



# The Role of Networks in Racial Disparities in HIV Incidence Among Men Who Have Sex with Men in the United States

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## Abstract

Network factors have been proposed as potential drivers of racial disparities in HIV among Black and Latino men who have sex with men (MSM). This review aimed to synthesize the extant literature on networks and racial disparities in HIV among MSM and identify potential directions for future research. We searched databases for peer-reviewed articles published between January 1, 2008 and July 1, 2018. Articles were included if the sample was comprised primarily of racial/ethnic minority MSM and measured one or more network characteristics. ( $n = 25$ ). HIV prevalence in networks, social support, and structural barriers were linked to disparities in HIV for Black MSM. Future research should focus on intervention development around social support and other strategies for risk reduction within networks. Given the contribution of structural factors to racial/ethnic HIV disparities, network-level interventions should be paired with policies that improve access to housing, jobs, and education for MSM.

**Keywords** Racial disparities · Networks · Systematic review · HIV/AIDS · Men who have sex with men

## Resumen

Los factores de redes han sido propuestos como posibles elementos contribuyentes a las disparidades raciales en el VIH entre hombres Afro-Americanos y Latinos que tienen sexo con hombres (HSH). Esta revisión sintetiza la literatura existente sobre redes y disparidades raciales en el VIH entre HSH e identifica posibles direcciones para investigaciones en el futuro. Revisamos estudios publicados entre el 1 de enero del 2008 y el 1 de julio, 2018. Los estudios se incluyeron si la muestra estuvo compuesta principalmente por HSH de minorías raciales/étnicas y si midieron una o más características de la red ( $n = 25$ ). La prevalencia del VIH en redes, el apoyo social, y las barreras estructurales estaban vinculadas a los disparidades en el VIH entre Afro-Americanos y Latinos HSH. Investigaciones en el futuro deberían centrarse en el desarrollo de intervenciones relacionadas con el apoyo social y otras estrategias para la reducción de riesgo dentro de redes. Dada la importancia de factores estructurales, las intervenciones de red deben estar emparejadas con políticas que mejoren el acceso a la vivienda, el empleo, y la educación para los HSH de minorías raciales/étnicas.

Men who have sex with men (MSM) continue to bear the largest burden of the HIV epidemic. In 2017 MSM in the United States (US) accounted for 82% of incident HIV cases among men [1]. Black MSM (BMSM) and Latino MSM experience disproportionately high rates of HIV, making up 37% and 29% of incident cases among MSM, respectively [1]. The disparity is even greater for young BMSM, ages

13–24, who made up 51% of the new HIV infections among young MSM in 2017 [1].

HIV prevention efforts have largely focused on reducing risk behaviors in populations affected by the disease. Research has shown, however, that these behavioral factors do not adequately explain racial disparities in HIV infection. A seminal paper from Millett et al. [2] found that BMSM report lower rates of substance abuse and fewer sexual partners than White MSM, and report similar rates of condomless anal intercourse (CAI), commercial sex work, sex with a partner who is known to be HIV positive, and lifetime HIV testing. A meta-analysis of HIV risk factors in MSM [3] found that BMSM were less likely to have a history of

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substance abuse and more likely to use condoms. Despite these risk-reducing behaviors, BMSM were found to have higher rates of HIV and were less likely to have initiated medical treatment. Importantly, this study found BMSM experienced structural barriers, including poverty, incarceration and unemployment, at twice the rate of White MSM. These findings suggest that behavioral factors are not a primary contributor to the racial disparities in HIV incidence in MSM, and that higher-level distal factors (e.g. network factors or structural factors) likely play a more prominent role [4].

One legacy of the Millett et al. [2] paper is the implication of sexual networks as a possible driver of racial disparities in HIV. This suggestion sparked a wave of inquiry into how the dynamics of social and sexual networks relate to HIV transmission risk [5–8]. It has been hypothesized that racial disparities in HIV are perpetuated and exacerbated by increased prevalence of HIV within Black communities and high racial homophily (i.e., the degree to which members of a network have the same racial identity) in the sexual networks of BMSM [9]. Social support within networks has also been identified as an influential factor in determining sexual risk behavior, viral load suppression, and HIV testing [10–12]. Recently, researchers have proposed network viral load, which refers to the total HIV viral activity within a connected network, as a metric of HIV risk [13].

