender was not included in the multivariable models because the study population had few cis-gendered women and transgender individuals. Variance Inflation Factors (VIFs) were tested and verified to be under 4 for all variables in each multivariable model, suggesting no occurrence of collinearity. Analysis was performed using STATA 14. The PrEP-network visualization presented in Fig. 1 was generated using NodeXL, a Microsoft Word extension. The visualization was created using an edge list

built from the data that contained all of the seeds (PrEP users) and how they are connected to other study participants, up to two connections away.

## Results

### Demographic & Behavioral Factors

Baseline demographic, social, and behavioral characteristics of the 218 participants in the Chicago arm of TRIP are presented in Table 1. The majority (88.8%) identified as black, and 71.1% of the sample consisted of black men who have sex with men. The average age was 29.8 (SD 10.4). About half (51.2%) of the population identified their sexual orientation as gay, and another quarter (25.4%) identified as bisexual. Overall, 57.8% of the sample was HIV negative and thus potentially eligible for PrEP. Just over half (56.9%) of the sample belonged to networks of people with recent HIV infections, 27.8% were network members of people with chronic HIV infections and 15.3% were HIV-negative controls that were not connected to a network.

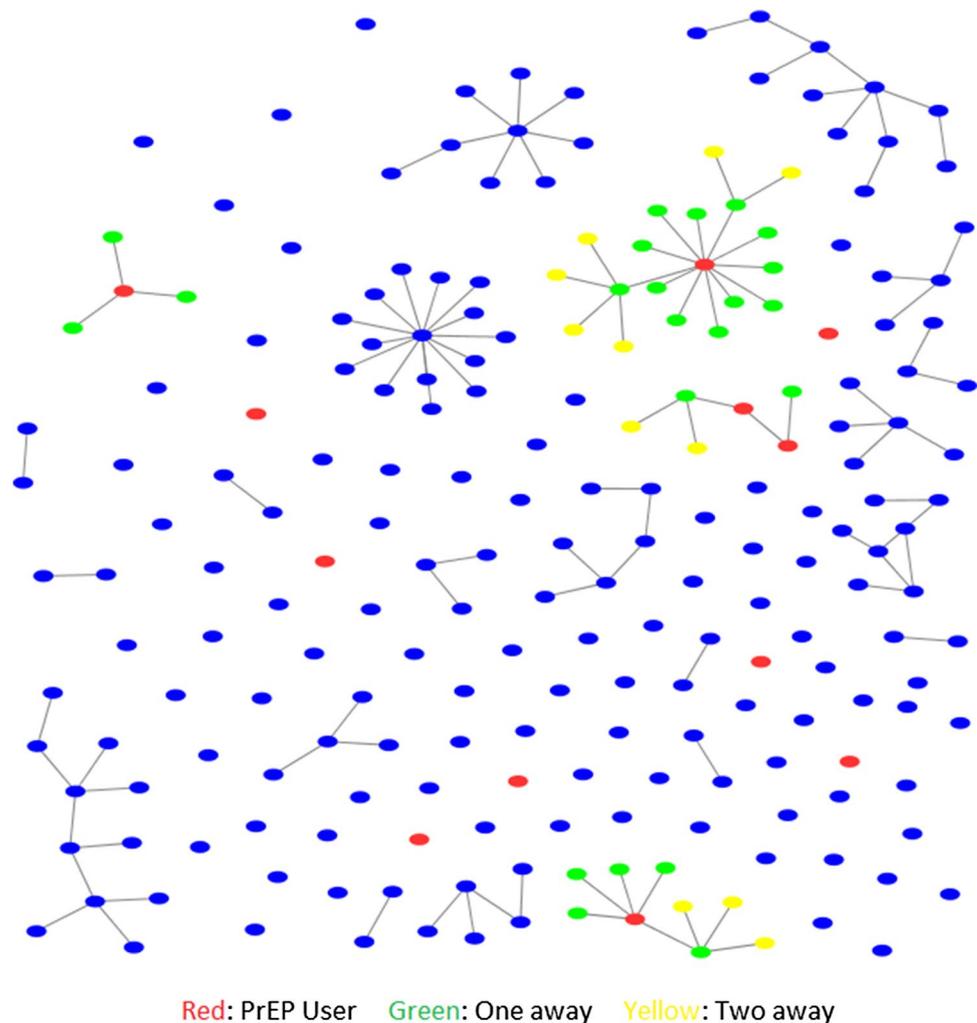
### PrEP Awareness

In total, 59.2% of participants had heard of PrEP before the baseline interview. Among HIV negative participants, about half (52.8%) had heard of PrEP. Experiencing HIV-related stigma was associated with increased awareness of PrEP in univariate analysis (OR 2.20, 95% CI 1.16–4.19), however, in the multivariable model neither observed nor experienced stigma was independently associated with PrEP awareness (Table 2). In the multivariable model (Table 2), awareness of PrEP was significantly associated with identifying as gay (aOR 4.61, 95% CI 1.40–15.23), completing some college or a higher education level (aOR 3.77, 95% CI 1.75–8.12), having an HIV test in the previous 6 months (aOR 2.43, 95% CI 1.12–5.27), and experiencing HIV-related social support (aOR 3.28, 95% CI 1.46–7.41).

### PrEP Use

Among all participants, 13 (6.0%) reported ever using PrEP, while 8 (6.5%) HIV-negative participants had used PrEP. The average age of PrEP users was 25 (SD 7.7). Eighty-five percent of PrEP-users identified as black and over three fourths (77%) identified as gay. Twenty-four percent of study participants knew at least one person who used PrEP (Table 1). Univariate analysis demonstrated an association between using PrEP and knowing two or more PrEP-users, compared to participants who reported knowing no PrEP-users (OR 5.42, 95% CI 1.53–19.14). PrEP use was also significantly associated with participants reporting that they

