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Social Networks, Sexual Networks and HIV Risk in Men Who Have Sex with Men

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Abstract Worldwide, men who have sex with men (MSM) remain one of the most HIV-vulnerable community populations. A global public health priority is developing new methods of reaching MSM, understanding HIV transmission patterns, and intervening to reduce their risk. Increased attention is being given to the role that MSM networks play in HIV epidemiology. This review of MSM network research studies demonstrates that: (1) Members of the same social network often share similar norms, attitudes, and HIV risk behavior levels; (2) Network interventions are feasible and powerful for reducing unprotected sex and potentially for increasing HIV testing uptake; (3) HIV vulnerability among African American MSM increases when an individual enters a high-risk sexual network characterized by high density and racial homogeneity; and (4) Networks are primary sources of social support for MSM, particularly for those living with HIV, with greater support predicting higher care uptake and adherence.

Keywords Review · Social networks · Prevention · Sexual networks · Men who have sex with men (MSM) · MSM · Gay men · HIV risk · HIV · HIV risk behavior levels · Risk behavior · HIV transmission patterns · MSM networks · Social networks

Introduction

Men who have sex with men (MSM) are among the community populations throughout the world most affected by HIV. After discovery of the first AIDS cases in the early 1980s, activist groups in San Francisco quickly responded to the disease's appearance by organizing grassroots educational groups for local social circles of MSM. "Stop AIDS" and similar programs reflected the first and urgent community response to the epidemic. The mobilization of community activist social groups was also a key feature in MSM community-level interventions such as the Popular Opinion Leader (POL) [1] and M-Powerment [2] approaches, both of which were successful in reducing risk behavioral levels among MSM in the U.S. and in other countries. These interventions engaged and trained popular persons in MSM communities to "broadcast" HIV prevention messages to their peers in community venues and at community events. Although not labeled as network interventions, these approaches relied on interaction between persons, social influence, and normative support, all of which are interpersonal in nature and have been extensively studied in social network research.

In the past decade, there has been wide research interest in studying HIV risk and prevention among MSM from network perspectives. The concept of networking underlies the very nature of sexual HIV transmission in that sexual interactions between individuals may be described using network theoretical constructs. In addition to sexual encounters that constitute components of "sexual networks," the social connections that exist between persons constitute "social networks." Network concepts have been utilized in epidemiological research related to a large variety of types and means of human interactions. Many of these recent applications have involved AIDS. The HIV vulnerability of many MSM remains high, particularly within MSM communities that are hidden or suppressed. Network methods can be used to: (1) reach and recruit MSM in the community [3]; (2) carry out behavioral and disease transmission epidemiological research; and (3) deliver interventions. In addition, network methodologies such as the network scale-up can be used to estimate the size of a hidden population. This approach was utilized by Ezoe et al. [4•], who estimated that 2.9 % of Japan's male population are MSM.

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Community-level interventions have been shown to reduce HIV transmission risk behaviors in a variety of populations including MSM. However, community-level intervention approaches often require advanced community infrastructures in which service providers such as nongovernmental organizations (NGOs) play major roles in delivering efficacious interventions to community members. To be successful, interventions must cover a high proportion of community members. These interventions often require the presence of a sufficient number of identifiable community venues in which MSM congregate and can be targeted with prevention messages and resources.

Network-level HIV prevention interventions can be undertaken under circumstances in which geographically-defined gay community venues are not present or an option. In addition, even where gay-identified venues are present, only a fraction of the MSM community may attend these venues while the rest of the community remains hidden and unlikely to be reached by conventional venue-based prevention programs. In contrast, network approaches rely on reaching community members through their connections with others. Thus, network models can "dig" deeply into a community and are thereby able to identify and recruit community members otherwise unlikely to be reached by conventional programs.

Apart from its benefits as a recruitment vehicle, the network concept is highly relevant to HIV prevention because the manner in which HIV and other STDs are transmitted in a community may be understood and mapped in relation to sexual and drug use network structures and characteristics. In addition, the interpersonal influence features of social networks lend themselves to applications to prevent further HIV transmission in the community. This is because members of networks often share similar life experiences, similar risk circumstances, shared norms and values, and—among sexual networks—shared linkages with sexual partners.

This paper provides a comprehensive review of the literature describing network approaches in HIV prevention among MSM. Its aim is to examine the utilization of network research methods within the field of HIV prevention among men who have sex with men. In particular, the article will summarize how networks: (a) constitute a microsocial environment with shared sexual behavioral norms, risk levels, and mutual social support (b) are utilized for behavioral interventions, and (c) impact HIV/STI transmission in the community and mediate HIV risk through sexual networking patterns.

