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The network structure of sex partner meeting places reported by HIV-infected MSM: Opportunities for HIV targeted control

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Abstract

Baltimore, Maryland ranks among U.S. cities with the highest incidence of HIV infection among men who have sex with men (MSM). HIV screening at sex partner meeting places or venues frequented by MSM with new diagnoses and/or high HIV viral load may reduce transmission by identifying and linking infected individuals to care. We investigated venue-based clustering of newly diagnosed MSM to identify high HIV transmission venues. HIV surveillance data from MSM diagnosed between October 2012 June 2014 and reporting ≥1 sex partner meeting place were examined. Venue viral load was defined according to the geometric mean viral load of the cluster of cases that reported the venue and classified as high (>50,000 copies/mL), moderate (1500e50,000 copies/mL), and low (<1500 copies/mL). 143 MSM provided information on ≥1 sex partner meeting place, accounting for 132 unique venues. Twenty-six venues were reported by > 1 MSM; of these, a tightly connected cluster of six moderate viral load sex partner meeting places emerged, representing 66% of reports. Small, dense networks of moderate to high viral load venues may be important for targeted HIV control among MSM.

Keywords

MSM; HIV; Sex partner meeting places; HIV control; Venue affiliation networks

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Conflict of interest

The authors declare that they have no conflict of interest.

1. Background

Current strategies for HIV prevention and control emphasize testing as many people as possible and linking infected individuals to care and treatment, to limit the complications of HIV and reduce the number of people in the community with high viral loads (White House Office, 2010; Marrazzo et al., 2014). Despite these efforts, in the United States, HIV incidence continues to persist at approximately 50,000 new infections each year and disproportionately affects certain populations such as men who have sex with men (MSM) (Centers for Disease Control and Prevention, 2015). In light of these challenges, and given limited availability of resources for implementing HIV prevention and control programs, more efficient strategies are needed. Current approaches may be enhanced by targeted control, which aims to identify and disrupt transmission in key networks, or groups of interconnected individuals who, through their sexual or needle-sharing connections, are actively transmitting HIV from one person to another and subsequently to others in the group.

Targeted control is an approach that is grounded in network theory, which emerged in the 1920s and 1930s, when social scientists introduced the concept of a social network as a group of individuals with distinct patterns of relationships and interactions with other individuals (Newman, 2003; Doherty et al., 2005). Early studies of social relationships among different groups of individuals illuminated the importance of the structure of networks, including an individual's position within the network, on individual behavior and overall group dynamics (Newman, 2003). The quantitative, visual analysis of social networks has extended to investigations of patterns of sexual contacts, emerging from historical efforts to prevent and control sexually transmitted infections (STIs) (Doherty et al., 2005). STI control efforts such as contact tracing routinely incorporate network theory. In contact tracing, STI infected individuals are asked during partner services interviews about their recent sexual partners. Attempts are then made to contact and inform the partners about their potential exposure.

To initiate targeted control of HIV within a transmission network, one important consideration is the structure of the network. For example, sexual networks can be analyzed to identify individuals who are more connected, directly or indirectly, to other individuals in a network. If infected, these "central" individuals play a principal role in the transmission of sexually transmitted infections, including HIV, within the network (Doherty et al., 2012; De et al., 2004; Wohlfeiler and Potterat, 2005; Rothenberg and Potterat, 1988). Moreover, their force of infectivity, i.e. the probability of transmission, increases in direct relationship to the connectivity or density of the network (Potterat et al., 1999).

Another important consideration for the force of infectivity of the network is the composition of the network, i.e. the mix of individuals who are either highly infectious or susceptible to infection (Potterat et al., 1999). The likelihood of transmission from an infected to a susceptible individual increases according to the amount of virus in the infected person. HIV infected individuals who are most likely to transmit are those with an unsuppressed viral load practicing transmission risk behaviors, particularly individuals newly infected within the past three months (Hollingsworth et al., 2008; Wawer et al., 2005;

Pilcher et al., 2004; Quinn et al., 2000; Brenner et al., 2007; Cohen and Pilcher, 2005; Cohen et al., 2011). Moreover, an estimated 23% and 69% of new infections in the United States are attributed to infection among individuals who are undiagnosed or who have been diagnosed but not engaged in care, respectively (Skarbinski et al., 2015).

Leveraging these two considerations e network structure and availability of high viral load individuals e may yield new and more effective targeted HIV control strategies to reduce the spread of HIV. When available, network and viral load data can be combined to identify the most likely high transmission networks, i.e., networks with a high force of infectivity. These networks can then be targeted by local outreach programs to implement HIV testing, and ultimately, link people living with HIV into care or introduce preexposure prophylaxis (PrEP) as a prevention tool for susceptible individuals.

An effective strategy for accessing transmission networks characterized by significant density and high viral load is to focus targeted control activities on social venues (Jennings et al., 2012; Polk et al., 2013; Weir et al., 2003). Social venues are places where individuals congregate and can include places where individuals meet sex partners and coalesce into sexual networks with specific structural characteristics, such as density of network connections. These sex partner meeting places can include formal venues such as bars, nightclubs, hair salons, schools, and informal venues such as parks, abandoned houses, street corners, and alleys (Wohl et al., 2011; Michaud et al., 2003; Grov et al., 2010; Stephens et al., 2014). More recently, the rapid rise of the use of social media has introduced new online platforms such as chat rooms and geosocial networking (GSN) applications for meeting sex partners (Doherty et al., 2005; Phillips et al., 2014; Wohlfeiler et al., 2013). Through the formation of sexual networks, some of these places may generate a context of HIV transmission risk through dense network connections that include infected individuals with unsuppressed viral loads and those who are susceptible to infection. Examining the density of network connections among the venues themselves (i.e., venues linked through multiple individuals reporting the multiple venues) yields an additional level of network information, which is rarely considered. Identifying venues with high HIV viral loads that are highly connected, or identifying high viral load venues connected to lower transmission venues would yield specific targets for HIV outreach programs.