**Fig. 1** PrEP-Networks in the Chicago arm of the Transmission Reduction Intervention Project (TRIP). This figure demonstrates the network connections between participants in the Transmission Reduction Intervention Project (TRIP). PrEP-Networks are those highlighted in the figure that contain a PrEP-user. A “one-away” connection reflects a participant that was recruited to the study by a PrEP-using participant. A “two-away” connection reflects a participant that was then recruited to the study by these “one-away” connections



had an HIV test in the prior 6 months (OR 10.56, 95% CI 1.35–82.70) (Table 2).

### PrEP-Network Membership

Figure 1 provides a visualization of the networks in TRIP, highlighting which networks contained PrEP-users and their one-away and two-away connections. A total of 45 participants were members of PrEP-Networks (PrEP-users and the participants connected to them) (Table 2), and no PrEP-Network member was more than two connections away from a PrEP user. In the multivariable model, being a PrEP-Network member was associated with identifying as Gay (aOR 4.87, 95% CI 1.0–23.90), being in the network of a person recently infected with HIV (aOR 6.48, 95% CI 1.29–32.59), and reporting knowing two or more people who use PrEP (aOR 3.59, 95% CI 1.33–9.69). PrEP-Network membership was negatively associated with participation in group sex in the prior 6 months (aOR 0.30, 95% CI 0.09–0.97).

### Community Stigma & Support

Nearly half (47.7%) of participants observed HIV stigma, while 28.9% directly experienced the stigmatizing actions of others. Sixty-five percent of participants observed support provided to HIV-infected individuals and 42.7% were directly provided support (Table 1). There was no significant association between PrEP use and observing stigma (OR 1.82, 95% CI 0.58–5.75) or experiencing stigma (OR 1.60, 95% CI 0.50–5.10), nor observing support (OR 1.24, 95% CI 0.37–4.16) or experiencing support (OR 1.17, 95% CI 0.38–3.59) (Table 2).

### Discussion

Understanding what factors affect awareness and uptake of PrEP among black MSM may help us develop ways to increase low PrEP uptake and combat continuing high infection rates among Chicago’s black MSM. Similar to other

**Table 1** Demographics and characteristics of participants in the Transmission Reduction Intervention Project (TRIP) (n = 218)

