Using GPS-defined venue-based affiliation networks among Black sexually minoritized men and transgender women to identify locations for HIV prevention interventions

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Abstract

Purpose: HIV biomedical intervention uptake is suboptimal among Black sexually minoritized men (SMM) and transgender women (TW). Venues where people meet and interact shape HIV-related risk and prevention behaviors. We aimed to construct GPS-defined venue-based affiliation networks and identify the unique set of venues that could maximize reach of HIV biomedical interventions among Black SMM and TW.

Methods: We used baseline survey and GPS data from 272 Black SMM and TW in the Neighborhoods and Networks (N2) Cohort Study in Chicago, Illinois (2018–2019). We mapped participants' GPS data to the nearest pre-identified SMM- and TW-friendly venue (n = 222) to construct affiliation networks. Network analyses were performed to identify influential venues that can yield high reach to intervention candidates.

Results: Participants were affiliated with 75.5 % of all pre-identified venues based on GPS data. Two influential venues were identified in the non-PrEP use network, which when combined, could reach 52.5 % of participants not taking PrEP. Participants that could be reached through these two influential venues reported more non-main sex partners than participants not affiliated with either venue (p = 0.049).

Conclusion: We demonstrate a potential for GPS-defined venue-based affiliation networks to identify unique combinations of venues that could maximize the impact of HIV prevention interventions.

Keywords

HIV; Sexual and Gender Minorities; Transgender Persons; Black or African American; Social Network Analysis; Geographic Information System

Introduction

Young Black sexually minoritized men (SMM) and transgender women (TW) bear a significant burden of new HIV diagnosis in the United States [1]. SMM and TW aged 25–34 years contribute the highest number of new HIV infections and Black SMM and TW are more vulnerable to HIV than other racialized groups of SMM and TW [1,2]. According to Center for Disease Control and Prevention (CDC) estimates, an estimated 1 in 2 Black SMM will be diagnosed with HIV before the age of 49 years [2,3]. Additionally, based on a review of HIV prevalence among US transgender population, Black TW carried the highest HIV prevalence of 44.2 % compared to White TW (6.2 %) [4]. Pre-exposure prophylaxis (PrEP) for people at increased vulnerability to HIV and antiretroviral therapy (ART) for people living with HIV (PLWH) are efficacious and effective for HIV prevention [5–8]. Structural barriers such as lack of geographically proximal HIV services, few neighborhood resources, and HIV-related stigma and discrimination [9–12] have resulted in suboptimal uptake of

these biomedical interventions and have hindered the Joint United Nations Programme on HIV/AIDS 95–95–95 targets to reduce new HIV infections by 95 % by 2030 and improve HIV-related health outcomes of PLWH [13]. There is an urgent need to develop intervention implementation strategies to maximize the dissemination and impact of HIV biomedical interventions among young Black SMM and TW.

It is increasingly recognized that venues where people socialize can play an important role in the transmission of HIV and sexually transmitted infections and the diffusion of HIV prevention strategies because they visit the same places, shape individuals' drug use and sex behaviors [14–20]. Engaging venues that have the highest coverage of the population at increased susceptibility to HIV allows opportunities for interventions. For example, Brantley and colleagues constructed venue-based affiliation networks based on sex partner meeting venues among a predominately young Black SMM sample in Baltimore City [17]. They found that venues with the highest HIV transmission potential (measured by venue total viral load) also had a high degree of connectedness to venue clusters with moderate transmission potential. They suggested intervention programs could maximize their reach by targeting venues that were bridges to other venues, were connected to more intervention candidates, and had the highest venue viral loads. Similarly, using molecular and affiliation network methodologies, Fujimoto and colleagues identified core-peripheral venue affiliation clustering patterns among young Black SMM PLWH in Houston and Chicago [19]. Their results show that venue co-attendance patterns were associated with HIV phylogenetic clustering, indicating that people who attended the same venues may have a closely related source of HIV transmission. Venues can also provide resources that facilitate HIV interventions. For example, recent studies among young Black SMM indicated that affiliations with venues that had a greater percentage of Black clients or venues located in Black communities were associated with greater PrEP awareness and uptake and better ART adherence and viral suppression [16,21].

One major challenge to constructing venue-based affiliation networks is collecting data on venue affiliations. To date, most studies use self-reported data on venues frequented such as lists of physical venues where socializing occurs [16,17,21,22]. However, self-reported venue attendance data often suffer from recall bias (e.g. omission/inclusion of relevant venues, errors in the location reported), and this may lead to errors in constructing affiliation relationships. Collecting venue attendance data based on GPS locations is not limited by recall bias, but has other limitations [23–25]. A recent study reported that PrEP access within GPS-defined activity space was significantly associated with current PrEP use, indicating individuals don't always seek HIV prevention or treatment services around their residential locations [12]. Using objective GPS data enable researchers to capture exact locations where individuals attend for a period of time and overcome spatial misclassification, which is critical in constructing venue-based affiliation networks.