One means to identify these transmission risk places or venues is to use a variation on sexual network analysis, venue affiliation network analysis. Compared to traditional sexual networks, venue affiliation network analysis connects individuals nominating sex partner meeting venues into a sexual network of venues (Frost, 2007; Oster et al., 2013; Hurt et al., 2012; Fujimoto et al., 2013; Schneider, 2013; Niekamp et al., 2013). The focus is thus on the network of venues and the connections between venues rather than the individual and the connections between individuals. The information required for venue affiliation network analyses is often less resource intensive to obtain and has fewer biases compared to other forms of sexual network analyses, which are limited by recall and disclosure of individual sex partner information (Frost, 2007). Moreover, venue affiliation network analyses can reveal tightly connected venues where HIV transmission may be occurring by evaluating different metrics related to network density and venue centrality (Frost, 2007; Borgatti and Halgin, 2011). Measures of degree, betweenness, and closeness centrality, have been useful

in studying HIV, STI, and tuberculosis transmission networks (Oster et al., 2013; Hurt et al., 2012; Klovdahl et al., 2001; Cook et al., 2007) and may be one approach to prioritizing venues for targeted control. In a venue affiliation network analysis conducted in Jackson, Mississippi, Oster et al. (2013) found that young Black MSM concentrated around a few urban venues where they reported socializing and meeting sex partners (Oster et al., 2013). The social and sexual networks of both HIV-infected and HIV-uninfected men overlapped through a small cluster of venues, establishing a setting for heightened risk of new HIV infections (Oster et al., 2013). While this and other studies (Frost, 2007; Oster et al., 2013; Hurt et al., 2012; Fujimoto et al., 2013; Niekamp et al., 2013) have demonstrated the value of venue affiliation network analysis to visualize local HIV epidemics, many are studies limited by a small sample size and few have taken advantage of the set of tools available to quantify and interpret centrality measures of local networks. In addition, the distribution of epidemiologically significant elements and their relationship to transmission risk and generalizability to different settings, populations, and geographies remains unknown.

This goal of this paper is to provide guidance to local HIV targeted control programs to develop new and potentially more effective venue-based targeted HIV control strategies to reduce HIV transmission among MSM. The objectives of this study were to evaluate the network structure (e.g., density, centrality) of sex partner meeting venues reported by newly diagnosed HIV-infected MSM in Baltimore City, Maryland using venue affiliation network analysis, and in an exploratory sub-analysis, to describe the variability of HIV viral load across the network of venues.

2. Methods

2.1. Setting

Baltimore City, Maryland ranks among U.S. cities with the highest incidence of HIV and other sexually transmitted infections (STIs) among men who have sex with men (MSM) (Centers for Disease Control and Prevention, 2015; Centers for Disease Control and Prevention, 2013). According to the National HIV Behavioral Surveillance System (NHBS) in 2011, an estimated 43% of Balti more's MSM were infected with HIV, with the majority being Black MSM (Maryland Department of Health and Mental Hygiene, 2012; Centers for Disease Control and Prevention, 2014). Moreover, the rate of unknown/undiagnosed infections among MSM in 2011 was estimated to be 31%, higher than every other NHBS city surveyed except San Juan, Puerto Rico (Centers for Disease Control and Prevention, 2014; Wejnert et al., 2013).

2.2. Study population

This work was conducted through a public-private partnership between the Baltimore City Health Department (BCHD) and the Johns Hopkins University Center for Child & Community Health Research (CCHR). One goal of the partnership is to reduce new HIV infections in Baltimore City through the innovative use of surveillance data. Reporting of HIV to state and local health departments is legally mandated in Maryland. BCHD refers all newly diagnosed individuals (with no prior record of HIV infection reported within Maryland) for partner services. During routine partner services, in addition to collecting

demographic, risk behavior, and sex partner information, BCHD routinely collects qualitative information on sex partner meeting places (e.g., name of bar, website, street corner) where new cases met sex partners in the last 12 months. These surveillance data allowed for the design of egocentric network analyses to understand the structure and composition of network ties between individual cases and the reported venues.

To further inform prioritization of local targeted control programs, BCHD implemented a new viral load testing protocol in October 2012. This protocol requires that all confirmed HIV- infected individuals tested through BCHD and affiliate programs (e.g., street and venue-based outreach, STI clinics, emergency departments, community based organizations, private health care providers) are routinely viral load tested. Eligible specimens are sent to the Maryland Department of Health and Mental Hygiene (DHMH) Laboratory for viral load testing using reverse transcription-polymerase chain reaction (RT-PCR) assays developed and validated by the DHMH Laboratory. The results of the viral load assays are used strictly for epidemiological purposes and not for HIV diagnosis or patient management protocols.

For this study, we used BCHD HIV public health surveillance data of MSM living in Baltimore City newly diagnosed with HIV from October 2012 through June 2014. Cases were considered to be MSM if during the partner services interview they self-identified as gay/bisexual or reported having sex with men. New diagnoses are routinely defined as no prior report of HIV infection in either the BCHD's HIV/STI morbidity registry or Maryland's Department of Health and Mental Hygiene's Enhanced HIV/AIDS Reporting System database (eHARS). Data were limited to cases with interview records and information on at least one sex partner meeting place. The Institutional Review Board at the Johns Hopkins School of Medicine approved this study.

2.3. Analysis

Descriptive analyses and network analyses were performed using R Version 3.2.0 (R Core Team, 2015) using the SNA Package (Butts, 2008). As a preliminary step, individuals reporting a sex partner meeting place were compared to those not reporting using chi-squared tests or t-tests, as appropriate. Significance was determined by a p value of <0.05. We described individuals included in the analysis by demographics (e.g. age, race), HIV risk behavior (e.g., number of sex partners), viral load, and venues reported. Venues were classified into six types: bar or club, internet based site (e.g., website, geo-social networking application [GSN app], chat line), market or mall, street or park or neighborhood, private residence, and other.