The persistent racial disparities, particularly between BMSM and non-Hispanic White MSM, in HIV incidence represents an urgent public health issue. BMSM experience simultaneous marginalization related to racial identity and sexual identity and are disproportionately burdened by a highly stigmatized disease. Network factors could play an important role in understanding how racial disparities in HIV have developed and persisted. The present review aims to (1) collect and summarize the existing body of literature on networks and HIV risk and disparities, (2) place the findings on network factors in the context of research on individual and structural factors, (3) explore implications for intervention and policy development, and (4) propose directions for future research.

## Methods

### Search Strategy

In collaboration with an academic librarian and an established HIV researcher, we collected scientific literature relevant to network factors in HIV among MSM from four databases representing the most comprehensive collections of behavioral HIV research: Pubmed, Scopus, PsycINFO, and Sociological Abstracts. Search logic was constructed by combining terms related to networks, social support, HIV

and other STIs, sexual risk behavior, racial disparities, and MSM (Fig. 1). The search was limited to peer-reviewed articles published between January 1, 2008 and July 1, 2018, representing all literature published since the release of the seminal review from Millett et al. in 2007 that identified network factors as possible drivers of racial disparities in HIV.

### Inclusion/Exclusion Criteria

We included articles if they described an empiric study that: (1) quantitatively measured either the structure (i.e., size, density, concurrency) or function (i.e., social support) of a social, sexual, or drug network, (2) measured one or more relevant HIV outcomes (i.e., HIV prevalence, seroconversion, sexual risk behavior), (3) sampled primarily racial/ethnic minority men, with more than 50% of the study population being racial/ethnic minorities, (4) sampled primarily MSM, with more than 50% of the study population being MSM, (5) took place in the US, (6) was published in a peer-reviewed journal, and (7) was published in English or Spanish. The first author screened the titles and abstracts of all articles identified from the search query using the inclusion and exclusion criteria and reviewed the full texts of the remaining articles in detail. Those marked for exclusion were annotated with specific reasons for exclusion. Any article that was not clearly a candidate for inclusion or exclusion was discussed with a second reviewer, and consensus was reached regarding inclusion/exclusion.

### Data Extraction

Data were extracted from the reviewed articles and compiled into a table of evidence. For each included article, we extracted the goal of the study, the data source (site of recruitment for primary data, name of original study for secondary data), the setting, the sample size, demographic characteristics of the sample, type of network measured, HIV outcome measures, and key findings.

## Results

A total of 1184 articles were found over the four databases queried. After removing duplicates, 656 unique articles remained for review. Of these, 581 were excluded in the title and abstract screening phase. An additional 50 articles were excluded in the full text screening phase: 22 studies were excluded because they did not include a network measure, 18 because they did not measure a relevant outcome, nine because they were not empiric papers, and one because it was not peer reviewed. The remaining 25 articles met criteria and were included in this review (Fig. 2).

**Fig. 1** Search logic used for Pubmed query, as an example

**Pubmed Search:**

("racial disparity" OR "racial disparities" OR health status disparities OR healthcare disparities OR African americans OR latinos OR minorities OR ethnic OR ethnicity OR black OR "racial inequity" OR minority) AND

(hiv infections OR "hiv transmission" OR acquired immunodeficiency syndrome OR "hiv seropositivity" OR sexually transmitted diseases OR STI OR gonorrhea OR syphilis OR chlamydia OR HPV OR "sexual risk behavior" OR "condomless sex" OR "condomless anal intercourse" OR "unprotected sex" OR "sex drug use" OR "unprotected intercourse") AND

(social support[mesh] OR social environment[mesh] OR community networks[mesh] OR social distance[mesh] OR "social networks" OR "sexual networks" OR sociosexual OR "support networks" OR homophily OR kinship OR kin OR couple OR dyad OR "respondent driven sampling" OR RDS OR "network analysis") AND

(male homosexuality OR gay OR lgbt OR "men who have sex with men" OR homosexuality OR homosexual OR sexual and gender minorities OR queer OR bisexual OR transgender OR msm[tiab])

AND

("2008/01/01"[PDat] : "2018/07/01"[PDat]) AND

(English[lang] OR Spanish[lang])