Methods

Search, Selection, and Identified Network Types in the Studies for This Review

Publications considered for review in this article were identified through Pubmed and other scientific research publication search engines. The following key words or phrasings were used: "HIV risk," "HIV transmission," "prevention," or "intervention," with the cross terms of "men who have sex with men," "MSM," or "gay men," and with the cross terms of "social network," "sexual networks," or "respondent driven sample (RDS)." This search resulted in the identification of 78 pertinent articles that were included in the review. These studies were systematically reviewed and grouped first by network type (social or sexual) and then by the research approach that was employed. The results of each study were reviewed to identify both content and consistency of research findings. Studies identified for this review include intervention randomized controlled trials (RCTs), program evaluations that were not RCTs, community surveys, and other epidemiological studies. The studies represented both egocentric and sociocentric networks as well as both social and sexual networks. Research data in these studies were collected either from multiple network members or—more often and given cost and feasibility constraints—from single individuals who reported about their personal networks. Several HIV phylogenetic or phylodynamic studies analyzed clinical records and biological specimens.

Geographic and MSM Subgroup Representation of the Research

Of the 78 studies in this review, most studies (65 %, n=51) included data collected in the United States (New York/Brooklyn: n=6, San Francisco: n=5, Los Angeles: n=4, and Chicago: n=3), and a significant proportion of research was undertaken in China (17 %, n=13, including two studies each in Beijing, Shanghai, and Hong Kong). Also represented were studies with data collected in Russia (n=4, all studies in St. Petersburg); in United Kingdom (n=4); 2 studies each in Australia, Bulgaria, and the Netherlands; and single studies conducted in El Salvador, India, Brazil, Canada, France, Germany, and Hungary. Several of the studies had cross-country samples.

The review included studies of general MSM community populations (44 %, n=34); studies specifically of racial and ethnic minority MSM in the U.S. (22 %, n=17); and studies of specific MSM subgroups including transsexuals, bisexuals, sex workers, drug users, or the homeless (13 %, n=10). In addition, the analysis included 23 % (n=18) studies of general samples of MSM persons living with HIV (PLH), 15 % (n=12) studies of PLH MSM who are racial and ethnic minorities in the U.S., and one study among HIV-positive bisexual men. Finally, one study included in the review was carried out with networks of MSM HIV care physicians. (The sum of percentages exceeds 100 % because the reviewed studies often included multiple target groups.)

The reviewed studies employed a variety of strategies to enroll networks. As a common practice, initial network indexes (also often referred as "egos" or "seeds") were identified in

community venues providing access to MSM, such as gay bars or community-based organizations. In cases where network members ("alters") were also recruited, this was normally done by the ego (in egocentric networks) and by previously-recruited alters (in multiple-chain, RDS, and sociocentric networks).

The studies employed various criteria for defining network members whose participation was deemed appropriate. For example, MSM networks usually included other MSM, and PLH MSM networks usually included other PLH MSM. However, the social support networks of PLH MSM frequently included the ego's family members or friends regardless of their HIV status or sexual orientation. Sexual networks most often referred to the sets of individuals interconnected with one another by having had sexual encounters in a defined past period (i.e., past 3 months).

The research studies in this review were classified by their approaches and included risk reduction behavioral interventions; quantitative and qualitative interviews on behavioral risks and network structural issues among minority MSM; network-based HIV epidemiology, geospatial network research, network methodological research; research on affiliation networks; and risk network modeling research. Research focusing on networks of MSM have addressed risks associated with sexual networking strategies, HIV transmission, drug use, migration, being homeless, and having an STD. Network research among MSM who are HIV-positive have included studies of network characteristics, HIV transmission clustering (phylogenetic and phylodynamic analyses), provision of social support, and having co-infections.

Results

Social Networks Establish an Immediate Social Environment with Shared Behavioral Norms and Risk Behavioral Characteristics

There is both theoretical and empirical evidence that social networks exert strong social influence on the behavior of network members. Social influence occurs in the form of both external and internal dynamics. Persons with common attributes, interests, or activities tend to associate with one another. These commonalities may be a basis for how networks form, and also on how networks affect the views, norms, and behaviors of network members. For example, among homeless MSM youth, having social network members who regularly attend school and do not drink heavily predicts significantly less likelihood of engaging in high-risk sex [5]. When an opinion about a certain theme prevails among network members, it is likely that other network members will eventually share similar views. In the HIV/AIDS field, members of the same network often have in common not only similar views and attitudes about risk but also shared levels of risky sexual practices [6] or drug use [7].