Venue-based affiliation networks could be used to inform selection of candidate venues that have the potential to reach the priority population or are bridges that connect many other venues frequented by the priority population. However, such approaches have been rarely used to promote HIV biomedical intervention related outcomes, such as PrEP and viral suppression. While literature has utilized venue-based affiliation networks to understand

HIV transmission and HIV related behaviors, very few studies utilize GPS data [26] and even fewer focused on HIV biomedical intervention related outcomes. The purpose of this study is to evaluate the network structure of GPS-defined venue-based affiliation networks and to describe venues that HIV biomedical interventions could target to maximize reach among young Black SMM and TW.

Methods

Study sample

The Neighborhoods and Networks (N2) Study is an ongoing cohort study designed to examine the relationships of neighborhood- and network-level characteristics with HIV care engagement outcomes among Black SMM and TW in Chicago, Illinois and in the southern U.S. This analysis used baseline data from the Chicago N2 site (2018–2019; n = 412). N2 Study methods have been described in detail elsewhere [27]. Briefly, individuals were recruited through peer-referral and were eligible for study if they 1) self-identified as Black or African American, 2) were 16–34 years old, 3) were assigned male at birth, 4) reported having at least one sexual encounter with a cisgender man or a transgender woman in the past year, and 5) resided in the Chicago metropolitan statistical area (MSA) and had no plans to move outside of the Chicago MSA for 2 years.

Interviewer-administered questionnaires assessed PrEP and ART use, sexual behaviors, and socio-demographic characteristics. Participants also completed an egocentric network inventory where they named up to 5 sex partners in the past 6 months. For each sex partner, participants reported their sex partners' demographic characteristics, HIV serostatus, sexual behaviors associated with greater vulnerability to HIV, and if the partner was their main partner. The N2 Study provides HIV diagnostic testing to confirm participants' HIV status. We triangulated missing data for PrEP use and viral load through participants electronic health records (EHR), including their HIV test results, viral load (if positive), and PrEP prescriptions ordered. All participants provided a separate consent to link other study data with their EHR.

As part of the baseline study, participants were provided with a GPS device (BT-Q1000XT, QStarz International Co., Ltd., Taipei, Taiwan) and asked to carry the device for 14 days. The GPS device was programmed to record their location in 10-second intervals. The exported GPS data were processed using a series of scripts to remove repeated time stamps and isolated GPS points. Our previous studies that used a similar GPS protocol showed that the GPS data collection was found to be acceptable among study participants [28,29].

We compiled and requested a list of venues that our study participants frequently visited in Chicago from the 2019 Chicago Department of Public Health HIV Services data, the Chicago site of the 2017 National HIV Behavioral Surveillance, our previous project (i.e., PrEP4Love) [30], and the Chicago Center for HIV Elimination outreach team in 2019. To ensure venues reflected those present during the baseline N2 Study period (2018–2019), venues were validated through historical Google Street view and/or validation from online search for operation status (e.g., names, addresses, contact information, hours of operation). Information of the names of the venues, addresses, and geo-coordinates were recorded. We

categorized venues as 1) health service (n = 145; e.g., clinics, pharmacy), 2) social service (n = 38; e.g., housing, food), or 3) entertainment (n = 39; e.g., restaurants, bars/clubs, gyms). We also linked HIV incidence and poverty data to each venue by Chicago community area, a well-established and static geographic boundary that are widely recognized by government agencies, scholars, and planners [31,32].

Outcomes

For PLWH, viral suppression was defined as viral load < 200 HIV RNA copies/ml. Participants who were vulnerable to HIV were asked "*Are you currently taking PrEP to prevent HIV?*". If participants' self-reported PrEP use data were missing, EHR PrEP prescriptions ordered were used.

Covariates

Participants' demographic characteristics included age, gender identity, sexual orientation, relationship status, educational attainment, past year employment status, annual income, and housing stability. Sex behaviors (i.e., any condomless anal sex, alcohol or drug use during sex to enhance sex, group sex, transactional sex) were based on behaviors reported with each sex partner in the network inventory and characteristics for each sex partner were reported by participants (i.e., partners' age and if they were 10 years older than them, race, employment status, HIV serostatus and if the partner was a main partner).

Statistical analyses

We used HIV status neutral approach to describe venues attended by individuals' care engagement status [33]. This analysis was restricted to participants who had GPS data and were not missing data on key study variables. Participants were excluded due to missing GPS data (n =108), lab-confirmed HIV status (n = 5), viral load (n = 7), current PrEP use (n = 2), and sexual partner information (n = 17), resulting in 272 study participants in the analytic sample. GPS points outside the city of Chicago were excluded.