**Results: 378**

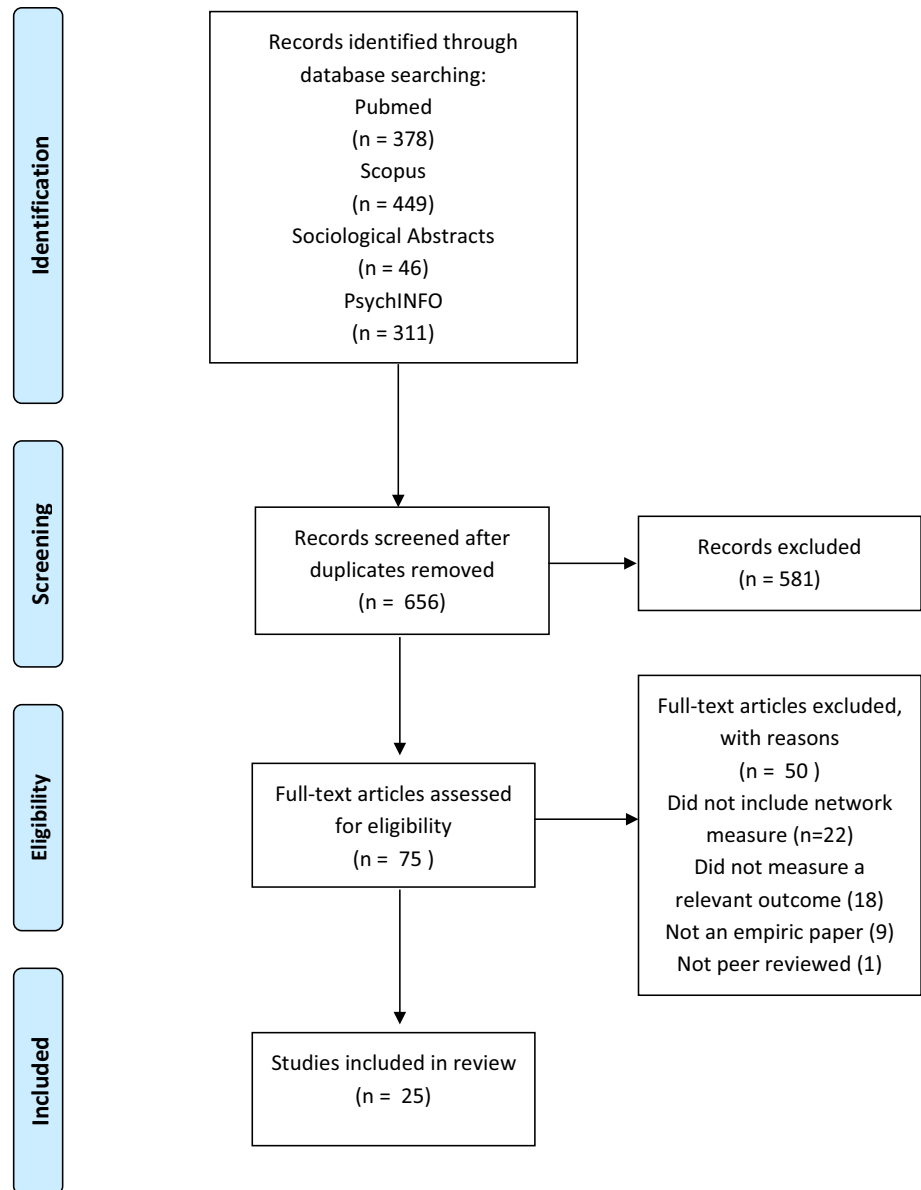
A summary of the data extracted for this review can be found in Table 1. Three of the included studies used a prospective cohort design, while the remaining studies used a cross-sectional design ( $n = 22$ ). All but one of the included studies ( $n = 24$ ) sampled from large and medium metro areas, as defined by the 2013 NCHS urban–rural classification scheme [14]. One study sampled 13 distinct communities and included several small metro areas and neighborhoods in large central cities [15]. Seven studies focused on young MSM, and the remaining studies included adult or older MSM ( $n = 18$ ). Sample sizes in the studies ranged from 121 to 10,295. Twelve studies enrolled only BMSM and Black transwomen. Nine studies measured social networks only, six measured sexual networks only, and ten studies measured both sexual and social networks. Of the studies reviewed, 22 measured egocentric networks (i.e. information is collected only from the participant) and three measured sociometric networks (i.e. information is obtained both from participants and from their network members). HIV outcomes measured included sexual risk behaviors, HIV prevalence, and seroconversion during study period.

## Structural Network Determinants

### Size and Density

The size and density of both social and sexual networks are possible predictors of HIV risk. Three studies found that the size of one's social network had an effect on sexual risk behavior, although the effect was different for BMSM than for Latino MSM. Larger social networks were associated with increased CAI in BMSM, while smaller social networks were associated with increased CAI in Latino MSM [16–18]. This difference by race was seen both in older MSM and young MSM (YMSM) and was consistent across studies in various US cities. In one study it was found that greater density amongst members of a social network was associated with lower rates of serodiscordant condomless intercourse (SDCI) with a non-primary partner, an effect that did not differ by race/ethnicity [19]. Another study found no connection between social network density and sexual risk behavior [20].