Data were used to create affiliation network graphics using two modes: newly diagnosed MSM and their reported sex partner meeting places. First, an affiliation network graph was generated to visualize the extent to which new diagnoses were connected to the entire set of all reported sex partner meeting venues. Then, focusing on the network of venues reported by at least two cases, an additional affiliation network graph was created and venues were evaluated by venue-case degree centrality, i.e., the number of cases connected to a particular venue (Borgatti and Halgin, 2011). To compare the relative prominence of venues, each venue-case degree centrality score was normalized by dividing the value by the maximum

value possible for the network, i.e., the number of newly diagnosed HIV-infected MSM in the network (Frost, 2007; Borgatti and Halgin, 2011).

To complement the venue affiliation network graphics and further illustrate the connectedness of venues, we generated a onemode “co-occurrence” network of sex partner meeting places reported by at least two cases. To create the graphic, venues were connected if they shared at least one MSM case. Exploratory analysis of the co-occurrence network was conducted using three centrality metrics, which were evaluated at the venue-venue level (degree, betweenness, and closeness). Venue-venue degree centrality was calculated by linking venues via shared cases, and node size was adjusted according to number of ties to other venues. Illustrating varying levels of venue-venue degree centrality may further refine the prioritization of venues for outreach to those venues that are highly central, while simultaneously identifying venues that are less central, i.e., where outreach efforts may become redundant and less efficient in yielding new cases. A second centrality measure, betweenness centrality, is used in traditional sexual network analyses to identify “bridging” individuals (Borgatti and Halgin, 2011). For this analysis, betweenness centrality was used to identify the location of certain venues within the broader network of venues and to begin to uncover potentially critical bridging venues. Venues characterized by high betweenness centrality are, for example, highly connected via bridging linkages to other venues, a characteristic which is fundamental to the persistence of HIV transmission in a given sub-population (Doherty et al., 2012; Potterat et al., 1999). The third centrality metric, closeness, is used to specify how closely connected an individual is to all other individuals through mutual ties with cases, or in sexual affiliation networks, a venue to all other venues through mutual ties with venues (Frost, 2007; Borgatti and Halgin, 2011). We used closeness to identify the venues that comprised the tightest-knit cluster.

For the exploratory sub-analysis, we hypothesized that transmission risk was not equal across venues, and thus with the data available, we sought to explore variation in viral load, specifically venue viral load, as a potential marker of the force of infectivity of a venue. Venues found to have higher viral load may signal the existence of high transmission networks where prevention among susceptible individuals such as pre-exposure prophylaxis (PrEP) may be critical. In addition these venues may be useful for targeted linkage to and retention in care. To determine variability in viral load, viral load data from individuals reporting the venue as a sex partner meeting venue were aggregated to create venue-level viral load. This approach is similar to approaches used for areas or subpopulations (i.e., community viral load) (Centers for Disease Control and Prevention, 2011). Specifically, among the network of venues limited to those nominated by at least two cases, venue viral load was calculated as the geometric mean viral load of cases linked to a particular venue (Centers for Disease Control and Prevention, 2011). The geometric mean was used compared to, for example, an arithmetic mean because it is less sensitive to extreme outliers. Venues were classified into three categories of geometric mean - low (<1500 copies/mL), moderate (1500e50,000 copies/mL), and high (>50,000 copies/mL) - as a proxy for transmission risk (Quinn et al., 2000).

Venues were ranked by venue-case degree centrality and plotted on a histogram to depict the most central venues during the study period, specifically identifying venues that accounted

for a majority of all reports of sex partner meeting venues (i.e., half or more). Venue viral load data were then layered onto the venuevenue co-occurrence network graph. In addition to characterizing locations according to transmission risk categories, venues were differentiated by venue type to better understand how different types of venues were connected (e.g., bars and web-based venues), which may be an important consideration for developing targeted and tailored outreach services.

3. Results

Among 256 newly diagnosed MSM during October 2012 to June 2014, 217 were interviewed by the BCHD for partner services. Of the interviewed cases, 143 (66%) provided information on at least one sex partner meeting place, accounting for a total of 315 meeting place reports. Cases who provided sex partner meeting place information were younger and reported more sex partners compared to those without meeting place reports; racial distributions and mean viral load were not significantly different between the two groups (data not shown).

Among the 143 cases who nominated at least one meeting place, the median age was 25 years (range: 16e53 years) and the majority of cases were African American or Black (86%) (Table 1). Seventyone percent reported having two or more sex partners in the past year and 57 (40%) had available viral load information. Among these, the geometric mean viral load was 6073 copies/mL (range: 500e381,259 copies/mL). Cases with viral load information, compared to those without viral load, were not significantly different by age, race, or number of sex partners.

Cases reported an average of two (range: 1e11) and a total of 315 sex partner meeting place reports in the past year. Among the 315 sex partner meeting place reports, internet-based sites were most commonly reported (n = 152, 48%), followed by bars or clubs (n = 73, 23%). The remaining nominations included streets, parks or neighborhoods (n = 41, 13%), other venues (n = 39%,12%), markets or malls (n = 7, 2%), and private residences (n 3, 1%). Among the 315 reports, 132 were unique venues, which included 25 internet-based sites (19%), 24 bars or clubs (18%), 37 street locations, parks, or neighborhoods (28%), 3 private residences (2%), 7 markets or malls (5%), and 36 other unique venues (36%). The venue affiliation network of these venues revealed a large variation in the report of unique places (Fig. 1). In the network of venues, one main component emerged, consisting of many peripheral venues and a few centrally located venues. Peripheral venues were connected to the main component via cases that reported more than one sex partner meeting place, creating linkages across multiple venues. Many of these cases also clustered around a set of venues located centrally within the main component. Separate from the main component were dyads of venue-case pairs that were not otherwise linked to the venues in the main component. These isolated venue-case pairs were primarily streets, parks, and neighborhoods and other types of public venues (e.g., train station, school) located throughout the city but also outside of the city limits, along the northeast corridor (e.g., Washington, D.C., Philadelphia, New York City).

One-fifth (n = 26) of all 132 venues in the network were reported by more than one case, and linked to 79% (n = 113) of the total sample of 143 newly diagnosed MSM. The majority of these venues were internet-based sites (n = 12, 46%) and bars or clubs (n = 8, 31%) (Fig. 2). The remaining venues were streets, parks, or neighborhoods (n = 3, 12%) and other (n = 3, 12%). Normalized venue-case centrality scoring revealed that venue ‘WEB 11’ was connected to the highest proportion of cases (nDegree: 0.44), followed by ‘WEB 1’ and ‘WEB 15’ (nDegree: 0.20), and ‘BAR 5’ (nDegree: 0.15). Fig. 2 visually suggests that a large number of cases were concentrated around few venues centrally located in the network.