We constructed GPS-defined venue affiliation networks in multiple steps. Participant GPS coordinates were mapped to the nearest pre-identified venue within 50 m, and were considered to have "visited" those venues. Second, we created a two-mode person-to-venue matrix where each row represented a study participant, and each column represented a venue. Third, we transformed the person-to-venue matrix to a venue-to-venue matrix which quantified the number of shared participants for each pair of venues (at least 2 shared participants were required to define an affiliation between two venues). We created three two-mode affiliation networks based on the participants visiting them: (1) participants not living with HIV and not using PrEP (Network 1), (2) PLWH who were not virally suppressed (Network 2), (3) participants not taking PrEP and PLWH who were not virally suppressed (Network 3).

We calculated one-mode and two-mode centrality measures for each venue in each network using key player analysis [34,35]. Within one-mode venue-to-venue networks, we used intra-modal cohesion centrality to identify venues positioned to quickly transmit information to the greatest number of other venues (i.e., identifying numbers of venues that each venue

is connected to via shared participants. For two-mode affiliation networks, we used cross-modal cohesion centrality to describe venues positioned to quickly transmit information to the greatest number of participants (i.e., identifying numbers of participants affiliated with each venue). We computed the percentage of (1) other venues and (2) participants that could be reached by each pair of two venues. We chose two venues as the cut-off based on our research team's venue-based outreach experience. Analyses were performed using R and the KeyPlayer analysis software (version 1.44) developed by Analytic Technologies, Lexington, KY [36]. We used Cytoscape for visualization with a force-directed layout [37].

Results

Within our analytic sample (n = 272), 54 % were not engaged in HIV care (PrEP or ART); 86 % identified as SMM, 11 % as TW. More than half of participants (58 %) self-identified as gay, homosexual, or lesbian. Most participants were single (64 %) and reported annual incomes less than USD $20,000 (68 %). Participants carried a GPS for a median of 11 days (range: 1 to 27 days). Of the 222 pre-identified SMM- and TW-friendly venues, participants were within 50 m of 75.5 % of all venues. On average, each participant was affiliated with 4.7 health service venues, 1.3 social service venues, and 2.8 entertainment venues (Table 1).

Three affiliation networks were constructed using the 147 participants who were not engaged in PrEP or ART. Network 1 consisted of 121 venues (79 health services, 18 social services, and 24 entertainment venues) attended by 99 participants who were not living with HIV and not taking PrEP. Network 2 consisted of 107 venues (79 health services, 18 social services, and 24 entertainment venues) attended by 48 PLWH who were not virally suppressed. Network 3 consisted of 92 venues (56 health services, 15 social services, and 22 entertainment venues), each attended by participants not taking PrEP or PLWH who were not virally suppressed (147 participants). Network densities and other network descriptive statistics are in the appendix.

Fig. 1 graphs the network 3 one-mode venue-to-venue network based on the number of participants attending each venue (venue-person degree) and the number of shared participants across the two venues. Venues B and D were both entertainment venues and were the two most visited venues. Venues B and D were in different Chicago community areas and had substantial differences in poverty rate (47.35 % vs. 23.43 %) and HIV incidence (4th quartile vs. 2nd quartile for HIV incidence).

Table 2 presents the top 5 key players the network measures for each. Across the three venue affiliation networks, there was variation in venues identified as the top 5, based on intra-model and cross-model cohesion centralities. However, some venues were repeatedly identified across the three networks. For example, Venues B and D have high intra-model cohesion centralities across all three networks, indicating these two venues hold positions of influence to other venues. They were also connected to 41.3 % to 79.3 % of other venues within each network. Similarly, across the three networks, Venues B and D (both entertainment venues) were identified as key venues based on the two-mode venue-to-participant network characteristics. For example, Venues B and D can each reach 30.3 % and 32.3 % of participants not taking PrEP in Network 1.

In addition to identifying specific venues as key players, we also identified the combination of pairs of venues with the potential to reach the largest proportion of individuals collectively (Table 3). For example, based on Network 1 statistics, Venue B is affiliated with 80.3 % of other venues and 30.3 % of the participants not taking PrEP. Affiliation increased to 89.3 % and 52.5 %, respectively, when targeting both Venues B and D. Lastly, we describe sexual behavior and sex partner characteristics for people who can versus cannot be reached by the pair of the venues (Table 4). Overall, there were no statistically significant differences in the behaviors of participants who were, or who were not, reached by the combination of venues B and D in Networks 2 or 3. However, in Network 1, participants not taking PrEP that were affiliated with venues B and D had a greater proportion of sexual partners that were identified as casual than those not reached (87 % vs 61 %, p = 0.0495).

