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# A Longitudinal examination of factors associated with Network Bridging among YMSM: Implications for HIV Prevention

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## Abstract

Social-environmental factors may be associated with social network stability, which has implications for HIV acquisition. However, the link between social-environmental factors, network composition and HIV risk has not been examined previously among a city-population based sample of young Black men who have sex with Men (YBMSM). Respondent driven sampling was used to recruit a cohort of 618 YMBSM. Respondents were evaluated at baseline, 9 and 18 months beginning June 2013. A logistic regression model was used to assess the relationship between bridging (i.e. having non-redundant contacts in one's network, indicating network instability) and social-environmental factors and HIV risk factors between respondents, and a conditional logit model was used to assess these relationships within respondents over time. Bridging was associated with adverse social-environmental factors and higher HIV risk, indicating that bridging may be on the explanatory pathway. Future studies should assess the extent to which network stability factors mitigate HIV risk.

## Resumen

Los factores socio-ambientales pueden estar asociados con la estabilidad de la red social, la cual tiene implicaciones para la adquisición del VIH. Sin embargo, el vínculo entre los factores socio-

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Compliance with Ethical Standards:

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

ambientales, la composición de la red y el riesgo de VIH no ha sido estudiado previamente entre una muestra de población urbana de hombres afro-americanos que tienen sexo con hombres (YBMSM). Se utilizó un muestreo dirigido por los entrevistados para reclutar una cohorte de 618 YMBSM. Los encuestados fueron evaluados al inicio, 9 y 18 meses a partir de junio del 2013. Se utilizó un modelo de regresión logística para evaluar la relación entre el puente (es decir, tener contactos no redundantes en la red de uno, indicando inestabilidad de la red) y factores socio-ambientales y de riesgo de VIH entre los encuestados a lo largo del tiempo. Los puentes fueron asociados con factores socio-ambientales adversos y un riesgo mayor de VIH, indicando que los puentes pueden estar en la vía explicativa. Los estudios futuros deberían evaluar la medida en qué los factores de estabilidad de la red mitigan el riesgo de VIH.

### Keywords

HIV/AIDS; Men who have Sex with Men; African-American; Social Network Analysis; Structural Factors; Resilience; Longitudinal Analysis; Youth

## INTRODUCTION

Research has shown associations between social-environmental factors and HIV risk, with social support being protective and exposure to violence and other adverse events being harmful.(1–4) The mechanism by which these factors are associated with HIV risk has not been identified. We examine whether the composition of one's social network may explain this association among a cohort of Young Black Men who have Sex with Men (YBMSM), as social network composition has been previously associated with HIV transmission and is impacted by social-economic status.

### Background

YBMSM are heavily impacted by HIV infection in the United States (U.S.) (5, 6) although they have historically engaged in lower rates of condomless anal sex and drug use during sex compared to young white MSM.(7, 8) The reasons for this HIV paradox and the higher rates among YBMSM have not been explained, potentially due to the dearth of studies with large samples of YBMSM, and limited examination of socio-environmental factors that may be drivers of HIV infections.(9)

Most of the extant research on YBMSM and HIV risk draws comparisons between individual risk factors for Black MSM and MSM of other race/ethnicities, limiting the ability to examine the heterogeneity of potential environmental drivers within a population and their potential associations with HIV incidence.(7, 8) This represents an important gap given a meta-analysis by Millet and colleagues that suggests that the epidemic among Black MSM in the U.S. may be, "inextricably linked to social and economic environments," such as unemployment, low income, criminal justice involvement (CJI), and low education.(8) In a subsequent meta-analysis; disparities in HIV have been attributed to social network factors.(8) Social network factors move beyond individual risk factors and are often a result of one's network position.(2, 10–12) However, the mechanisms by which these social, economic and network factors relate to HIV risk have not been determined among YBMSM.

A clearer understanding of social networks and the socio-environmental factors that influence their stability may have important implications for HIV prevention and intervention among YBMSM. Therefore, this study focuses on the relationship between social network and environmental exposures over time, and how "bridging" (the extent to which an individual connects otherwise unconnected groups) in social networks (13) is related to the social environment and HIV risk among a large cohort of YBMSM in the U.S.