	Total n = 218 <sup>b</sup> n (%) / M (SD)	PrEP unaware n = 87 n (%) / M (SD)	PrEP aware <sup>a</sup> n = 116 n (%) / M (SD)	PrEP use n = 13 n (%) / M (SD)
Age	29.8 (10.4)	32.7 (13.1)	28.2 (7.8)	25.0 (7.7)
Race				
Black	190 (88.8)	76 (40.2)	102 (54.0)	11 (5.8)
White	4 (1.9)	0 (0)	4 (100.0)	0 (0)
Other	20 (9.4)	10 (50.0)	8 (40.0)	2 (10.0)
Ethnicity				
Latin(x)	20 (9.3)	8 (40.0)	11 (55.0)	1 (5.0)
Non-latin(x)	196 (90.7)	79 (40.5)	104 (53.3)	12 (6.2)
Gender				
Male	183 (84.3)	61 (33.5)	109 (59.9)	12 (6.6)
Female	27 (12.4)	25 (92.6)	1 (3.7)	1 (3.7)
Transgender female	6 (2.8)	1 (16.7)	5 (83.3)	0 (0)
Transgender male	1 (0.5)	0 (0)	1 (100.0)	0 (0)
Sexual orientation				
Straight	36 (16.6)	29 (80.6)	6 (16.7)	1 (2.8)
Gay	111 (51.2)	29 (26.4)	71 (64.6)	10 (9.1)
Bisexual	55 (25.4)	20 (36.4)	34 (61.8)	1 (1.82)
Other	14 (6.9)	9 (60.0)	5 (33.3)	1 (6.7)
Education				
High school or lower	97 (44.9)	50 (51.6)	42 (43.3)	5 (5.3)
Some college or higher	119 (55.1)	37 (31.1)	74 (62.2)	8 (6.7)
Employment				
Unemployed	63 (29.2)	26 (41.3)	34 (54.0)	3 (4.8)
Part-time	50 (23.2)	23 (46.0)	23 (46.0)	4 (8.0)
Full-time	66 (30.6)	21 (32.3)	39 (60.0)	5 (7.7)
Student	16 (7.4)	5 (31.3)	11 (68.8)	0 (0)
Other	21 (9.7)	11 (52.4)	9 (42.9)	1 (4.8)
Relationship status				
In a relationship	75 (35.0)	36 (48.0)	35 (46.7)	4 (5.3)
Not in a relationship	139 (65.0)	51 (37.0)	79 (57.3)	8 (5.8)
Transmission network membership				
HIV-negative control	33 (15.3)	15 (45.5)	16 (48.5)	2 (6.1)
Network of chronic infection	60 (27.8)	34 (57.6)	22 (37.3)	3 (5.1)
Network of recent infection	123 (56.9)	37 (30.3)	77 (63.1)	8 (6.6)
Number of people participant knows that have used PrEP				
0	162 (75.7)	86 (53.1)	70 (43.2)	6 (3.7)
1	23 (10.8)	1 (4.4)	20 (87.0)	2 (8.7)
2+	29 (13.6)	0 (0)	24 (82.8)	5 (17.2)
Health care access				
Good	190 (87.2)	11 (40.7)	102 (54.0)	11 (5.8)
Poor	28 (12.84)	76 (40.2)	14 (51.9)	2 (7.4)
Transmission risk factors (in past 6 months)				
Condomless sex	200 (91.7)	78 (39.4)	110 (55.6)	10 (5.1)
Group sex	38 (18.5)	14 (36.8)	24 (63.2)	0 (0)
Sex drug use	79 (36.4)	27 (34.2)	49 (62.0)	3 (3.8)
# of sex partners				
0–2	129 (59.2)	56 (44.1)	61 (48.0)	10 (7.9)
3+	89 (40.8)	31 (34.8)	55 (61.8)	3 (3.4)

**Table 1** (continued)

	Total n = 218 <sup>b</sup> n (%) / M (SD)	PrEP unaware n = 87 n (%) / M (SD)	PrEP aware <sup>a</sup> n = 116 n (%) / M (SD)	PrEP use n = 13 n (%) / M (SD)
<b>HIV status</b>				
HIV negative	123 (57.8)	58 (47.2)	57 (46.3)	8 (6.5)
HIV positive	90 (42.3)	25 (28.4)	59 (67.1)	4 (4.6)
<b>HIV testing history</b>				
HIV test in past 6 months	120 (55.1)	30 (25.0)	78 (65.0)	12 (10.0)
No HIV test in past 6 months	98 (44.9)	57 (59.4)	38 (39.6)	1 (1.04)
<b>HIV infectivity knowledge</b>				
Accurate	98 (45.0)	50 (51.0)	41 (41.84)	7 (7.1)
Inaccurate	120 (55.1)	37 (31.4)	75 (63.6)	6 (5.1)
<b>Stigma</b>				
Observed	104 (47.7)	36 (35.0)	59 (57.3)	8 (7.8)
Experienced	63 (28.9)	17 (27.4)	40 (64.5)	5 (8.1)
<b>Support</b>				
Observed	141 (64.7)	47 (33.6)	84 (60.0)	9 (6.4)
Experienced	93 (42.7)	20 (21.7)	66 (71.7)	6 (6.5)

<sup>a</sup>This category includes individuals who were aware of PrEP but reported never using PrEP

<sup>b</sup>Due to missing data for some variables, not all categories sum to 218. No variable is missing more than 5% of total observations

analyses, we found that individuals who were aware of PrEP were more likely to identify as gay, be highly educated, engaged in health care, and have HIV-related social support. In addition, participants connected to a PrEP user were more likely to identify as gay, know more PrEP-users, not participate in group sex, and be in the transmission network of an individual with a recent HIV infection. Finally, we found that PrEP users were more likely to know other PrEP users.