Discussion

Our study contributes to the literature by identifying the combination of SMM- and TW-friendly venues that when combined could reach the highest proportion of young Black SMM and TW study participants eligible for HIV prevention or treatment interventions. Together, two entertainment venues located in different community areas in Chicago were affiliated with 52.5 % of all participants eligible for PrEP but not taking PrEP and 43.8 % of all study participants eligible for ART but not virally suppressed. This novel use of two-mode venue-to-participant affiliation networks, identified via GPS data and pre-identified SMM- and TW-friendly venues could be employed by others to identify key venues to intervene on to scale up HIV biomedical interventions among young Black SMM and TW.

Our two-mode venue-to-person affiliation network analyses show a promising opportunity to identify influential venues to promote biomedical HIV interventions among young Black SMM and TW. We determined that by selecting only the most influential venue, less than one-third (30.3 %) of PrEP-eligible candidates but who were not taking PrEP could be reached. However, if an intervention was implemented at two distinct influential venues in different parts of Chicago, the proportion of PrEP-eligible candidates that could be reached increased to > 50 %. Furthermore, our analyses revealed that PrEP candidates reached through the top two influential venues (both were entertainment venues: both are restaurants/bars) were more likely to have sex with non-main sex partners. By applying this affiliation network approach, we identified the two influential venues that, if selected as intervention sites, could maximize an intervention's reach to PrEP-eligible candidates [38]. In addition to identifying potential intervention sites through this approach, selection of PrEP and ART implementation sites should also consider which venues have the strongest buy-in. Despite observational studies having demonstrated the potential utility of venues in promoting HIV biomedical interventions [15,20,21], limited HIV prevention and intervention strategies have been implemented in venues that are frequented by young Black SMM and TW [39]. Multilevel interventions at these influential venues such as providing rapid HIV testing and linkage to care, increasing condom availability (structural-level), and addressing social norms and stigma regarding HIV biomedical interventions (social-level) on site through peer change agents may be warranted [40,41].

It is worth noting that the pair of influential venues identified differed depending on the specific population the intervention aimed to target. For example, among Network 2 (PLWH who are not virally suppressed), Venue B (entertainment venue) and Venue C (health venue) were the top 2 key-player venues identified. Individually, they had the potentially to reach 33.3 % and 16.7 % of PLWH who were not virally suppressed, respectively. Venue B is located in a historically Black neighborhood that is characterized by high HIV incidence and high poverty rates (>40 %). Venue C is located in the downtown business area, is a transportation hub, and has a very low HIV incidence and poverty rate. This finding is consistent with previous studies that indicate SMM and TW, including Black SMM and TW, are spatially polygamous [42,43] and highlights a notable benefit of our approach, which objectively captures the heterogeneity in spatial mobility for subgroups of study participants and identifies venues that optimize reach based on this heterogeneity.

This study has certain limitations. First, GPS-coordinates are mapped to the nearest pre-identified SMM- or TW-friendly venue, but it is not known whether the participant actually visited the venue or was just in the area surrounding the venue. However, because we used a short buffer radius (i.e., within the "line of sight") [44,45], an intervention at a venue identified via this approach could be visible to those who both attend the venue and pass by the venue, and is considered accurate [12]. We did not standardize venue affiliation by the length of time spent at each location. While this is a worthwhile endeavor to pursue in more depth, there is limited literature supporting a specific approach for such standardization. The pre-identified list of SMM and TW friendly venues may not have been complete so venue affiliation may be underestimated. We may have been underpowered to identify differences in venue affiliation for participants with different gender identities (e.g., TW, non-binary individuals), and future studies with a larger sample of expansive gender identities would allow for a more meaningful subgroup analysis. Lastly, the networks were based on a sample of participants and may not have the same impact with respect to reach if applied to the entire Chicago area and is limited in the generalizability.

With limitations acknowledged, this study is one of only a few studies that construct venue-based affiliation networks based on GPS data. Future studies are warranted to develop and evaluate implementation strategies based on this approach, especially among highly marginalized populations that are not typically reached through convention outreach interventions.

Acknowledgements

Appendix

Table 1

Descriptive statistics of venue-to-venue networks by participants' HIV care continuum status among young Black sexually minoritized men, the N2 Cohort Study, 2018–2019 (n = 147).

	Network 1:One mode network of venues attended by people vulnerable to HIV and not taking PrEP	Network 2:One mode network of venues attended by people living with HIV who were not virally suppressed	Network 3:One mode network of venues attended by people who were not engaged in care
Nodes (venues)	121	107	92
Edges (total # of ties)	2286	1489	706
Mean # of venues with shared patrons	37.79	27.83	15.69
Network density *	0.315	0.263	0.176
Clustering coefficient †	0.743	0.727	0.637

*
Network density: proportion of actual/observed ties relative to total potential ties; indicates the extent to which the network is completed connected. A network in which each venue was connected to every other venue would equal 1.