Our conceptual model hypothesizes that social-environmental factors (such as residential instability, economic hardship, and CJI) affect the composition of social networks by preventing the maintenance of strong social ties (causing a higher likelihood of bridging). We hypothesize that exposure to violence leads to a lack of trust in one's community and thus less dense social networks (i.e. more bridging). Our model also hypothesizes that under these low collective efficacy conditions, social network composition (bridging) may be associated with HIV risk due to benefits received from the risk behaviors, which aligns with social exchange theory.(14) Resilient individuals may engage in more sexual activity with more partners to gain access to resources and potential emotional support not available through their immediate social ties.

## Networks and HIV Transmission

The extent to which an individual connects otherwise unconnected groups is known as "bridging" in social network analysis.(13) Bridge metrics are useful for assessing network instability because the bridging position tends to be temporary; in the context of organizations, approximately 90% of people who hold bridge positions within an organization only hold them for a year or less.(15) Network theory suggests that dynamism exists in the networks of bridges because the maintenance of social ties requires frequent interaction, which strengthens some ties and degrades others, thus terminating the bridge position.(13) Likewise, ties between individuals in groups that were otherwise unconnected often develop when relationships are maintained, terminating the bridge position.(16) This implies that the more likely one is to be a bridge, the less stable their network. Previous literature has demonstrated the link between bridge status and high social capital as a result of a bridge's exposure to non-redundant information and subsequent opportunity for innovation.(17)

In the context of infectious disease transmission, bridges serve as essential targets for reducing transmission because they potentially transmit infection from an infected cluster to an uninfected cluster. Research has shown that immunization based on bridging is more effective than immunization based on number of contacts alone,(16) and in the HIV literature, bridging was independently associated with HIV seropositivity.(2) High network turnover has also been associated with HIV transmission among people who inject drugs.(18) Bridging may have different implications for those who are HIV-seropositive versus HIV-seronegative. Those who are HIV-seropositive who are in a bridge position may introduce the virus to different susceptible populations if they have uncontrolled virus, and could therefore be recruited to engage in treatment to prevent onward transmission. Likewise, engaging HIV-seronegatives in bridge positions in HIV preventive care, such as

linkage to pre-exposure prophylaxis, could prevent acquisition and consequent future transmission.

## Possible Factors Influencing Social Network Composition

Social-environmental factors can have both protective and adverse effects on HIV risk and social networks. Previous literature has shown social support and community acceptance to be associated with fewer reports of condomless anal intercourse, higher rates of HIV testing, and lower rates of serodiscordant sex.(19, 20) However, factors such as CJI, exposure to community violence, and increased rates of unemployment have been associated with greater odds of transactional sex, substance use during sex, condomless sex, gang involvement and general substance use among YBMSM and adolescents.(12, 21) Millet and colleagues found that, among MSM of all ages, associations differed by race/ethnicities between social-environmental factors (low income, low education, CJI, unemployment, health insurance access for HIV-positive MSM) and HIV risk outcomes.(8)

Networks are significant drivers of HIV risk and other behaviors, as relationships influence a person's behavior beyond the influence of their individual attributes.(22) It is likely that social-environmental factors (e.g. exposure to community violence, economic hardship indicators, and CJI) affect the stability of social networks, and that stability is in turn linked to HIV risk. Networks and social-environments are related in that physical proximity, shared interests and shared norms commonly influence network formation.(10) The intersection of these factors allows for a confluence of effects on HIV risk, with each factor having the potential to be either protective or detrimental. For instance, factors related to social disorder such as CJI and violent death are of particular importance when assessing social network composition because they lead to network shocks, such as the loss of a close confidant due to death or incarceration.(11) These forced social network losses are more detrimental to one's health and social capital than losses by choice due to the difficulty in recovering, and therefore difficulty in replacing the quality of the social tie.(11, 12) Likewise, those who experience high residential transience (frequently changing residences) are less likely to have main sexual partners and more likely to participate in HIV risk behaviors.(23, 24) The weak, fleeting, nature of the connections in unstable networks leads to poor health outcomes. Longitudinal network data from the National Social Life, Health, and Aging Project found that Black and low-SES respondents lost more confidants and had more difficulty replacing them than their higher SES individuals later in life.(11) On the contrary, elements of one's social network, such as having emotionally supportive confidants, can also be protective with regard to HIV risk.(25) In a sample of YBMSM, having a social network comprised of two or more family members was associated with decreased odds of sex-drug use and group sex, and increased odds of discouraging these behaviors in others.(21) In this paper, we assess the extent to which protective factors (e.g. parental support, religion, and community belonging) and exposure to adverse social-environment circumstances affect network composition (e.g. bridging) over time.