Fig. 3 illustrates the one-mode venue-venue co-occurrence network limited to the 26 sex partner meeting places reported by more than one case. The network graphic differentiates which cases reported meeting sex partners at multiple venues of the same or different types (e.g., bars and internet sites), in addition to the number of shared case ties between venues, indicated by width of lines. The venue node size represents the venue-venue degree centrality metric and was used to visually locate venues with the most shared cases of newly diagnosed MSM, informing ways to maximize outreach coverage by targeting a select number of venues. Overall, the network was characterized by a high degree of connectedness across venues. Venues were tied to an average of 5.5 venues (density: 0.22), suggesting that a large proportion of cases met sex partners at multiple venues. Venue WEB 11 demonstrated the highest venue-venue degree centrality (i.e., most number of venue connections), followed by BAR 5 and WEB 15. The venue with the highest betweenness centrality was BAR 5 followed by WEB 11 and WEB 1. WEB 11 and BAR 5 tied for highest for venue closeness centrality, followed by WEB 15. Connections between different meeting place types were common. For example, bars or clubs were primarily connected to other bars or clubs but also internet-based sites, suggesting that newly-diagnosed MSM meet sex partners within a tight network of both physical and internet based places. Of note, WEB 11 demonstrated particularly strong ties between WEB 13, WEB 15, WEB 1 and BAR 5, suggesting that cases who frequented WEB 11 also met partners at these other places.

Eighty-eight percent (n = 23) of the 26 venues within this network were reported by at least one case with available viral load information (mean: 4 cases with viral load per venue; range: 1–22). Venues were classified as high (n = 4), moderate (n = 18), or low transmission risk (n = 1). Fig. 4 illustrates an ordered ranking of venue-case degree centrality (i.e., number of reports) and highlights venues with the largest case clusters according to transmission risk. Four of the 26 venues (WEB 11, WEB 1, WEB 15, BAR 5) accounted for more than half of the venue reports; an additional two venues (WEB 13, BAR 10) at the bottom of the “elbow” of the histogram captured two-thirds (66%) of reports. These six venues were characterized by moderate viral load (1500e50,000 copies/mL). Four venues were characterized as high viral load (WEB 24, BAR 8, SPN31, WEB 6). Fig. 5 depicts the venue co-occurrence network to visualize how closely the four high transmission risk venues were linked to the tightly connected cluster of the six most centrally located, moderate transmission risk venues. BAR 8 was a high transmission venue with the most connections to the cluster, including both bars and internet-based venues. Notably, BAR 8 was directly linked to venues with the highest centrality, betweenness, and closeness values in the network (WEB 11, BAR 5). WEB 24 exhibited the strongest ties (i.e., most shared cases) to

other venues, limited to a set of three internet-based venues (WEB 11 WEB 13, WEB 15) located within the central cluster.

4. Discussion

The overall goal of this study was to inform targeted HIV control strategies through the evaluation of the structure of a network of sex partner meeting venues of newly diagnosed HIV-infected MSM, and in an exploratory sub-analysis, to describe the variability of viral load across the network of venues. This study applied a novel methodology, namely venue affiliation network analysis and the findings have important implications for public health programs considering how best to allocate resources for targeted HIV control. The majority of the study population (n = 143) was Black and almost half were young (≤24 years) Black MSM. These demographics are notable because in Baltimore City, as well as other cities across the U.S., young Black MSM are a population that has continued to experience a high incidence and in some places, an increasing incidence of HIV. Targeted control strategies tailored for this population are desperately needed to reverse the epidemic (Maulsby et al., 2015). Identifying venues most centrally connected within this network, and furthermore, those with the highest HIV transmission risk (i.e., venue viral load), can help direct local programs to places for prioritized outreach and linkage to care.

Affiliation network analysis among individuals reporting at least one sex partner meeting place (n = 143) revealed that the majority of MSM, 79% (n = 113), were linked to a network of 26 sex partner meeting places. Overall, the network was characterized by a high degree of connectedness across venues suggesting that a large proportion of cases met sex partners at multiple venues. Among venues with venue viral load information (n = 23), 96% (n = 22) had high or moderate venue viral loads. The centrality metrics (i.e. venue-venue degree centrality, betweenness centrality, venue closeness centrality) all suggested that newly-diagnosed MSM meet sex partners within a tight network of both physical and internet-based places. The tight network included a cluster of six places, represented by two-thirds of all case reports, consisting entirely of bars or clubs and internet-based sites with moderate venue viral loads.

Programs that attempt to interrupt the transmission of HIV by increasing awareness of infection, improving linkage and adherence to HIV medical care, and minimizing risk behaviors among people infected with HIV are critical to achieving significant reductions in HIV transmission. Strategic, targeted control activities, such as HIV testing outreach, are critical for addressing the epidemic, especially in light of the limited economic resources available for public health HIV prevention and control programs (Holtgrave, 2015). The observed pattern of many moderate and high viral load venues clustering in a dense network sets up the necessary and sufficient factors for the propagation of HIV transmission. Depending on the degree of sexual mixing of high viral load individuals and susceptible individuals at venues and between venues, this pattern may suggest opportunities to utilize new tools, such as pre-exposure prophylaxis (PrEP), to interrupt HIV transmission. In settings with limited resources to conduct outreach across a large network of venues, programs can maximize their impact by identifying the most centrally located venues, and focusing on those with the highest viral load. Venues with the highest venue-case degree

centrality (i.e., concentration of newly diagnosed MSM around a venue) may serve as places with the potential for maximum yields of both newly infected and susceptible individuals. Moreover, venue-venue network measures such as venue betweenness centrality add value by denoting the venues that most prominently serve as "bridges" to the overall network, thus indicating key focal points for the interruption of HIV transmission.