**Fig. 2** PRISMA flow diagram for systematic review. From Ref. Moher et al. [53]



The studies that focused on size and density of sexual networks were not conclusive. One large multi-city study of BMSM found that larger sexual networks had a bivariate association with higher rates of CAI [21], however a separate analysis of the same dataset that used SDCI as an outcome rather than any CAI found no association between sexual network size or density and SDCI in multivariate models [22]. Similarly, for YMSM in Chicago, no association was found between size or density of sexual networks and CAI [23]. Structural characteristics of social and sexual networks are inconsistent predictors of sexual risk behavior. The structure of social networks is more salient to behavior than the structure of sexual networks,

and network factors manifest differently across racial/ethnic groups.

## Functional Network Determinants

### Social Support

The role of support networks and social support was investigated in seven of the reviewed studies. Studies varied in how they measured social support, although most either measured general social support, or measured specific subdomains of social support (i.e. emotional, instrumental, informational, appraisal) [24]. Two studies included measures of “HIV-related” social support [15, 20]. Most studies

**Table 1** Summary of studies on networks and HIV risk and disparities for MSM in the U.S

Identifier	Data source	Setting	Sample composition	N	Network definition	Outcome measures	Key findings
Arnold et al. [20]	Recruited from HBC events, gay venues, and gay pride events	San Francisco	All BMSM and Black Transwomen	274	Social network	CAI	Social support for safer sex was found to be associated with lower rates of CAI. Additionally, homophily on sexual identity was associated with lower rates of CAI
Birkett et al. [23]	Recruited from a parent study of YMSM	Chicago	54% BMSM, 22% LMSM, 13% WMSM, 10% Other* MSM	175	Sexual network	CAI	Bivariate association found between social/sexual network multiplexity and CAI
Carlos et al. [16]	Brothers y Hermanos, RDS	Los Angeles, New York, and Philadelphia	50% BMSM, 50% LMSM	1648	Social network	CAI	Greater MSM network size was related to higher rates of CAI among casual partners for Black MSM, while smaller network size was related to CAI for Latino MSM
Choi et al. [19]	Seeds were recruited from MSM venues and events	Los Angeles CA	34% BMSM, 33% LMSM, 33% Other* MSM	1196	Social network	SDCAI with a non-primary partner	Greater density amongst alters was associated with lower rates of SDCAI. Egos with closer ties to their alters were more likely to have SDCAI. Peer norms attenuated this effect in "medium" and "high" closeness ties, but did not effect "low" closeness ties
Flores et al. [15]	Community intervention trial for youth	13 cities in the US	28% BMSM, 37% LMSM, 22% WMSM, 12% Other* MSM	10,295	Social network	CAI	MSM/W were less likely to have high social support than MSM. MSM/W were less likely to have CAI than MSM
Fujimoto et al. [33]	YMAP	Houston and Chicago	All BMSM	365	Social/sexual network	HIV prevalence	Larger sexual networks were associated with greater odds of being HIV positive

Table 1 (continued)

Identifier	Data source	Setting	Sample composition	N	Network definition	Outcome measures	Key findings
Gorbach et al. [38]	NIDA's Sexual Acquisition and Transmission of HIV—Cooperative Agreement Program	Los Angeles	53% BMSM, 22% LMSM, 19% WMSM, 6% Other*	1125	Sexual network	CAI	Men with more women in their sexual networks reported less CAI, and men with more people living with HIV in their sexual network reported more CAI. Being home- less in the past year was associated with greater odds of CAI
Grey et al. [37]	Men's Atlanta Networks (MAN) Project	Atlanta	61% BMSM, 39% WMSM	142	Sexual network	CAI, HIV prevalence	Black men have higher odds of having an HIV positive partner (increased HIV prevalence in sexual network) and higher odds of having an unknown positive partner (higher undiagnosed seropositivity in sexual network)
Hermanstynne et al. [27]	BROTHERS (HPTN 061)	6 US cities	All BMSM	1000	Social network	Seroconversion	Emotional support, medical support, and social participation support were all protective against seroconversion
Hernandez-Romieu et al. [31]	Men's Atlanta Networks (MAN) Project	Atlanta	60% BMSM, 40% WMSM	195	Sexual network	Network HIV prevalence	BMSM were more likely to have HIV positive partners in their networks than WMSM. Young HIV negative BMSM have greater prevalence of HIV in their networks than older HIV negative BMSM. Unemployment was related to higher HIV prevalence within networks