## Study Contributions

This paper makes a significant contribution to social science and public health intersectional literature demonstrating the influence of social-environmental factors on bridge status and

HIV risk. It employs a longitudinal design that is based on a city-population of YBMSM, which improves the generalizability of significant findings more broadly than those based on small convenience samples. Specifically, we assess two research questions: 1) How do protective factors (such as social support, religion, and community belonging) and factors related to social disorder (such as residential transience, CJI, and exposure to violence) affect the composition of social and sexual networks (measured by bridging) over time? and 2) How does bridging affect HIV risk controlling for age and economic hardship over time?

# METHODS

## Study Population

Data comes from uConnect, a longitudinal study of YMSM ages 16–29 who reside in Chicago.(1, 12, 21, 26) Respondents were evaluated every 9 months for 18-month period (3 study visits total). Baseline data were collected between June 2013 and July 2014. Wave 3 was complete in February 2016. All three waves of data were included in the analysis. Respondent Driven Sampling (RDS) was used for recruitment. RDS is a modified snowball sampling technique that starts with an initial group of respondents, "seeds" which then recruit others who are from the same population.(27) RDS is particularly useful for recruiting populations that are difficult to reach through standard methods.(28) RDS seeds were selected from a distribution of social spaces that YBMSM occupy (both physical spaces and virtual spaces such as Facebook). Eligibility criteria included: 1) self-identification as African American or Black, 2) born male, 3) between 16 and 29 years of age (inclusive), 4) report of oral or anal sex with a male within the past 24 months 5), willing and able to provide informed consent at the time of study visit, 6) primary residence in South Chicago, the most populous contiguous Black community in the U.S.(12) Respondents were given up to six vouchers to recruit others who fit the eligibility criteria. Each respondent was given $60 for participation and $20 for each recruit successfully enrolled into the study. Respondents were administered a network and behavioral survey and provided blood samples at each study visit. Bivariate analyses were conducted to assess differences between those retained and those lost to follow-up as well between productive seeds and unproductive seeds using chi-square tests and Kruskal-Wallis tests. The Institutional Review Board at the University approved all protocols and procedures.

## Laboratory Testing

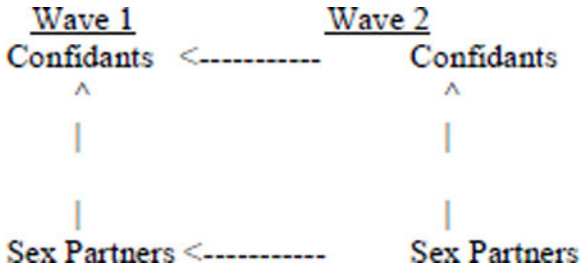
HIV infection was determined by three assays applied to samples eluted from dry blood spots: ARCHITECT HIV Ag/Ab Combo; Multispot HIV-1/HIV-2 Bio-Rad; and Realtime HIV-1 RNA, Abbot. In cases where test data were missing at the study visit, available HIV viral load and serostatus surveillance data were used from the Chicago Health Department (n=30 baseline, n=3 wave 2, n=1 wave 3). We obtained a Release of Information from each respondent to obtain these data.

## Network Generation and Construction

**Social Network Data Collection—**A set of name-generating and interpreter (descriptor) questions was used at each study visit to collect data on participants' social and sexual networks as described previously.(1) In brief, participants were asked to list up to five

confidants with whom they "discuss things that are important to you." Participants were asked to provide demographic information on each, such as first name, last name, nickname, gender (male, female, transgender), age, education, employment status, ethnicity (Hispanic or not), and race. Participants were also asked to list their (up to) five most recent sexual partners in the past six months. After providing this list, respondents were further prompted with a question asking if they were in a relationship with someone they consider their main sexual partner. If they listed someone and that person was not listed initially, this person was added as a sixth sexual partner. The same demographic information was collected for sex partners. At their first visit, participants were asked if any of their sex partners were the same as persons listed as confidants and matches were recorded. The same name generators were used in each wave. Verification of matches between network partners differed slightly between waves. At their wave 2 visit, after generating their list of confidants, participants were asked if the confidants listed were the same as any of their confidants named in wave 1. Later when they generated the list of their most recent sex partners, they were asked if any of these corresponded to confidants they had just named and if any were the same as any of their sex partners named at their previous visit. It should be noted that the respondent was *not* asked to compare their confidants with sex partners from Wave 1 nor were they asked to compare their sex partners in Wave 2 with the confidants from Wave 1. (See diagram)