Various network characteristics are associated with being HIV/STI-positive [8–10], getting tested for HIV [8, 11] (studies in China), and engaging in HIV risk behavior [7, 9, 12]. The latter finding has been corroborated in egocentric network studies in which data were collected from all network members [6, 13] and which found that persons with elevated risk levels tend to belong to the same networks. Low normative support for safer sex [6, 13–15] and lack of disapproval of risky sex [16] within networks were found to be associated with high-risk behaviors. Geospatial research in the New York city neighborhoods with high presence of MSM residents [17, 18] suggests that safer sex norms may be shared not only within egocentric networks but also within a neighborhood, and that the odds of higher risks are mediated by venue or network type (i.e., "party and play") and homophily (having predominantly other MSM in one's network) [17]. "Bridging" of infection transmission between neighborhoods exists but has been largely ignored in the field. Studying the role of bridging positions or "structural holes" has been suggested as an emerging public health and network research priority [19]. A study among HIV-positive MSM showed that HIV transmission may be either enabled or obstructed by network structure [20].

Close relationships with others in the networks of Black MSM have been associated with reduced stress over identity, racism and homophobia [21], with reduced general stress, and with greater status disclosure and care retention among those with HIV [22]. "House and ball" communities often function to assist Black MSM to find accepting environments and needed social supports [21, 23].

The phenomenon of risk clustering within networks can be utilized in both research and program delivery. Several studies in China that compared sampling approaches to recruit MSM in communities found that internally migrating MSM network samples were higher in their behavioral risk levels than venue-based samples [24], although MSM from a network sample more often had stable relationships [25]. Peer referral among HIV-positive Black MSM in the U.S. have been used to identify samples with very high HIV prevalence levels [26–28] including previously-undiagnosed persons [26, 27], although there are considerable challenges associated with this recruitment method [29]. Sociocentric network sampling approach that was used in the Russian/Hungarian study of MSM [30] established HIV prevalence of 9 %, a rate higher than reported from the venue-based community samples of MSM in these countries. The utilization of RDS method—another peer referral approach—has resulted in the recruitment of MSM of lower socioeconomic status than MSM recruited through either snowball or time-location sampling strategies [31].

Social Network Interventions Have Been Shown to Significantly Reduce Levels of HIV Risk Behavior

A review of social network interventions in the broad field of HIV prevention [32] found that network intervention research has primarily been focused on injection drug users [cf, 33–35]. However, sexual risk reduction network interventions have also been carried out with high-risk men [36] and women [37], female sex workers [38], and methamphetamine users [39]. Five HIV prevention interventions with social networks of MSM have been reported to date in the literature. Table 1 provides methodological details and key findings of these intervention studies.

The first two of these intervention studies were reported from Eastern Europe [40, 41]. The first study was a pilot evaluation of a social network HIV prevention program for MSM undertaken in Russia and Bulgaria [40]. A total of 14 egocentric networks were recruited by first observing in community venues to identify seeds with high potential for reaching other MSM in their networks; then recruiting the seeds; and, finally, enrolling the immediate network members of each seed. Sociometrically-identified network leaders were invited to attend a program of 5 weekly and one biweekly booster session that provided training in how to deliver tailored and personalized theory-based consultation risk reduction messages to other network members. Sessions were themed around trans-theoretical behavior change constructs such as HIV knowledge, condom attitudes, and safer sex peer norms, intentions, and self-efficacy [42, 43]. At the end of each session, leaders were assigned to communicate HIV prevention messages with other network members, emphasizing the topic covered during that session. The format and method of communication was not prescribed, and leaders were asked to use their regular, everyday style of communication. All participants completed assessments of risk behavior before and again 4 months post-intervention. Even though not an RCT, the intervention demonstrated the feasibility and high potential of network-level intervention to reduce risk behavior. Consistent condom use with main partners doubled from 22 to 45 % and, with casual partners, increased from 50 to 62 %.

A much larger trial of a similar intervention was carried out in Russia and Bulgaria using a full-scale RCT design [41]. Intervention content and format were similar to the first study. Egocentric MSM networks were recruited in the community, members of the networks were assessed for risk, network leaders were sociometrically identified, and network leaders attended intervention sessions that provided training in how to deliver risk reduction conversations to other network members. In contrast to the single booster session used in the first pilot intervention, this larger trial expanded the number of booster sessions to four to further empower network leaders to continue HIV prevention communication with network members over an extended period of time. The intervention produced very robust outcomes at the 3-month followup, with a decrease in proportion of participants engaged in unprotected intercourse from 72 to 48 %. At the 12-month followup point, the change was maintained among MSM in Bulgaria but not Russia. However, the study found stable, well-maintained reduction in the percentage of men in both countries who engaged in unprotected sex with multiple partners over the past 3 months, from 32 to 13 % at the 3-month followup to 16 % at the 12-month followup. Significant positive changes were also observed for secondary outcomes including AIDS risk knowledge, risk reduction norms and intentions, as well as frequency of social network leader-to-member communications about HIV.