**Table 1** (continued)

Identifier	Data source	Setting	Sample composition	N	Network definition	Outcome measures	Key findings
Hickson et al. [36]	BROTHERS Study (HPTN 061)	6 US cities	All BMSM and Black Transwomen	1306	Sexual network	SDCAI	Racial homophily in sexual networks was higher for participants living with HIV. SDCAI was more common with commercial partners than with primary or steady non-primary, but was not significantly different from casual partners. Greater frequency of communication was associated with lower rates of SDCAI
Jeffries et al. [39]	Brothers y Hermanos	New York and Philadelphia	All BMSM	1140	Social network	CAI	Homophobia was related to increased CAI in HIV negative men and SDCAI in men living with HIV. In fully adjusted models, social support and other network variables were insignificant predictors of CAI, while homophobia remained significant
Joseph et al. [17]	Three intervention trials	Philadelphia, Chicago, Los Angeles	All BMSM	584	Social network	CAI	Larger social network was associated with slightly increased rates of CAI. Social support was found to be related to decreased CAI. Homonegativity was also found to be protective against CAI

Table 1 (continued)

Identifier	Data source	Setting	Sample composition	N	Network definition	Outcome measures	Key findings
Kapadia et al. [18]	Baseline visit from a longer prospective cohort study	New York City	19% BMSM, 45% LMSM, 36% WMSM	501	Social network	CAI	For Latino YMSM, greater social network size reduced CAI. Across racial groups, having a sex partner in ones social network was related to higher odds of CAI, as did being in a relationship. There was a trend towards gay community affiliation being related to increased CAI in White and Latino YMSM
Lauby et al. [29]	Brothers y Hermanos	Los Angeles, New York, and Philadelphia	48% BMSM, 52% LMSM	1286	Social network	Unrecognized HIV infection, CAI with non-main partner	Social support was associated with lower rates of unrecognized HIV infection. Social support was also associated with lower rates of CAI with non-main partner and higher HIV testing rates. Tests for mediation revealed that these relationships mediated the effect of social support on unrecognized infection
Mimiaga et al. [28]	RDS seeds recruited from HIV and social service organizations	Boston	All BMSM	197	Social/sexual network	CAI	Social isolation, homelessness, and using poppers at least weekly were all associated in multivariate models with CAI with a male partner



**Table 1** (continued)

Identifier	Data source	Setting	Sample composition	N	Network definition	Outcome measures	Key findings
Morgan et al. [34]	uConnect	Chicago	All BMSM	343	Social/sexual network	Seroconversion	Participants with more recently infected network members were more likely to seroconvert during the study period, as were participants with more total network members. Having more HIV negative network members and more PrEP using network members was protective against seroconversion
Raymond et al. [54]	NHBS, Black Men Testing (SF Dept. of Public Health), Trans-women Empowered to Advance Community Health (SD Dept. of Public Health), HIV surveillance data, US census data	San Francisco, CA	32% BMSM, 5% Black transwomen, 11% Latino transwomen, 7% White transwomen, 9% Other* trans-women, 36% WMSM	523	Sexual network	SDCAI	BMSM reported higher number of SD partners, and a greater number of SDCAI acts than WMSM or transwomen. HIV prevalence by zip code was related to more SDCAI for transwomen, less SDCAI for WMSM, and was unrelated to sexual behavior for BMSM
Schneider et al. [35]	RDS seeds recruited from health clinics, LGBTQ center, substance use treatment groups, and other community based organizations	Chicago	All BMSM	204	Social/sexual network	CAI	Men reporting an "enabler" (someone who does not disapprove of a risk behavior) in their social networks were more likely to engage in CAI, but not men reporting an "enabler" in their sexual networks

Table 1 (continued)

Identifier	Data source	Setting	Sample composition	N	Network definition	Outcome measures	Key findings
Schneider et al. [30]	uConnect	Chicago	All BMSM	618	Social/sexual network	CAI	Sexual network stability was associated with decreased odds of engaging in CAI (as well as group sex and sex drug use). Confidant network stability predicted decreased sex drug use. Criminal justice involvement was associated with decreased stability in both sex and confidant networks
Scott et al. [21]	HPTN 061 (Brothers)	6 US cities	All BMSM and Black transwomen	1553	Social/sexual network	STI incidence, CAI	Larger sexual networks were associated with higher rates of CAI, higher rates of rectal chlamydia and gonorrhea, but not with HIV status or other STI measures. Racism, stigma, and homophobia were also associated with larger sexual networks. In multivariate models having more partners, using poppers, and being HIV positive were associated with higher rates of STIs
Shah et al. [41]	RDS seeds recruited from health clinics, LGBTQ center, substance use treatment groups, and other community based organizations	Chicago	94% Black, 2% White, 2% Other*, 4% transwomen†	620	Social/sexual network	HIV prevalence	Moderate and high levels of bridging were associated with greater rates of HIV infection, when controlling for sexual risk behavior and age. Bridging was at least moderately associated with CAI in bivariate models, but was not in the multivariate model