†
Clustering coefficient: Coefficient of how nodes cluster together (the number of ties connecting a vertex's neighbors divided by the total number of possible edges between the vertex's neighbors) and how connected neighborhoods are to each other; indicates "cliques.

Abbreviations:

ART	Antiretroviral therapy/treatment
GPS	Global Positioning System
HIV	Human Immunodeficiency Virus
MSA	Metropolitan Statistical Area
PLWH	Persons living with HIV
PrEP	Pre-exposure prophylaxis
SMM	Sexually Minoritized Men
STI	Sexually Transmitted Infection
TW	Transgender woman

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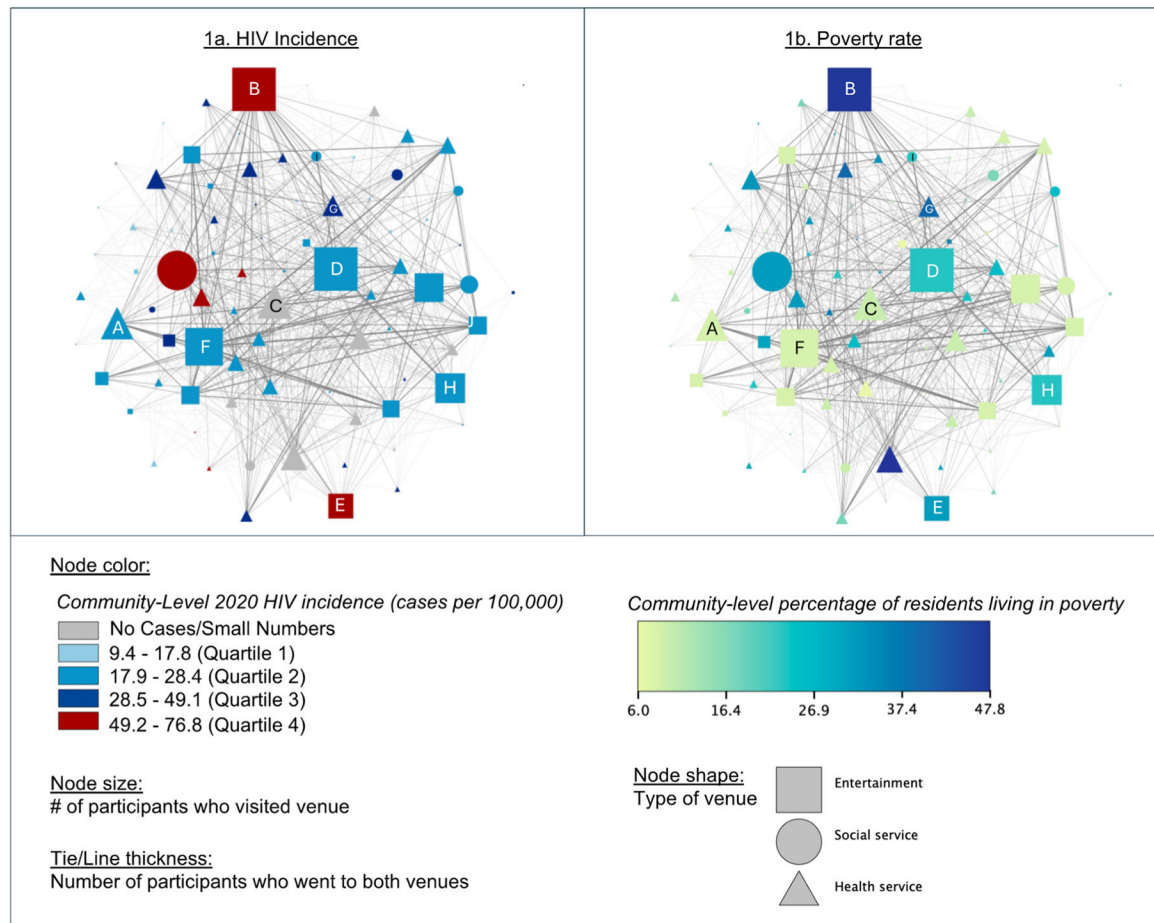
Fig. 1.

Visualization of the one mode network of venues *(venue-to-venue network)* attended by participants not engaged in care, the N2 Cohort Study, 2018–2019 *(*n = 147, including 99 people vulnerable to HIV but not taking PrEP and 48 PLWH who were not virally suppressed*)* [1]Nodes (venues) are connected to other venues by lines which represent the number of participants affiliated with both venues. The thickness of the line corresponds with the number of shared patrons (i.e., venues connected by thicker lines shared more patrons). The node shape indicates the type of venue (square = entertainment venue, circle = social service venue, triangle = health service venue). Node size corresponds with venue-person degree, indicating the total number of participants who attend each venue. [2] The visualizations are displayed using a force-directed layout, using Cytoscape's internal algorithm, by the numbers of shared patrons (i.e., weight), indicating that venues shared more patrons when they appear closer in visualization or connected by thicker lines.