A small-scale, test-of-concept network intervention RCT was carried out in Hong Kong, China [44••]. In the study, eight "peer educators" were recruited, randomized to intervention or control conditions, and then asked to recruit five to ten MSM friends, who in turn were also asked to recruit their own friends. Intervention condition peer educators received a theory-based program that provided knowledge about HIV infection, testing, and "window period" of latent infection; taught on self-efficacy and ways to lessen barriers to condom use and HIV testing; addressed issues related to condom use with regular partners; and discussed risk assessment and perceived severity of STDs. The peer educators were asked to deliver personalized intervention messages based on these themes to other network members during the course of their regular social interactions. Friends of peer educators were subsequently trained to become "second generation peer educators" and to deliver intervention to their own MSM friends. However, the researchers concluded that this strategy was ineffective due to low second-wave recruitment and limited motivation by first-wave network members to also be trained as peer educators. This pilot study found significant increases from 83 to 94 % in intentions to consistently use condoms among intervention participants as well as in voluntary HIV testing self-efficacy (81 to 97 %).

Two other recent studies were reported from China [45, 46••]. The first trial examined the effects of a venue-based popular opinion leader intervention. POLs—identified by others in gay community social venues as being among the most popular persons—were trained to distribute education materials and condoms, and also to promote HIV/STI testing [45]. A POL intervention to encourage safer sex was also implemented in "MSM peer networks," although this aspect of the intervention was minimally described. Rates of unprotected sex in the last three intercourse instances over the past 6 months among intervention participants decreased from 20 to 11 %, and rates of HIV/STI testing uptake increased from 9 to 22 % at the assessment point immediately after the 6-month period of intervention. There was no change among participants in the control group.

Table 1 Roster of network intervention studies among men who have sex with men included in the review

City and country	References	Design and sampling frame	n (seeds), N[a] (participants, total), and M[b] (mean network size)	Intervention	Findings
St. Petersburg, Russia and Sofia, Bulgaria	Amirkhanian et al., 2003 [40]	Pretest to 4-month posttest program evaluation. Each egocentric network included MSM friends of the seed, a community member observed to be popular with others. Network structural evaluations were used to empirically identify sociometric network leaders.	*n*=14, *N*=82, *M*=5.9	Each network's sociometric leader attended 6-session (5 main and 1 booster session) group intervention program. The objective was to train the leaders to effectively deliver risk-reduction advice and consultation to other network members to encourage them to reduce their sexual risk behavior levels by improving their AIDS knowledge, creating positive safer sex norms, attitudes, intentions, and self-efficacy through messages conveyed in regular daily communication.	Past 3-month consistent condom use during anal intercourse with main male partner increased from 22 % to 45 % and with casual male partners from 50 % to 62 %. Condom use at last intercourse increased from 44 % to 54 % with main, and from 69 % to 80 % with casual, male partners. In addition, there were significant increases in scores of AIDS knowledge as well as safer sex norms, attitudes, intentions, and self-efficacy.
St. Petersburg, Russia and Sofia, Bulgaria	Amirkhanian et al., 2005 [41]	Randomized controlled trial with assessment points at baseline, 3-month, and 12-month post-intervention followup. Each egocentric network included MSM friends of the seed, a community member observed to be popular with others. Network structural evaluations were used to empirically identify sociometric network leaders. All participants received brief AIDS risk-reduction one-on-one counseling before networks were randomized to either intervention or control condition.	*n*=52, *N*=276, *M*=5.3	All intervention condition network sociometric leaders attended groups with one another and received a 9-session (5 main and 4 booster session) group intervention program. The objective was to train the leaders to effectively deliver risk-reduction advice and consultation to other network members to encourage them to reduce their sexual risk behavior levels by improving their AIDS knowledge, creating positive safer sex norms, attitudes, intentions, and self-efficacy through messages conveyed in regular daily communication.	Past 3-month percentage of intervention condition participants engaging in unprotected intercourse decreased from 72 % to 48 % at 3-month followup and increased to 54 % at 12-month folloup (a country interaction effect was observed at the last followup, with intervention effect sustained in Bulgaria but not in Russia). Among intervention condition participants who had unprotected sex with multiple partners in the past 3 months, the percentage engaging in unprotected intercourse decreased from 32 % to 13 % at 3-month followup and 16 % at 12-month folloup (intervention effects remained strong in both Bulgaria and Russia). No risk reductions were observed among control condition participants at either followup point.
Hong Kong, China	Lau et al., 2013 [44••]	A pilot randomized controlled trial with assessment points at baseline and immediate post-intervention followup. Seeds were purposively recruited as peer educators from multiple sources based on potential of having good communication skills and large social networks. Prospective seeds were assessed for confidence that they could recruit at least 5 network members. Seeds were randomized into either an intervention (training) condition or control (printed material distribution) condition. The seeds then recruited members of their networks into the study. All first wave participants beyond the seeds were asked to recruit their own MSM network members; 6 out of 50 agreed to do so. No network structural evaluations were reported.	First wave: *n*=8, *N*=58, *M*=7.3; Second wave: *n*=6, *N*=25, *M*=4.2	All intervention condition seeds were trained in a workshop to become peer educators. The objective was to focus on 10 pre-identified themes such as AIDS knowledge, awareness about and self-efficacy in condom use, overcoming barriers to testing, skills of condom use with regular partners, and HIV susceptibility. Peer educators were asked to deliver risk-reduction advice and consultation to other network members to encourage them to reduce their sexual risk behavior levels using theme-based messages in regular daily communication. The peer education workshop was then offered to the first-wave network members so they could become educators to their own (second wave) MSM network members.	The intervention produced two significant outcomes. First, the intention to use condoms consistently during anal sex in the next 6 months significantly increased from 83 % to 94 % among intervention group participants and decreased from 76 % to 61 % among the control group participants. Second, the self-efficacy on taking up voluntary counseling and testing has increased from 81 % to 97 % among intervention group participants and decreased from 82 % to 73 % among the control group participants.