**Table 1** (continued)

Identifier	Data source	Setting	Sample composition	N	Network definition	Outcome measures	Key findings
Tieu et al. [22]	HPTN 061 (Brothers)	6 US cities	All BMSM and Black transwomen	1349	Social/sexual network	SDCAI	In multivariate models, no network characteristics were associated with SDCAI. For HIV negative men, the odds of SDCAI were higher for those with less than a college degree and those with an anonymous or exchange sex partner
Tieu et al. [32]	NYC M2M	NYC	29% BMSM, 34% LMSM, 38% WMSM	1267	Social/sexual network	HIV prevalence	Higher racial homophily was seen among Black participants. Black and Latino men had higher HIV prevalence in their sexual network than White men
Tucker et al. [26]	Recruited from homeless service sites and street sites	Los Angeles	33% BMSM, 21% LMSM, 17% WMSM, 29% Other* MSM	121	Social/sexual network	CAI	CAI was higher among participants reporting more family members in their social network. CAI was lower among those with more education, more positive condom beliefs, and ties to individuals attending school. No relationship was found between tangible social support and CAI

SDCAI serodiscordant CAI, LMSM Latino MSM, WMSM White MSM

\*Other refers to other racial/ethnic minority groups

†Racial/ethnic demographics for transwomen were not reported separately

measured perceived social support (i.e. a personal belief that social support is available and adequate) [25], although one study measured enacted social support [26]. The majority of the studies measured network-wide social support, but three studies used an actor-specific measure of social support where support from individual network members was assessed [20, 26, 27]. General perceived social support within a network was associated with lower rates of CAI [17, 28, 29] as was a measure of actor-specific HIV-related social support [20]. Lauby et al. [29] found that the relationship between general perceived social support within a network and HIV infection in their study was partially explained by changes in CAI. The direct impact of perceived social support on HIV incidence was explored in one notable prospective cohort study of BMSM in six major US cities, which found that having more people in one's emotional support network, medical support network, and social participation support network were all protective against seroconversion during the study period [27].

Two studies found no connection between social support and sexual risk behavior. One small study of homeless youth found no connection between actor-specific tangible enacted social support and sexual risk behavior [26]. A large multicity study of YMSM found that social support was unrelated to CAI [15], although this study employed a measure of HIV-related social support within a network that had not previously been used or validated. Social support is an important determinant of sexual risk behavior and HIV risk, although differences in measurement and study population might modify this relationship.

## Compositional Network Determinants

### Stability

To our knowledge, only one study has investigated the effects of network stability (i.e., the extent to which the members of an individual's network stay constant over time) on sexual risk behavior [30]. This study found that stability in sexual networks was associated with decreased odds of engaging in condomless sex, as well as with decreases in other sexual risk behaviors. Stability in social networks was found to be protective against sex drug use, but was not protective against condomless sex. Network stability remains a potentially important factor in racial disparities in HIV and additional research is warranted.

### Racial Homophily

Four studies explored aspects of the hypothesis that racial disparities in HIV are amplified by high HIV prevalence among BMSM and high racial homophily in the sexual networks of BMSM. The networks of BMSM in Atlanta

had higher HIV prevalence than those of White MSM [31]. BMSM in New York City had higher rates of HIV and higher levels of racial homophily when compared to White MSM [32]. Birkett et al. [23] found that racial homophily in egocentric networks was associated with participant HIV status among BMSM, but not among other racial ethnic groups. One notable exception to this pattern of findings was a multi-city study with young BMSM that observed no connection between egocentric network HIV prevalence and participant HIV status [33].

### Network Viral Load

Morgan et al. [34] investigated the effects that differences in HIV transmissibility among network members plays in HIV risk, a concept known as network viral load. This prospective cohort study exploring network factors and HIV found that for young BMSM in Chicago, each additional recently infected HIV positive partner (high transmissibility) in one's network was associated with 13 times greater odds of seroconversion during the study period. There was no relationship between number of long-term infected partners (low transmissibility) and seroconversion, and number of HIV negative partners and number of partners using PrEP (both have negligible transmissibility) were each significant protective factors against seroconversion. These results are consistent with network viral load being a key HIV risk factor.