By recruiting individuals within social and sexual networks of HIV-positive persons, TRIP assembled a sub-sample that is at higher risk of HIV infection than typical identity sub-groups. A 2016 study of young black men who have sex with men in Chicago found a PrEP awareness rate of 40.5% [37]. Comparatively, our study found a moderate level of PrEP awareness (59%) in potential transmission networks of black men who have sex with men. Unfortunately, awareness appears to be lower among certain demographic groups within these networks. Our research suggests that individuals with higher education levels who experience HIV-related social support and are engaged in regular HIV testing are the types of network members who are more likely to be aware of PrEP. Positive relationships between social support and awareness of HIV services, uptake of HIV services, as well as retention in care, have been demonstrated previously [32, 45]. It is possible that similar mechanisms are driving our finding that experiencing HIV-related social support is associated with higher awareness of PrEP. Taken together, these findings demonstrate that our current efforts to expand PrEP awareness may not be reaching the most at-risk members

of potential HIV transmission networks. Targeted efforts to connect and maintain these transmission network members in regular sexual health care may provide an effective pathway to increasing PrEP awareness. Our research also demonstrates that individuals that identify their sexual orientation as straight are also largely (81%) unaware of PrEP. Though the networks in our study are largely composed of MSM, there are network members that identify as straight and they may share in the heightened risk of HIV infection. Outreach efforts targeted at the MSM community may be ineffective in reaching these individuals and may require innovative approaches.

In our study only 6.5% of HIV-negative participants had ever used PrEP, suggesting that awareness may not be a major driving factor for PrEP use in this population. Other studies have found a similar gap between awareness and use [15, 24, 37]. Knowing other PrEP users, however, appeared to be an important factor that was associated with PrEP use, although this specific univariate analysis was underpowered. It is unclear whether this clustering of PrEP-users is due to homophily—the tendency for similarly-behaved people to be friends and form a network—or whether peer pressure within networks influences the behavior of network members. If these findings are due to the former, it is imperative that we target the networks in which PrEP use is low. Social norms or influence within networks has the potential to play a positive role, such as encouraging PrEP use by members, or a negative role, such as propagating stigma or other negative messages surrounding PrEP use. Previous

**Table 2** Unadjusted and adjusted odds ratios for PrEP awareness, PrEP use, & PrEP-network membership among participants in the Transmission Reduction Intervention Project (TRIP) (n = 218)