The study findings are also informative for developing approaches to target different types of venues frequented by newly diagnosed MSM, particularly young Black MSM, a key HIV population that represented the majority of the cases in our study. Internet-based sites were the most common type of sex partner meeting place reported, representing almost half of all venue nominations. Bars and clubs were also common meeting places, accounting for almost a quarter of all nominations. These two venue types e internet and bars/clubs e were also central to the predominant cluster of meeting places identified through affiliation network analysis. The co-occurrence network highlighted important linkages between these two types, supporting the growing body of evidence that MSM are increasingly using internet-based technologies to find sex partners (Phillips et al., 2014; Wohlfeiler et al., 2013; Beymer et al., 2014). In this local jurisdiction, there are currently no strategies being systematically implemented for internet-based venues. Given the clustering with physical venues, it may also be that intervening at the physical venues that are closely connected to the internet-based venues may be sufficient. The findings also reinforce the need for continued research into potential differences in transmission risk by typology (Grov et al., 2010; Lehmiller and Ioerger, 2014).

Our observations were consistent with a recent affiliation network analysis of venues frequented by young (17–25 years) Black MSM in Jackson, Mississippi, which described a tight network of MSM that overlapped through a small group of venues, primarily websites and bars, in addition to a few other venues such as public cruising areas and a mall (Oster et al., 2013). Oster et al. suggest that young Black MSM may be drawn to the few venues that are safe and free of stigma, bringing together both HIV-infected and uninfected men into similar spaces and creating an "enriched" HIV prevalence and heightened opportunities for HIV transmission (Oster et al., 2013). A 2013 study by Fujimoto et al., examined affiliation networks of drug-using male sex workers (MSW) in Houston, Texas and found wide variation in popularity of venues across the entire network (Fujimoto et al., 2013). Ultimately, though, the findings yielded a few dominant venues common among the sample of MSWs (Fujimoto et al., 2013). Researchers also identified overlap in venues, suggesting that MSW tended to frequent both bars and street venues to meet sex partners.

There are important limitations to this study. Data were limited to venues reported by newly-diagnosed MSM and may be subject to recall bias, and therefore may not represent all venues MSM frequented to meet sex partners in the past 12 months. Also, because affiliation network analysis is a tool to identify opportunities for social and sexual connection, these data are not necessarily a reflection of where direct connections occurred or where HIV-infection was acquired. Missingness of information in the surveillance data did not allow for a thorough examination of individual risk information such as drug use, commercial sex work, unprotected sex, and co-infection, which if incorporated may have helped to further elucidate the transmission potential of venues. For the exploratory sub-analysis, viral load

data for each individual were captured at the time of diagnosis and may not reflect the level of transmission risk at the time of frequenting a particular venue. However, these cases and their biological and behavioral HIV risk profiles remain important components of the larger venue network, which has been shown to remain stable over time (Jennings et al., 2015). Viral load information was missing for a number of cases, and therefore, the venue viral load estimates may be not representative of all HIV diagnosed individuals frequenting the venue; we also did not have information on susceptible individuals frequenting the venue which is also important for transmission potential of the venue. To determine the true level of transmission risk, future work should collect information to better estimate the distribution of both high viral load and susceptible individuals.

Despite limitations, one important advantage to our current approach is that it utilizes an innovative approach and capitalizes on existing public health surveillance data. Another advantage is that information on sexual affiliation networks may be more reliable compared to other sexual network data such as direct sexual contacts (Frost, 2007). Without requiring additional resources or extensive data collection, affiliation network analysis of existing HIV surveillance data can help us understand the HIV transmission risk related to places where MSM meet sex partners. Our findings highlight places where local programs have the potential to increase efficiency of HIV control activities by maximizing local resource allocation of scarce public health dollars through the targeting of highly central venues with the greatest potential for transmission. Future research should seek to confirm the generalizability of our findings in other settings and to evaluate if the findings, when utilized for targeted HIV control, result in the identification of more positives and specifically, more high HIV viral load individuals and ultimately, future declines in HIV transmission.

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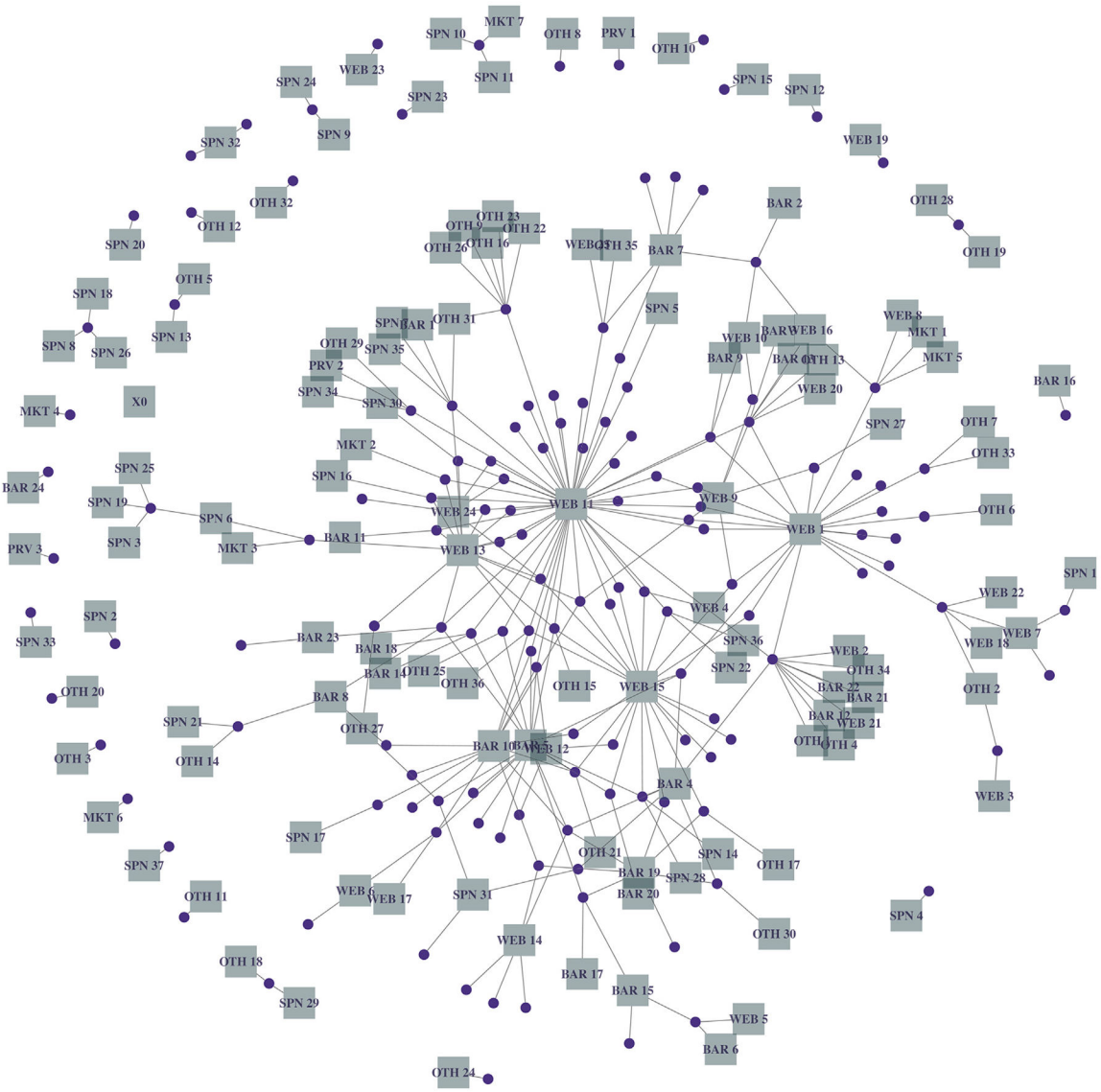