Table 1 (continued)

City and country	References	Design and sampling frame	n (seeds), N[a] (participants, total), and M[b] (mean network size)	Intervention	Findings
Mianyang and Yibin, Sichuan Province, China	Zhang et al., 2009 [45]	Non-randomized trial with the assessment points at baseline and 6-month post-intervention followup. Mianyang was assigned as the intervention city and Yibin as the control. Education materials and HIV counseling and testing were available in both cities.	n: n/a, *N*=400, M: n/a	40 participants in Mianyang received training in skills and AIDS knowledge to become popular opinion leaders (POLs). The trained POLs actively distributed education materials, advocated for safe sex, promoted condom use, and encouraged HIV testing in their peer networks.	AIDS knowledge and condom use self-efficacy significantly increased among intervention condition participants and did not change among controls. In the intervention city, the rate of inconsistent condom use in the last 3 instances of sexual intercourse decreased from 20 % to 11 % and the rate of HIV testing uptake increased from 9 % to 22 %. Little change was found among control condition participants.
Hefei, Wuhu, and Fuyang, Anhui Province, China	Zhang et al., 2010 [46••]	Pretest to 3-month posttest program evaluation. Recruitment of each network was initiated with a single MSM seed and continued as a peer referral chain. The networks included 3 to 5 waves of references. The seed was a community member respected by peers and recruited in a previous study. No network structural evaluations were reported.	*n*=12, *N*=218, *M*=18	Both seeds and their referral chain network members together attended a 4-session intervention group training. The objective was to train network members to encourage them to reduce sexual behavior risk levels by increasing their AIDS knowledge, evaluating behavioral risks, developing individual risk reduction plans, overcoming obstacles and barriers to practicing safe sex, and improving communication skills about sexual topics.	Past 2-month consistent condom use in the last 3 instances of anal intercourse with male partners increased from 50 % to 60 %. The overall rate of condom use in the last 3 instances increased from 55 % to 65 %; with casual male partners from 43 % to 52 % and with regular male partners from 49 % to 61 %. Condoms were not used at last intercourse with partners of either gender by 45 % at pretest and 31 % at posttest assessment points. HIV testing rates increased from 10 % to 52 %.