Table 1

Participant characteristics by HIV care continuum status among young Black sexually minoritized men and transgender women in Chicago, the N2 Cohort Study, 2018–2019 (n = 272 participants).

	Overall (N = 272)	Taking PrEP (N = 54)	Not taking PrEP (N = 99)	p-value*	Virally suppressed (N = 71)	Not virally suppressed (N = 48)	p-value*
	n (%)	n (%)	n (%)		n (%)	n (%)	
Number of venue attended							
Total, mean (SD)	8.81 (7.20)	10.33 (8.70)	8.41 (7.22)	0.17	8.73 (6.06)	8.00 (6.84)	0.55
Health service venues, mean (SD)	4.73 (4.21)	5.19 (4.73)	4.47 (3.95)	0.35	5.03 (4.01)	4.31 (4.47)	0.375
Social service venues, mean (SD)	1.32 (1.40)	1.81 (1.63)	1.22 (1.40)	0.026	1.13 (1.15)	1.21 (1.41)	0.74
Entertainment venues, mean (SD)	2.76 (3.16)	3.33 (3.86)	3.71 (3.46)	0.33	2.58 (2.42)	2.48 (2.60)	0.836
Age (years)							
Mean (SD)	25.7 (3.99)	24.4 (3.44)	25.5 (4.22)	0.07	26.2 (3.84)	26.9 (3.93)	0.29
Gender identity							
Cisgender man	234 (86.0 %)	46 (85.2 %)	81 (81.8 %)	0.34	63 (88.7 %)	44 (91.7 %)	1.00
Transgender woman	29 (10.7 %)	4 (7.4 %)	14 (14.1 %)		7 (9.9 %)	4 (8.3 %)	1 (1.4 %)
Another identity	9 (3.3 %)	4 (7.4 %)	4 (4.0 %)		1 (1.4 %)	0 (0 %)	
Sexual identity							
Gay, homosexual or lesbian	160 (58.8 %)	37 (68.5 %)	46 (46.5 %)	0.04	45 (63.4 %)	32 (66.7 %)	0.86
Bisexual	85 (31.3 %)	16 (29.6 %)	43 (43.4 %)		16 (22.5 %)	10 (20.8 %)	
Straight or heterosexual	19 (7.0 %)	1 (1.9 %)	8 (8.1 %)		7 (9.9 %)	3 (6.3 %)	
Relationship status							
Single	175 (64.3 %)	34 (63.0 %)	65 (65.7 %)	0.88	38 (53.5 %)	38 (79.2 %)	0.01
In a relationship	97 (35.7 %)	20 (37.0 %)	34 (34.3 %)		33 (46.5 %)	10 (20.8 %)	
Education							
High school or higher	236 (86.8 %)	49 (90.7 %)	81 (81.8 %)	0.22	63 (88.7 %)	43 (89.6 %)	1.00
No high school	36 (13.2 %)	5 (9.3 %)	18 (18.2 %)		8 (11.3 %)	5 (10.4 %)	
Past year full-time employment							
No	137 (50.4 %)	17 (31.5 %)	54 (54.5 %)	0.01	43 (60.6 %)	23 (47.9 %)	0.24
Yes	135 (49.6 %)	37 (68.5 %)	45 (45.5 %)		28 (39.4 %)	25 (52.1 %)	
Annual income							