Fig. 1.

Affiliation network of newly diagnosed MSM (circles, n = 143) and sex partner meeting venues (boxes, n = 132), Baltimore City, October 2012-June 2014.

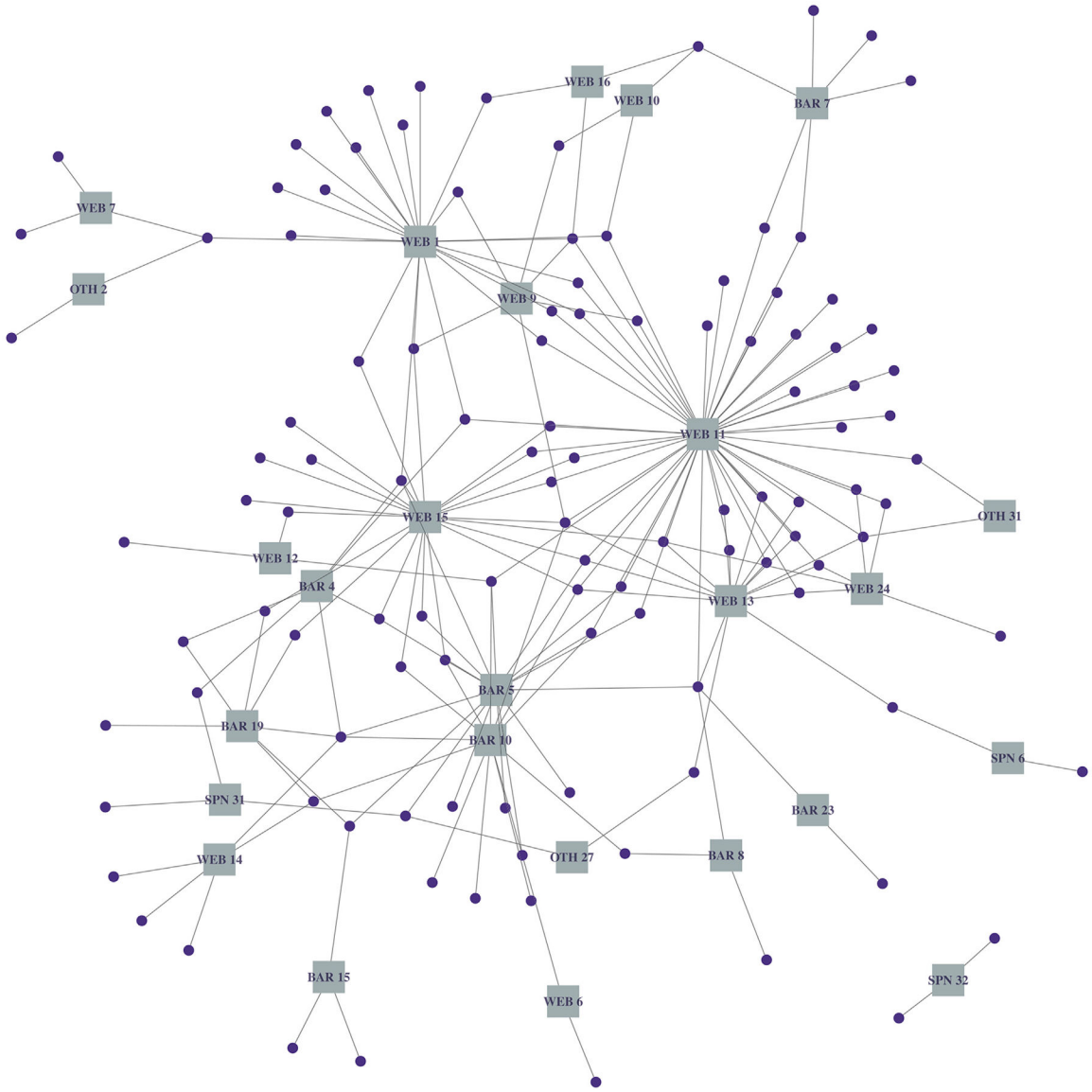

Fig. 2.

Affiliation network of newly diagnosed MSM (circles, n = 113) and sex partner meeting venues reported by >1 MSM (boxes, n = 26), Baltimore City, October 2012-June 2014.