Characteristic	PrEP awareness		PrEP-network membership		PrEP use
	Unadjusted OR (95% CI)	Adjusted <sup>a</sup> (n = 186) OR (95% CI)	Unadjusted OR (95% CI)	Adjusted <sup>b</sup> (n = 196) OR (95% CI)	Unadjusted OR (95% CI)
<b>Age</b>					
< 30 years	2.82 (1.57–5.05)***	1.84 (0.82–4.14)	1.31 (0.63–2.74)		6.45 (0.82–50.66)
<b>Race</b>					
Black (ref)	1.0		1.0		1.0
White	–		3.75 (0.51–27.45)		–
Other	0.67 (0.27–1.69)		0.42 (0.09–1.87)		1.80 (0.37–8.75)
<b>Ethnicity</b>					
Latin(x)	1.02 (0.40–2.61)		0.40 (0.09–1.77)		0.80 (0.10–6.52)
<b>Sexual orientation</b>					
Straight (ref)	1.0	1.0	1.0	1.0	1.0
Gay	11.57 (4.57–29.3)***	4.61 (1.40–15.23)**	7.51 (1.71–33.04)**	4.87 (1.0–23.90)*	3.5 (0.43–28.24)
Bisexual	7.25 (2.69–19.5)***	2.68 (0.75–9.57)	2.08 (0.40–10.94)	1.16 (0.19–7.13)	0.65 (0.04–10.70)
Other	2.76 (0.74–10.4)	0.87 (0.15–5.11)	4.25 (0.63–28.60)	2.87 (0.37–22.14)	2.5 (0.15–42.80)
<b>Education</b>					
High school or lower (ref)	1.0	1.0	1.0		1.0
Some college or higher	2.36 (1.35–4.11)**	3.77 (1.75–8.12)***	1.80 (0.91–3.59)		1.32 (0.42–4.19)
<b>Employment</b>					
Full-time (ref)	1.0		1.0		1.0
Unemployed	0.68 (0.33–1.40)		0.47 (0.20–1.10)		0.60 (0.14–2.62)
Student	1.05 (0.32–3.41)		0.57 (0.15–2.23)		–
Other	0.52 (0.26–1.04)		0.55 (0.25–1.24)		0.91 (0.25–3.30)
<b>Relationship status</b>					
Not in a relationship (ref)	1.0		1.0		1.0
In a relationship	1.57 (0.89–2.78)		0.82 (0.41–1.63)		1.09 (0.32–3.75)
<b>Health care access</b>					
Poor (ref)	1.0	1.0	1.0		1.0
Good	1.02 (0.45–2.32)	1.39 (0.47–4.11)	2.36 (0.68–8.22)		0.77 (0.16–3.69)
<b>Transmission network membership</b>					
HIV-negative control (ref)	1.0		1.0	1.0	1.0
Network of chronic infection	0.61 (0.26–1.45)	0.55 (0.16–1.90)	3.1 (0.64–15.09)	4.54 (0.82–25.03)	0.83 (0.13–5.24)
Network of recent infection	1.91 (0.87–4.20)	1.37 (0.46–4.08)	5.45 (1.23–24.08)*	6.48 (1.29–32.59)*	1.09 (0.22–5.39)
<b>Number of PrEP-users participant knows<sup>c</sup></b>					
0 (ref)	N/A	N/A	1.0		1.0
1	N/A	N/A	3.07 (1.17–8.02)*	2.92 (0.48–6.52)	2.48 (0.47–13.07)
2+	N/A	N/A	4.67 (2.0–10.94)***	3.59 (1.33–9.69)**	5.42 (1.53–19.14)**
<b>Transmission risk factors (in past 6 months)</b>					
Condomless sex	1.54 (0.59–4.05)		0.90 (0.28–2.89)		0.27 (0.07–1.07)
Group sex	1.12 (0.54–2.32)		0.36 (0.12–1.09)	0.30 (0.09–0.97)*	–
Sex drug use	1.50 (0.84–2.67)		0.65 (0.32–1.33)		0.50 (0.13–1.88)
<b># of sex partners</b>					
0–2 (ref)	1.0		1.0		1.0
3+	1.61 (0.86–3.03)		0.59 (0.29–1.19)		0.61 (0.25–1.47)
HIV positive status	2.25 (1.26–4.03)**	0.67 (0.28–1.59)	1.18 (0.60–2.30)	0.58 (0.25–1.36)	0.68 (0.20–2.35)
HIV test in past 6 months	4.34 (2.45–7.83)***	2.43 (1.12–5.27)*	1.13 (0.54–2.32)		10.56 (1.35–82.70)*
<b>HIV infectivity knowledge</b>					
Inaccurate (ref)	1.0	1.0	1.0		1.0

**Table 2** (continued)

Characteristic	PrEP awareness		PrEP-network membership		PrEP use
	Unadjusted OR (95% CI)	Adjusted <sup>a</sup> (n = 186) OR (95% CI)	Unadjusted OR (95% CI)	Adjusted <sup>b</sup> (n = 196) OR (95% CI)	Unadjusted OR (95% CI)
Accurate	0.44 (0.25–0.76)**	0.54 (0.26–1.14)	0.97 (0.50–1.88)		1.4 (0.47–4.42)
Stigma					
Observed	1.53 (0.88–2.65)		0.95 (0.49–1.83)		1.82 (0.58–5.75)
Experienced	2.20 (1.16–4.19)*		1.48 (0.74–2.97)		1.60 (0.50–5.10)
Support					
Observed	2.20 (1.24–3.89)**		1.91 (0.90–4.02)	1.73 (0.71–4.24)	1.24 (0.37–4.16)
Experienced	4.23 (2.30–7.78)***	3.28 (1.46–7.41)**	1.37 (0.71–2.65)		1.17 (0.38–3.59)