	Overall (N = 272)	Taking PrEP (N = 54)	Not taking PrEP (N = 99)	p-value*	Virally suppressed (N = 71)	Not virally suppressed (N = 48)	p-value*
	n (%)	n (%)	n (%)		n (%)	n (%)	
Below $20,000	185 (68.0 %)	33 (61.1 %)	71 (71.7 %)	0.25	49 (69.0 %)	32 (66.7 %)	0.95
$20,000 or above	87 (32.0 %)	21 (38.9 %)	28 (28.3 %)		22 (31.0 %)	16 (33.3 %)	
Housing stability (past 3-month)							
Stable housing	187 (68.8 %)	40 (74.1 %)	66 (66.7 %)	0.44	49 (69.0 %)	32 (66.7 %)	0.95
Unstable housing	85 (31.3 %)	14 (25.9 %)	33 (33.3 %)		22 (31.0 %)	16 (33.3 %)	
Sexual behaviors (past 6 months)							
Condomless anal sex	183 (67.3 %)	43 (79.6 %)	67 (67.7 %)	0.17	53 (74.6 %)	37 (77.1 %)	0.93
Alcohol or drug use during sex†	171 (63.1 %)	36 (66.7 %)	62 (62.6 %)	0.75	44 (62.9 %)	29 (60.4 %)	1.00
Group sex	111 (40.8 %)	29 (53.7 %)	39 (39.4 %)	0.13	21 (29.6 %)	22 (45.8 %)	0.11
Transactional sex (buy or sell sex)	28 (10.3 %)	1 (1.9 %)	16 (16.2 %)	0.02	6 (8.45 %)	5 (10.4 %)	0.97
10 years older than participant	54 (19.9 %)	15 (27.8 %)	18 (18.2 %)	0.18	17 (23.9 %)	9 (18.8 %)	0.66
Non-Hispanic black	263 (96.7 %)	52 (96.3 %)	94 (94.9 %)	1.00	70 (98.6 %)	47 (97.9 %)	1.00
Unemployed	193 (71 %)	38 (70.4 %)	79 (79.8 %)	0.76	44 (62 %)	32 (66.7 %)	0.74
Not main sex partner	203 (74.6 %)	44 (81.5 %)	77 (77.8 %)	0.74	45 (63.4 %)	37 (77.1 %)	0.17
Serodiscordant sex partner/HIV status unknown partner†‡	157 (58.1 %)	29 (53.7 %)	31 (31.3 %)	0.01	55 (78.6 %)	42 (89.4 %)	0.25

2 The means of the venue attended represent the means of averages number of venues that were affiliated with participants across different subgroups of participants.

* p values were derived from Chi-square tests or t-tests.

† There was 1 missing from PLWH who were virally suppressed; therefore, % have been adjusted for new denominator of 271 for overall

‡ There were 1 missing from PLWH who were not virally suppressed and 1 missing from PLWH who were virally suppressed; therefore % have been adjusted for new denominator of 270 for overall, 47 for not virally suppressed, and 70 for virally suppressed

Table 2

Top 5 key players based on venue-to-venue intramodal cohesion centrality and venue-to-person cross-modal cohesion centrality by HIV care engagement status among young Black sexually minoritized men not engaged in care, the N2 Cohort Study, 2018–2019 (n = 147).

Intramodal cohesion centrality of venues (venue-to-venue network)

Two-mode Network 1: People vulnerable to HIV and not taking PrEP and their attended venues (n = 99 participants)(n = 121 venues)			Two-mode Network 2: PLWH who were not virally suppressed and their attended venues (n = 48 participants)(n = 107 venues)			Two-mode Network 3: People who were not engaged in care and their attended venues (n = 147 participants)(n = 92 venues)		
Venue	**Centrality**	**Degree[†]% (n/121)**	**Venue**	**Centrality**	**Degree[†]% (n/107)**	**Venue**	**Centrality**	**Degree[†]% (n/92)**
Venue A (health)	2.21	69.4 (84)	Venue D (entertainment)	1.75	49.5 (53)	Venue B (entertainment) *	2.71	67.4 (62)
Venue B (entertainment) *	2.16	79.3 (96)	Venue B (entertainment) *	1.75	71.0 (76)	Venue D (entertainment)	2.60	41.3 (38)
Venue C (health)	2.15	71.9 (87)	Venue G (social)	1.69	49.5 (53)	Venue A (health)	2.51	31.5 (29)
Venue D (entertainment)	2.12	73.6 (89)	Venue H (entertainment)	1.63	41.1 (44)	Venue C (health)	2.44	58.7 (54)
Venue E (entertainment)	1.92	61.2 (74)	Venue I (health)	1.46	39.3 (42)	Venue H (entertainment)	2.40	35.9 (33)

Crossmodal cohesion centrality of venues (venue-to-person network)

Venue	**Centrality**	**Degree[‡]% (n/99)**	**Venue**	**Centrality**	**Degree[‡]% (n/48)**	**Venue**	**Centrality**	**Degree[‡]% (n/147)**
Venue A (health)	0.46	28.3 (28)	Venue B (entertainment) *	0.72	33.3 (16)	Venue B (entertainment) *	0.32	31.3 (46)
Venue D (entertainment)	0.46	32.3 (32)	Venue D (entertainment)	0.52	29.2 (14)	Venue D (entertainment)	0.31	31.3 (46)
Venue B (entertainment) *	0.42	30.3 (30)	Venue J (entertainment)	0.49	16.7 (8)	Venue A (health)	0.28	23.8 (35)
Venue F (entertainment)	0.41	21.2 (21)	Venue C (health)	0.47	16.7 (8)	Venue C (health)	0.27	25.2 (37)
Venue C (health)	0.40	29.3 (29)	Venue G (social)	0.47	25.0 (12)	Venue F (entertainment)	0.25	19.0 (28)

[1] Participants who were not engaged in care included participants who were vulnerable to HIV and not taking PrEP and participants living with HIV who were not virally suppressed.