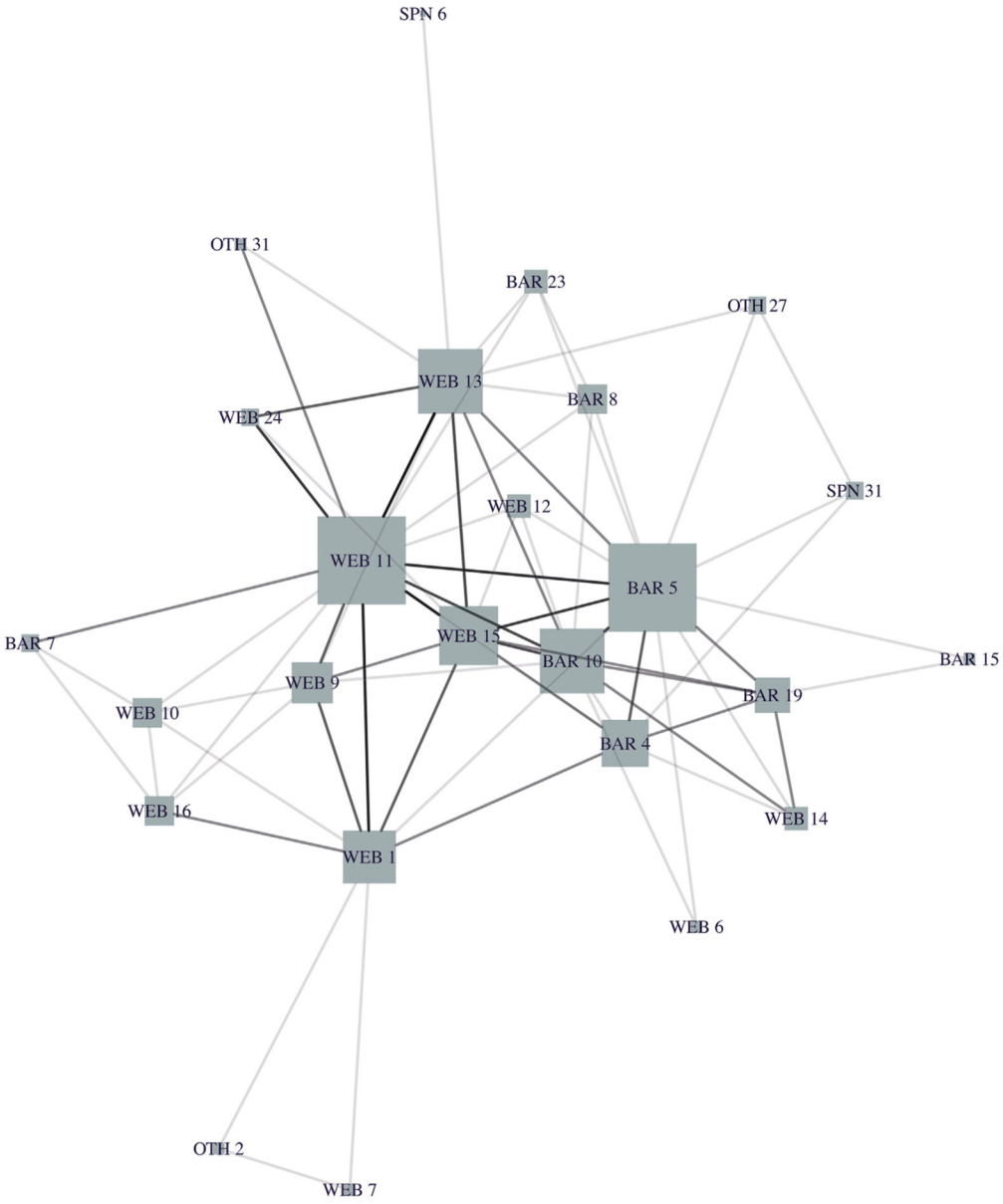

Fig. 3.

Connectivity across venues: co-occurrence network of sex partner meeting venues reported by >1 MSM (n = 26), Baltimore City, October 2012-June 2014. Note: Venues are linked if they have at least one shared case. The size of the node reflects level of degree centrality (i.e., a larger node represents more venue connections). The width of the lines indicates tie strength (i.e., wider tie reflects more shared cases between venues).

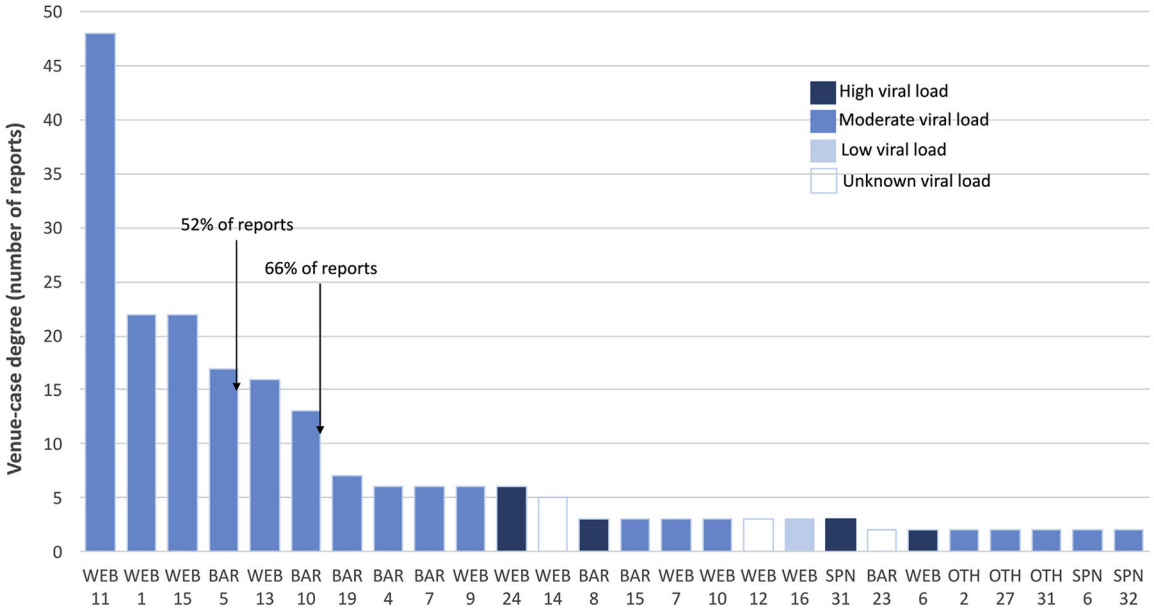

Fig. 4.