### Non-Network Correlates

In the reviewed literature, constructs at multiple ecological levels were implicated consistently across many studies. A majority of the studies reviewed ( $n = 18$ ) examined factors related to HIV risk and disparities at multiple levels in addition to network factors; the findings related to these non-network factors are summarized here.

Nine studies reported results related to psychosocial factors including six that investigated how attitudes and norms influence sexual risk behavior and three that explored the role that communication within relationships plays in HIV risk. Norms and attitudes were found to be consistently connected to sexual risk behavior [15, 16, 19, 20, 26, 35], and partner communication and power dynamics emerged as key relationship factors that could influence HIV risk and disparities [22, 36, 37].

Nine studies included structural factors in their main analysis. Socioeconomic status was the most commonly measured structural factor ( $n = 5$ ), but a small number of studies explored incarceration ( $n = 2$ ) or discrimination ( $n = 2$ ) as a determinant of HIV risk. Higher educational achievement, current employment, and stable housing were all found to be related to lower HIV risk [22, 28, 31]. Incarceration was related to participation in exchange sex and instability in

social and sexual networks, but was not tied directly to HIV outcomes [30, 38]. There was not clear consensus regarding the effects of discrimination, either related to racism or to homophobia, on HIV risk and additional research in this area is warranted [21, 39].

## Discussion

We sought to conduct a systematic review of the literature on networks and racial disparities in HIV to describe the state of the science and identify potential directions for future research. The findings suggest that size and density of sexual networks may be less influential than the size and density of social networks, that social support plays a protective role regarding HIV risk, and that racially homophilous networks with high HIV prevalence are linked to disparities in HIV. In addition to network factors, psychosocial factors and structural factors were also found to be involved in determining HIV risk and were often studied alongside network factors. This review highlights the importance of studying network characteristics in understanding racial disparities in the HIV epidemic. Where individual behavioral factors fail to explain disparities, network factors and their antecedent structural factors emerge as key drivers of sexual risk behavior and racial disparities in HIV incidence.

Networks have emerged as a central factor in HIV risk and disparities. While a great deal of research has measured structural characteristics of networks such as size and density, the relationship between these structural network factors and HIV risk and disparities is not clear. Little evidence was found to suggest the structure of sexual networks was highly predictive of HIV risk, and the relationship between the structure of social networks and risk was complicated. Of note, we discovered that social network size had different effects on CAI in BMSM and Latino MSM samples. We believe this may be attributed to the different relationships that Black and Latino men might have to the mainstream gay community. Patterns of racism in the MSM community, including racialized sexual stereotypes [40], may lead to Latino MSM finding greater support within this community, while BMSM may experience alienation or discrimination. Thus, as we consider the role of social networks in HIV risk among MSM, it is important to acknowledge varying effects that may be experienced among racial/ethnic minority groups. While basic structural characteristics such as size and density should still be measured, future research that measures more complex measures of network position, such as bridging [41], could offer additional insight into how networks affect HIV risk.

Social support within networks was well studied in the literature surrounding HIV risk and disparities. Social support was seen to be protective against HIV infection among

BMSM. Additionally, there was evidence that this relationship was partially mediated by the effect of social support on sexual risk behavior. One of the few prospective cohort studies reviewed found a direct relationship between social support and decreased seroconversion [34]. These findings are compelling because they reveal the influence of social support on HIV risk, as well as suggesting sexual risk behavior as a potential mechanism by which this effect operates. Several evidence-based interventions for racial/ethnic minority MSM have been described that leverage social networks to influence behavior change (e.g. Many Men, Many Voices and d-up: Defend Yourself! [42, 43]), but little is known about the effects of these interventions at the network level. Research and intervention development should focus on evaluating their impact on network-level characteristics (e.g., changes in size, density, heterogeneity) and its mechanisms of change (e.g., increased availability of social support), alongside HIV outcomes, in an effort to inform strategies that address racial disparities in HIV.