[a] The N's include both seeds and their network members;

[b] The M=N/n; when not originally reported, calculations were performed by the author

In a second pretest-posttest program evaluation study, the researchers recruited the seeds and five outward waves of MSM contacts who originated from these seeds [46••]. The recruitment strategy resembled RDS, in which recruitment was accomplished through the referrals of up to three persons by each already-enrolled participant. Members of each RDS network were trained in a session together using an intervention based on the AIDS Risk Reduction Model [47]. The rate of HIV testing uptake increased from 15 to 52 % at an assessment point 3 months after the intervention. The proportion of participants who reported consistent condom use increased from 50 to 60 %, and the mean rate of condom use increased from 55 to 65 % including an increase from 43 to 52 % during sex with casual partners, and 49 to 61 % with main partners.

Impact of Sexual Networks on HIV/STI Transmission in the Community

HIV Risk and Impact of Sexual Networks Important findings concerning HIV/STI transmission have been reported from MSM sexual network research. While overlap between social and sexual networks of MSM is often high [48, 49], each type of network plays a unique role important for understanding and preventing HIV transmission [50]. Both individual risk behavior and sexual network structural characteristics play important roles in understanding HIV transmission among MSM. In contrast to the common perception that more frequent risky practices are responsible for the greater HIV incidence in MSM community populations, recent research suggests that network attributes—structure, density, homophily, and a person's centrality within a sexual network—are even more important risk factors [51]. High risk for HIV may be partly explained by sexual network dynamics. For example, high levels of sexual partnership concurrency and concurrent unprotected anal intercourse (UAI)—commonly reported patterns [52]—appear to be substantially responsible for the high rates of HIV transmission among MSM.

Several network studies add to our understanding of why HIV prevalence and incidence in the U.S. are disproportionally high among Black MSM. African American MSM report less frequent unprotected sex than other groups [53] but are the most racially homophilous group of MSM with respect to their sexual partnerships [49, 53, 54]. Since HIV prevalence is so high among Black MSM, this homophily in sexual networks makes it much more likely that Black MSM will have infected persons as their sexual partners. However, some researchers argue that homophily is not a single factor of quick HIV transmission among Black MSM. For example, substance use prior to sexual intercourse [55], engaging in unprotected intercourse with partners of both genders [55], and high level of mixing between behaviorally low- and high-risk individuals [56] are also important factors that facilitate HIV transmission within sexual networks. A study by Hurt et al. [57•] mapped a very large sexual network of Black MSM. The network had an HIV prevalence rate of at least 29 %, and 47 % of members did not know their serostatus. Thus, risk for contracting HIV increases dramatically from the moment one enters the sexual network. Sexual network research also sheds light on reasons for elevated rates of HIV transmission among younger gay men. Four studies suggest that choosing older partners increases one's likelihood of HIV exposure [50, 58–60]. A prospective cohort study showed that sexual partner selection based on concordance of HIV status or seroadaptation among HIV-positive MSM is very common, was a strategy adopted early by MSM, and is believed to have reduced HIV transmission by 98 % [61]. A study in China showed shifts in the use of venues for establishing sexual partnerships [62], with increases in sexual network density and degree centrality. This suggests that connectivity between MSM is increasing through sexual networks, thereby increasing the probability of HIV transmission during unprotected sex.

Although epidemiological patterns of HIV transmission in communities—including MSM—are well-established, HIV is not evenly distributed. Neighborhoods or other geographic units separate from one another often differ greatly with respect to socioeconomic status of their residents and have very different HIV prevalence [63]. Network structural characteristics may determine the outcomes of risk behavior (whether or not HIV is contracted) more strongly than individuals' risk practices [20]. Interestingly, a New York City study found that neighborhood-level gay "presence" was associated with higher rates of consistent condom use [18]. However, another New York study found that little evidence of neighborhood effect on risk with the exception of "Party and Play," a high-risk partnering strategy that combines drug use and sex [17]. A study in South Florida has found that living in a "gay neighborhood" was also associated with both protective factors (lower cocaine use and lower substance dependence) and risk factors (higher methamphetamine use, higher levels of UAI, and lower prosocial engagement) [64]. Collectively, these studies suggest that behavioral norms, either pro- or counterproductive to health, have a broad influence at the level of neighborhood. Within a neighborhood, network composition and type were found to mediate the likelihood of engaging in risk practices [17, 65].

A number of studies have raised an important public health concern over "bridging" effects in HIV transmission, whether this occurs across community boundaries or populations. For example, a study by Youm et al. [19, 66] found that, out of Chicago's 77 geographic community areas, there are eight hidden "bridging" communities—most located in the city's periphery—with low HIV prevalence, elevated levels of sexual ties, and high in- and outflows of low-income persons, an important finding that would have been missed without sexual

network research methodology. Two other studies—one carried out among MSM contacts of HIV-positive MSM in South Wales, U.K. [67] and another among truck drivers in the U.S., some of whom also engage in sex with other men [68]—show that sexual networks with high rates of unprotected intercourse often span across geographic areas.