Venue-case degree centrality and variability in venue viral load across an affiliation network of sex partner meeting venues reported by >1 MSM (n = 26), Baltimore City, October 2012-June 2014.

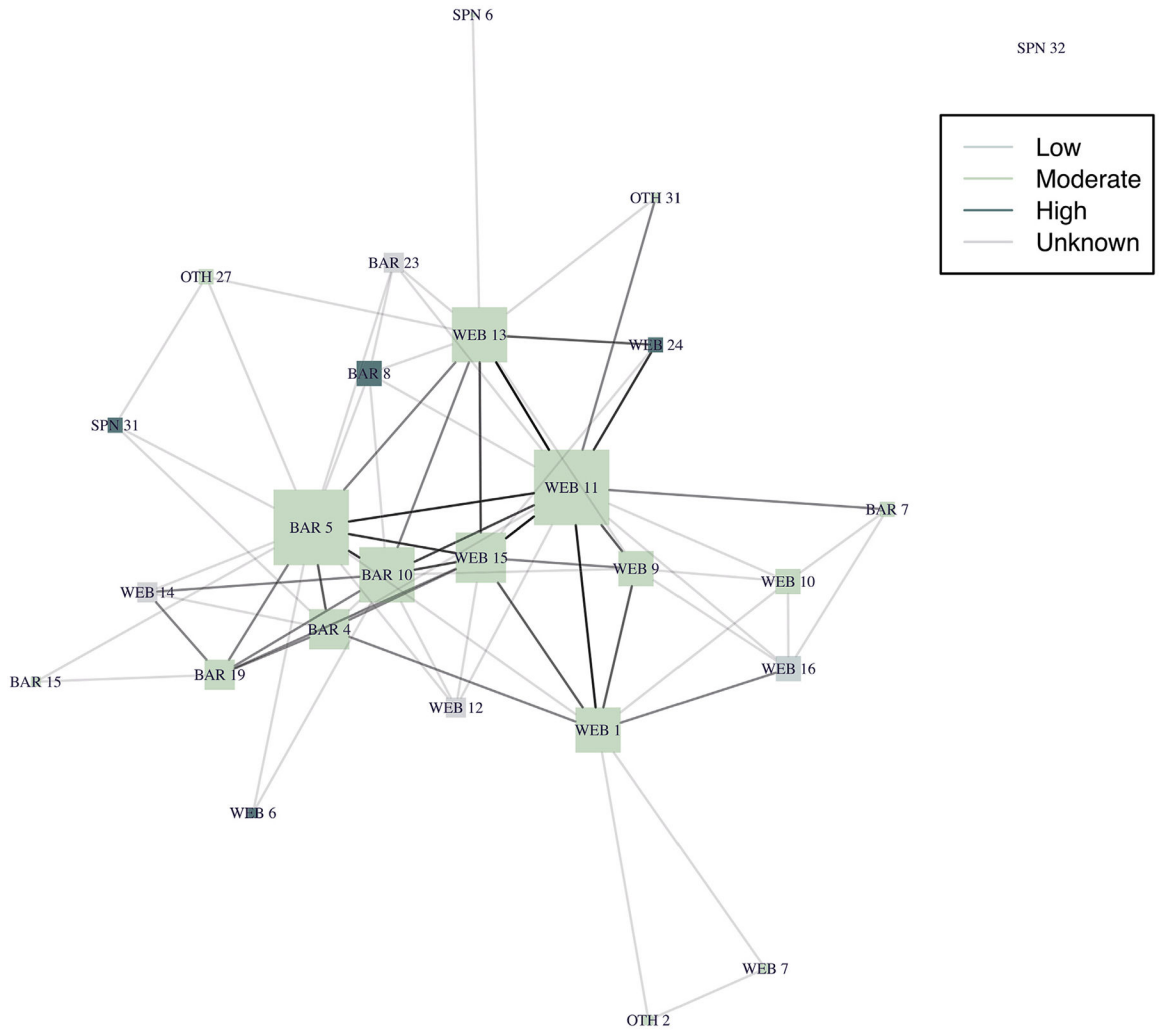

Fig. 5.

Connectivity and variability in venue viral load across venues: co-occurrence network of sex partner meeting venues reported by >1 MSM (n = 26), Baltimore City, October 2012-June 2014. Note: Venues are linked if they have at least one shared case. The size of the node reflects level of degree centrality (i.e., a larger node represents more venue connections). The width of the lines indicates tie strength (i.e., wider tie reflects more shared cases between venues). Venue geometric mean viral load: high [>50,000 copies/mL], moderate [1500–50,000 copies/mL], low [<1500 copies/mL].

Table 1.

Characteristics of newly diagnosed HIV-infected MSM reporting ≥1 sex partner meeting place (n = 143), Baltimore City, October 2012-June 2014.

Characteristic	N	%
Age, years		
Median (range)	25	(16, 53)
<18	5	3.5
18–24	58	40.6
25–34	57	39.9
35–44	15	10.5
≥45	8	5.6
Race		
Black	123	86.0
White	13	9.1
Other	7	4.9
Number of sex partners, past 12 months		
Median (range)	2	(0, 30)
<2	42	29.4
2–4	47	32.9
5–9	11	7.7
≥10	43	30.1
Viral load (copies/mL)		
Geometric mean (range)	6073	(500, 381,259)
High (>50,000 copies/mL)	9	6.3
Moderate (1500–50,000 copies/mL)	32	22.4
Low (<1500 copies/mL)	16	11.2
Unknown	86	60.1
Venue nominations		
Reports per case, mean (range)	2	(1,11)
Reports by typology (n = 315)		
Internet/app	152	48.3
Bar/club	73	23.2
Street/park/neighborhood	41	13.0
Other	39	12.4
Market/mall	7	2.2
Private residence	3	1.0