The compositional characteristics of networks offered important insights into the connection between networks and HIV disparities. The evidence largely supported the hypothesis [7] that BMSM tend to have racially homophilous networks and networks with greater HIV prevalence than White MSM. It was found that viral load within a network emerged as a highly predictive correlate of seroconversion. This suggests that network viral load may be a more salient measure of HIV risk within a network than network HIV prevalence. Assessing network viral load also has several advantages over community viral load, another common measurement of aggregated viral activity [44]. Community viral load captures transmissibility within a geographic area. Since sexual networks often span wide geographic areas, network viral load offers a more direct measurement of transmissibility within socially defined networks.

While compositional characteristics of networks are an important factor in HIV risk and disparities, addressing network HIV prevalence and racial homophily through policy and intervention could prove problematic. The elevated rates of HIV within the networks of BMSM are both the cause and the consequence of racial disparities, and offers little direction for intervention. In fact, seeking to address racial homophily without mitigating the structural forces that have historically shaped these networks (e.g. racism, segregation) will be insufficient [45, 46]. Additionally, focusing on racial homophily as a risk factor for HIV risks pathologizing love and connection among communities of color [47]. Intervention and policy should instead focus on testing and treatment, as well as improving access and adherence to PrEP and routine HIV care, to reduce viral load within the networks of BMSM. Increasing regular testing and improving partner communication skills could also help to narrow the knowledge gap about partner HIV status.

Confirming a large body of research connecting individual level factors to HIV risk, psychosocial processes were found to have effects on sexual risk behavior. Theory-driven measurements should be incorporated into intervention design to better target the most salient psychological pathways leading to behavior change. Interventions that are theoretically based have been proven to reduce HIV risk behaviors and lower HIV incidence among MSM, including racial/ethnic minority MSM [48, 49].

Structural factors are key determinants of racial disparities in HIV. The mechanisms by which structural factors affect HIV disparities are not well understood and warrant investigation. The role of networks as mediators between structural factors and HIV disparities have largely been unstudied [50]. Research that measures how network stability might mediate a relationship between incarceration and HIV risk behavior and disparities would help illuminate this possible connection. Additionally, investigations into how structural discrimination such as homophobia and racism might manifest in social and sexual networks could be a fruitful direction for further research. The two studies in this review that explored the effects of discrimination used validated measures of perceived discrimination [21, 39], and future research should adopt or adapt these measures to insure comparability across studies.

Change in structural factors remains the foundation of an effective response to the persistent racial disparities in the HIV epidemic. Studies included in this review demonstrated that incarceration affects network stability and contributes to the interplay among sexual risk behaviors, sex work, and drug use. A limited body of research suggests that the criminal justice system could be a point of intervention to reduce these disparities [4]. Reforming policies and policing tactics that target sex workers, injection drugs users, and people of color could help to reduce network instability and HIV transmission [51]. Standardizing post-release support, including connection to testing and treatment, may serve to mitigate the effects of incarceration on sexual networks. Finally, policies that improve access to housing, jobs, and education for racial/ethnic minority MSM will be fundamental to efforts to reduce racial disparities in HIV.

## Limitations

This review had several limitations. First, by limiting our review to studies that used quantitative measurement of network factors, we may miss important insights from foundational qualitative work. Second, our review was limited in scope. We only examined research that had an explicit focus on racial/ethnic disparities with individual-level outcomes in order to address our research question efficiently. As a result, our review excludes some network research (e.g.,

stochastic network modeling studies; see Fujimoto et al. for exemplar study) [52] that informs racial/ethnic HIV disparities. Additionally, the majority of the reviewed studies employed a cross-sectional study design, limiting our ability to draw conclusions about causation. Finally, there are inherent limitations to the egocentric (information derived solely from participant) network designs used by most studies in this review. Sociometric designs (information derived from all members of network), while more costly and burdensome, offer a more robust measurement of social and sexual networks. Future research should aim to measure complete networks over time in order to better understand how the dynamics of social and sexual networks effect HIV risk and disparities.

## Conclusions

Racial disparities in HIV remain a pressing public health issue and a top priority to be addressed by future research, intervention development, and policy change. The existing literature supports a multilevel model of HIV risk that implicates factors at the individual, network, and structural levels in creating and propagating racial disparities. Structural, functional, and compositional characteristics of networks have all been linked to HIV risk behaviors or racial disparities, suggesting that networks play a key role in shaping these outcomes. Development of intervention and policy should look beyond individual level behavior change. Research and intervention that focuses on factors at the network and structural levels to effectively address racial disparities in HIV are needed. These higher-level factors, which require cultural and economic shifts, may address the fundamental causes of these disparities and hold the potential to affect lasting change.

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## Compliance with Ethical Standards

**Conflict of interest** None of the authors are aware of any potential conflicts of interests regarding the findings of this study.

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