For example, a study of HIV surveillance records in North Carolina revealed that behaviorally bisexual men had an average of over ten partners a year prior to their diagnosis and these partners were often also bisexual. Network analysis among HIV-positive students identified that behaviorally bisexual men occupied a central position [69]. Behaviorally bisexual men were found to be at greater behavioral HIV risk than exclusively heterosexual men but also report lower levels of risk behavior practices than MSM [70, 71]. Finally, behaviorally bisexual men were found to more often engage in commercial sex, both as traders and clients, and had more partners who were drug users [71]. A study carried out in Baltimore [72] found that crack-using African American MSM had increased odds of bisexual identity as compared to non-crack using MSM; had greater numbers of HIV-positive partners, commercial exchange partners, and partners for both sex and drugs; and had lower levels of condom use. HIV transmission across populations may also occur in high-risk sex "environmental" networks such as group sex events in which MSM, bisexuals, and heterosexual men and women of discordant HIV/STI status participate with low condom use [73].

HIV and Hepatitis C Virus (HCV) Transmission Networks in Communities of HIV-Positive MSM MSM sexual networks are also pathways for the transmission of HIV and other infections. HIV phylogenetic clusters indicate that individuals are linked together through viral phylogeny with other members of the same cluster. A number of recent phylogenetic analysis studies carried out worldwide have found that various but significant proportions of HIV [74–80] and HCV [81, 82] infections form clusters. Uniform cutoffs for classifying clusters by size have not been used; most studies reported proportions of unlinked infections (no clustering), small-to-medium size clusters (2–10 infections), and medium-to-large size clusters (3–36 infections). Brenner et al. [80] reported from data collected in Canada that large clusters of primary HIV type 1 infection disproportionally increased from 25 % in 2005 to 39 % in 2009 suggesting that UAI with members of large clusters of sexually-interconnected MSM increases the risk of contracting infection. A London, U.K. study analyzed "dated phylogenies" of HIV clusters and found that two-thirds of the transmissions within clusters took place between 1995 and 2000, and one-quarter of them were estimated to have occurred within six months after infection [78]. A phylogenetic study in the southern U.S. (of which 39 % of sample members were MSM) found that MSM and heterosexuals formed discrete clusters, and that substantial mixing between these two groups was observed [79]. In this study, persons were more likely to be in clusters if they were age 30 or younger, had acute infection, were local residents, and contracted drug resistant HIV, but were not Latino. Clustering factors in an El Salvador study [75] were recent infection, sex with stable male partners, and sex with over two partners in the past year. A Hong Kong study [77] of recently HIV-infected MSM employed both phylogenetic and social network analyses. The study found three large clusters, one of which was "internet-centered" (characterized by younger age and multiple partners) and two of which were associated with attending saunas for sexual partnerships. The viral strains in sauna users were more disperse compared with the "closely-knit" strains of internet-centered cluster.

Social Support and Affiliation Networks

Social support, provided primarily by members of one's social network, has shown positive impact on many health outcomes. Network-level social support is associated with network composition, homogeneity, and size. For example, Liu et al. [48] found, in a Chinese study, that tangible and emotional support from MSM non-sexual partner friends is greater than support from one's sexual partners. The important role of family members in support networks has been well-documented, for both HIV-positive [83] and HIV-negative MSM [12]. Having more family members within the network was associated with lower levels HIV risk practices in samples of Black MSM [12]. The study carried out in the U.S. Midwest found that the more family members were perceived as supportive by HIV-positive MSM, the less likely they intended to engage in HIV transmission risk behavior and family support played greater influence on reducing behavioral risk than support from one's friends [84].

Living with HIV poses additional life stress including social isolation, stigma, discrimination, and fear of potential consequences of serostatus disclosure. However, research has shown that PLH who have high levels of social support deal far better with life stressors associated with being HIV-positive than those who lack support [85, 86].