-Too few observations to be used in regression analysis

<sup>a</sup>Adjusted odds ratios were determined by the final multivariable model, which included HIV status (negative/positive), age, transmission network membership, educational attainment, sexual orientation, HIV testing history, relationship status, access to health care, experienced support, and knowledge about HIV infectivity. Relationship status, health care access, and transmission network membership were forced into the model due to their potential to be important confounders. Due to missing data for some variables, this multivariable model included data from 186 participants

<sup>b</sup>Adjusted odds ratios were determined by the final multivariable model, which included sexual orientation, HIV status, participation in group sex, number of PrEP-users participant reports knowing, observed support, and transmission network membership. Due to missing data for some variables, this multivariable model included data from 196 participants

<sup>c</sup>Participants were asked about the number of people they know that have used PrEP only if they were aware of PrEP

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

research demonstrated that stigma surrounding PrEP is a serious concern among those considering using PrEP [12, 23, 46, 47]. Our study found that almost half of the participants observed HIV-related stigma. Thus, it is encouraging that we did not find a significant association between experiencing or observing stigma and PrEP awareness or use. In fact, we found that experiencing stigma may be associated with increased PrEP awareness, which parallels the findings of Sang et al [26]. It's possible that the experience of stigma motivates individuals to seek out information about HIV due to fear of becoming HIV positive, but this finding warrants further study in a larger sample.

We also found that PrEP-Network membership was associated with being in the network of a person with a recent HIV infection. This is an important finding that suggests there may be overlap between these networks. Individuals with recent HIV infections typically have high viral loads, conferring a higher risk of transmitting the infection [48]. Thus, these represent networks in which PrEP use will make the greatest impact by preventing new infections. However, the relevance of this result is unclear, as our analysis of PrEP use did not find a significant relationship between PrEP use and transmission network membership.

Our conceptualization of a “potential transmission network” differs from the traditional sense of a network of transmission, as we did not conduct molecular analysis of the viruses to determine transmission pathways. Combined with the challenge of recruiting network contacts to the study and resulting missing network members, this makes

the network a sample of what a true transmission network would look like, which is common in network studies, and potentially impacts the validity of the analysis. The analysis also relies on the idea that contacts within a network share similar HIV risk and impact each other's beliefs and actions up to two connections away, which is supported by prior network studies [42]. This is likely due at least in part to the incomplete network characterization whereby an individual observed two or three steps away may in fact be only one step away given the propensity for unobserved ties in high-risk networks. In addition, because the survey asked about stigma related to having a recent HIV infection, this study was unable to specifically investigate how PrEP-related stigma impacts PrEP awareness and use, however, qualitative research suggests that HIV stigma impacts black MSM's willingness to accept and use PrEP [49]. Furthermore, the validity of this study may be impacted by the use of self-reported HIV status for the minority of participants with missing lab results. Our data suggests that nearly two thirds of these individuals reported having an HIV test within a year of reporting their status during the baseline questionnaire interview, though it's possible that not all of these participants accurately reported their true HIV status. Finally, low uptake of PrEP limited the study's analytic power to detect significant associations with PrEP use and PrEP-Network membership. Though a person must be aware of PrEP in order to begin using it, PrEP awareness may not be the strongest predictor nor the driving factor behind PrEP use. Thus, further research is needed to effectively delineate the

facilitators and barriers that drive PrEP use—not just awareness—among individuals in high transmission networks.

Future research should explore the connections we described between groups of PrEP users by seeking to understand whether homophily or influence drives these findings. The role of stigma specific to PrEP use should also be investigated in order to determine if this commonly referenced fear is truly impacting the uptake of PrEP, or whether general HIV-related stigma is the main driver. The rate of PrEP awareness we found is encouraging compared to previous estimates, but our goal must be to find new and innovative interventions that go beyond increasing awareness. We need to understand what drives PrEP use so that we can effectively increase the uptake of PrEP, not just awareness, among the members of these potential transmission networks. Our efforts should be guided by this deeper understanding of the network members we are failing to reach who are at the heart of the HIV epidemic in urban epicenters like Chicago and across the United States.

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## Compliance with Ethical Standards

**Conflict of interest** The authors have no conflict of interest to declare.

**Ethical Approval** Institutional Review Boards of participating institutions approved all research activities related to this study (ClinicalTrials.gov identifier: NCT01827228). We obtained written informed consent from all study participants. Participants were educated about HIV prevention during the intervention and were connected to appropriate health care or other supportive services when needed. All protocols and policies for this study were approved by the Institutional Review Board at the University of Chicago. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed Consent** Informed consent was obtained from all individual participants included in the study.

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