### Comparisons of alter lists between network generators and interviews




A similar procedure was used in Wave 3, except that the confirmation list was cumulative. For example, respondents in Wave 3 were asked whether any of the confidants listed corresponded to a combined list of confidants and sex partners from the previous interview. And in Wave 3, similarly respondents were asked whether the sex partners listed corresponded to a cumulative list of the confidants and sex partners from the current and previous interview waves. Matches were recorded.

**Construction of Matched Network—**A multiple step process combining computerized scoring and manual verification was used to construct a de-duplicated network of all respondents and social and sexual network partners across all three waves. The first step was to run a computer program (using R software)(29) on the initial list of 8,522 respondents, social, and sexual network partners listed and described in all interviews to create a file of information on and a "matched score" for pairs of nodes. The score was based on and ordered by information on the following: phoneticized last name, phoneticized first name, phoneticized nickname, age, gender, and race (defined as Black/African American versus not Black/African American due to the sample being predominately Black/African American).

The file produced at this step contained all pairs with scores that met a threshold that allowed us to consider them potential matches as well as their demographic information. This list was compared with and updated to include missing pairs based on a list of all matches that had been reported by respondents (i.e. confidants who were also sex partners, or either confidants or sex partners who appeared in multiple waves from one respondent) resulting in a file with 205,127 pairs.

Two independent coders then reviewed and scored the composite list of paired nodes and manually scored each pair on a 4-point scale from 3 indicating that they were "extremely confident that it is the same person" to 0 indicating that they were "extremely confident that it is not the same person". Senior research staff reviewed the file with the manual scores to resolve any discrepancies. After an initial pass to resolve coder differences, a computer program was run to verify that matched pairs were transitive and to add missing pairs to achieve transitive sets of pairs (i.e., if A matched B and B matched C, if a match between A and C was missing it was generated, etc.) Comparisons with a score of 3 were considered to be a "match" (the same person). A new set of unique IDs was created for all nodes with matched nodes receiving the same the ID. An edge (tie) list was created for all Egos (respondents) and Alters (social and sexual network partners) based on the new unique IDs. The complete network was generated and checked for coherence (e.g., respondents being matched). This allowed us to identify a small number of incorrect matches (n=< 10) which were then removed prior to analyses and the renumbering with unique IDs was redone. This resulted in 5,994 unique IDs for the original list of 8,522 nodes from all the interviews.

## Analytic Plan

### Measures

**Research question 1: Social-Environmental Factors and Bridging:** The outcome of interest was the effective size bridging metric developed by Burt.(17) Effective size is conceptualized as the number of disconnected groups that an individual connects. Specifically, it measures the number of, non-redundant contacts in an individual's network. (17) It can be calculated as $n-2t/n$, where $n$=the number of network members and $t$=the number of ties between network members.(30) For instance, if an individual has a network of 8 people and there are four ties between the network members, the effective size would be 8-(8/8)=7.(30) Higher effective size indicates more bridging. Effective size was dichotomized at the median given the shortage of information on its distribution among this population. We calculated effective size across both the social and sexual networks rather than separately due to the large amount of overlap between social and sexual ties and the high frequency of social connections becoming sexual connections and vice versa over time. (1)

The primary independent variables of interest were protective measures and adverse social-environmental exposures. Protective measures included: 1) The level of emotional support received from a mother figure and/or father figure (very supportive vs. less than very supportive), feeling close to the gay community and/or Black community (very close vs. less than very close), being a member of the house ball community (yes/no), being a member of a gay family, and the importance of religion in the respondent's life (very important vs. very

important). Use of a hook-up application (yes/no) was also assessed due to literature showing that MSM under the age of 25 are more likely to use online applications for social support than older MSM who use them to meet sex partners.(31) Hook-up application use could therefore be an indication of weak ties within the physical, real-world MSM community.