An association between network support and medication adherence among MSM has been reported [87]. However, Woodward et al. [88] found that the impact of social support on medication adherence among MSM who are in HIV care is indirect and is mediated by lower levels of depression and anxiety. Greater perceived social support among MSM in Mumbai, India was also associated with lower rates of major depression and anxiety, as well as with lower risk of suicidality [89]. In a sample of bisexual Latino and Black MSM in the U.S., the major predictor of successful retention in care was serostatus disclosure to more network members [22]. Earlier, Wohl et al. [90] found much lower levels of HIV

serostatus disclosure by Black and Latino HIV-positive MSM than by Black and Latina women. Furthermore, Garcia et al. [91] found that disclosure by Latino MSM of their sexual orientation was predicted in part by their satisfaction with social support, and that persons who disclosed their sexual orientation were also more likely to disclose their positive HIV status. A study of HIV-positive Black MSM [92] found that the network members to whom one's sexual orientation was most likely to be disclosed were other HIV-positive persons, those providing emotional support, those who socialized with the participant, and those who were not female sexual partners. In addition, HIV-positive serostatus was more likely to be disclosed to older persons, other HIV-positive persons, those providing emotional and financial support, and those who were not male sexual partners.

In addition to the informal support that MSM receive from network members, their affiliations with broader group-level units—such as health care providers, community organizations, socializing venues, or networking websites—are also important both for understanding HIV transmission patterns [77, 93] and from HIV care perspectives [94–96]. These affiliation groups may also be considered in network studies as actors and, together with individual network members, constitute two-mode data sets. With respect to HIV transmission, Oster et al. [93] found a cluster of three venues in Jackson, Mississippi in which a majority of HIV-positive Black MSM had met partners from throughout the state during the 12 months before diagnosis. As reported earlier, an HIV phylogenetic analysis among HIV-positive MSM in Hong Kong also found distinct HIV infection clusters that were based on either internet or sauna [77]. Over the past decade, internet use to find sexual partners has increased. However, recent studies indicate that risk levels of internet-based partnerships are not significantly different than those relationships established elsewhere [97]. High- and low-risk MSM in New York City who met partners online did not differ demographically from one another. However, high-risk behavior was predicted by HIV optimism-skepticism and sexual sensation seeking [98]. Affiliation with certain venues may substantially increase the density of sexual networks and elevate the risk of contracting HIV infection even among members with modest behavior risk levels.

In contrast to venues that facilitate risk, affiliations with other types of venues may have a positive effect. For example, a qualitative study found that MSM relied primarily on their care providers—rather than individual network members—for support in accessing and maintaining HIV care [95]. Another study among Black MSM in Chicago showed that, despite their affiliations with HIV health centers, these centers rarely provided appropriate HIV prevention services for uninfected men, potentially missed opportunities to prevent future infections among HIV-negative but high-risk men [94].

Conclusion

A number of important findings have emerged from social and sexual network research among MSM. Social networks constitute micro-environments in which persons interact, share information, provide and receive social support, and influence one another thus forming network peer norms, attitudes, and behaviors. Belonging to a network may be a stronger risk behavior predictor than individual-level risk characteristics alone. A similar effect was reported with respect to sexual behavior, suggesting that frequency of unprotected intercourse does not solely explain risk exposure, but having unprotected intercourse within certain high-risk sexual networks exposes one to a very high risk.

Research has also demonstrated that network sampling methods in reaching MSM may be especially useful, particularly in settings where community venues are nonexistent or do not represent the community. Therefore, network sampling methods can be used in MSM communities for reaching hidden and hard-to-reach persons along with snowball and RDS, and also can establish and measure social ties between individuals in the sample for assessing social influence, structural characteristics, as well as sources and types of social support provided by network members. Sexual network samples allow researchers to establish patterns of HIV/STI transmission and identify network characteristics associated with risk exposure. HIV phylogenetic studies have established that large proportions of infections belong to close-knit clusters of HIV transmission which often spread beyond a single geographic area.

Finally, the review demonstrated that social networks can be successfully utilized as vehicles for efficiently delivering HIV prevention interventions to MSM community members. Although only a few social network-level interventions have been reported to date and were carried out in Eastern Europe and China, they show high potential for reducing HIV risk in MSM communities. Expansion of network intervention research among MSM is needed, particularly in areas where coverage by existing prevention programs is inadequate and where most vulnerable population members cannot be reached by conventional prevention programs. With respect to sexual network interventions, among possible approaches suggested by Wohlfeiler [99] are altering network structures, fragmenting networks to pull low- and high-risk persons apart, and focusing on institutions where sexual mixing occurs.

Established network methodology may be successfully applied to emerging new AIDS prevention approaches such as pre-exposure prophylaxis (PrEP), test-and-treat, and treatment-as-prevention approaches because all of these require high levels of program coverage. Future research should

examine how network interventions can promote and increase HIV testing among HIV-negative MSM, as well as HIV care entry, adherence, and social support among HIV-positive MSM.

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Compliance with Ethics Guidelines

Conflict of Interest Yuri A. Amirkhanian declares that he has no conflict of interest.

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- •• Of major importance

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