* Indicates the venue located in the highest quartile of HIV incidence and the poverty rate is > 40 %

[†] Intramodal degree indicates percentages of other venues with shared participants.

[‡] Crossmodal degree indicates percentages of participants attended the venue.

Table 3

Top and set of 2 key players from the key player analysis in two-mode affiliation networks among young Black sexually minoritized men, the N2 Cohort Study, 2018–2019 (n = 147).

	Network 1:Affiliation network of people vulnerable to HIV and not taking PrEP (n = 99 participants) (n = 121 venues)			Network 2:Affiliation network of PLWH who were not virally suppressed (n = 48 participants) (n = 107 venues)			Network 3:Affiliation network of people not engaged in care[*] (n = 147 participants)(n = 92 venues)		
Venue	**% venues reached**	**% participants reached**		**Venue**	**% venues reached**	**% participants reached**	**Venue**	**% venues reached**	**% participants reached**
1 key player									
Venue B (entertainment)	80.3 %	30.3 %		Venue C (health)	72.0 %	16.7 %	Venue C (health)	71.0 %	25.2 %
2 key players									
Venue B (entertainment)	89.3 %	52.5 %		Venue C (health)	84.1 %	43.8 %	Venue J (entertainment)	85.0 %	38.8 %
Venue D (entertainment)				Venue B (entertainment)			Venue D (entertainment)		

[*] Participants who were not engaged in care included participants who were vulnerable to HIV and not taking PrEP and participants living with HIV who were not virally suppressed.

Table 4

Participant sexual behaviors and sexual partners' characteristics for participants who can vs. cannot be reached from the combination of the top 2 key player venues by HIV care engagement status among young Black sexually minoritized men, the N2 Cohort Study, 2018–2019 (n = 147).

	People vulnerable to HIV and not taking PrEP (n = 99)			PLWH who were not virally suppressed (n = 48)			People who were not engaged in care* (n = 147)		
	Reached†n (%/52)	Cannot be reached†n (%/47)	p-value	Reached‡n (%/21)	Cannot be reached‡n (%/27)	p-value	Reached§n (%/57)	Cannot be reached§n (%/90)	p-value
Sexual behaviors (past 6-month)									
Condomless anal sex	34 (65.4 %)	33 (70.2 %)	0.77	18 (85.7 %)	19 (70.4 %)	0.36	43 (75.4 %)	61 (67.8 %)	0.42
Alcohol and drug use during sex	36 (69.2 %)	26 (55.3 %)	0.22	14 (66.7 %)	15 (55.6 %)	0.63	39 (68.4 %)	52 (57.8 %)	0.26
Group sex	18 (34.6 %)	21 (44.7 %)	0.41	11 (52.4 %)	11 (40.7 %)	0.61	20 (35.1 %)	41 (45.6 %)	0.28
Transactional sex	9 (17.3 %)	7 (14.9 %)	0.96	4 (19.0 %)	1 (3.7 %)	0.21	7 (12.3 %)	14 (15.6 %)	0.76
Sex partner characteristics (past 6-month)									
10 years older than participant (any)	8 (15.4 %)	10 (21.3 %)	0.49	6 (28.6 %)	3 (11.1 %)	0.24	11 (19.3 %)	16 (17.8 %)	0.71
Non-Hispanic black (any)	49 (94.2 %)	45 (95.7 %)	1	21 (100 %)	26 (96.3 %)	1	54 (94.7 %)	87 (96.7 %)	0.88
Unemployed (any)	40 (76.9 %)	39 (83.0 %)	0.62	12 (57.1 %)	20 (74.1 %)	0.36	40 (70.2 %)	71 (78.9 %)	0.32
Not main sex partner (any)	45 (86.5 %)	32 (68.1 %)	0.0496	16 (76.2 %)	21 (77.8 %)	1	44 (77.2 %)	70 (77.8 %)	1
Serodiscordant sex partner/HIV status unknown partner (any)	49 (94.2 %)	45 (95.7 %)	1	18 (85.7 %)	24 (88.9 %)	1	52 (91.2 %)	84 (93.3 %)	0.88

*
Participants who were not engaged in care included participants who were vulnerable to HIV and not taking PrEP and participants living with HIV who were not virally suppressed.

†
Participants can be reached and cannot be reached by the combination of Venues B (entertainment venue) and D (entertainment venue)

‡
Participants can be reached and cannot be reached by the combination of Venues C (health venue) and B (entertainment venue)

§
Participants can be reached and cannot be reached by the combination of Venues J (entertainment venue) and D (entertainment venue)