Adverse social-environmental measures included exposure to community violence, economic hardship indicators, and CJI. Exposure to community violence was assessed using the Lifetime Exposure to Violence Probe at baseline and Wave 3.(32) The probe consisted of seven items that assess the level of exposure to witnessing or being a victim of community violence. Each item was on a 7-point scale, ranging from 0 (never) to 6 (6 or more times). A continuous measure of the total violent exposures experienced was used in the multivariate analysis. CJI was defined as having ever previously been detained, arrested, or spent time in jail or prison. We also assessed how many separate occasions respondents had CJI experiences. These measures were collected at all three waves. Finally, social economic hardship was assessed by summing responses captured on two items: residential transience (reporting two or more addresses in the previous 12 months) and a question assessing how often in the past 6 months there was not enough money in the household for rent, food, or utilities (ever/never). The items in the index were strongly associated with each other and with the outcome. Overall index scores ranged from 0 to 2, with higher scores indicating more economic hardship. We did not include degree or density in the model as they are both components defining the outcome, effective size. For comparison purposes, we ran additional models using degree (network size) and density (total ties divided by total possible ties)(33) as outcomes (both dichotomized at the median).

**Research Question 2: HIV Risk and Bridging:** The outcome of interest in this model was once again the effective size bridging metric dichotomized at the median. The primary independent variables of interest were HIV risk measures. The independent variable measures included: 1) Sex-drug use included non-injection drug use or alcohol use during sex (drugs included marijuana, MDMA, volatile nitrates, cocaine, heroin, psychoactive drugs, methamphetamines, and prescription pain killers) as defined previously.(9) Sex-drug use was dichotomized; 2) Any condomless anal sex in the past 6 months; 3) Number of male/transgender anal sex partners in the past 6 months; 4) Transactional sex in the previous year, defined as paying or receiving pay for sex (yes/no); 5) Participation in group sex in the past year (yes/no); 6) Concurrency, defined as the number of overlapping partners (2 or more) in the past 6 months; 7) Other demographics and social characteristics. Injection drug use was not included in the model due to its low prevalence in the sample. Analyses controlled for age, economic hardship, sexual orientation, and recruitment wave. All analyses excluded seeds that did not recruit other respondents (n=27) as previous studies have demonstrated that excluding unproductive seeds has little impact on generalizability. (34) As above, we ran additional models using degree and density as outcomes (both dichotomized at the median) for comparison.

### Statistical Analysis

Two sets of analyses were performed, one focusing exclusively on *between-respondent* (i.e., cross-sectional) variability and another focusing exclusively on *within-respondent* variability over time. The first set involved fitting logistic regressions to the number of observations per respondent (n = 1–3) for which each outcome (i.e., bridging, degree, and density) was above the median; the covariates in these models are average values for each respondent across their observations. These models thus describe how the respondent-specific probability of exceeding the median of an outcome is related to a respondent's average value of each covariate. The second set of analyses involved using conditional logistic regression to model the within-respondent association between exceeding the median of an outcome and the individual values of the covariates; respondents whose observations are all below (or all above) the median are excluded, as are those with only a single observation. After an initial analysis, all models were refit using weights estimated to be proportional to the probability of selection using Gile's Sequential Sampling (SS) estimator.(35) This estimator relies on the RDS sampling procedure together with information on network size obtained from the question: "Now, please estimate the number of Black men who have sex with men between the ages of 16 and 29 who know you well, on a first name basis, and with whom you are likely to have contact within the next two weeks. Including men we've already talked about, how many is that?" Standard errors were obtained using the robust (sandwich) variance estimator.(36) All regression analyses were conducted using Stata version 15.(37)

## RESULTS

### Baseline Demographics and HIV Serostatus

Our sample included 38 productive seeds that generated a baseline sample of 591 respondents (27 non-productive seeds were excluded). The follow-up rate for Wave 2 was 500 (85%) and 482 (82%) in wave 3. At baseline, the mean age of the participants was 23 (range 16–29), 100% were Black/African-American, 34 (7%) had less than a high school degree, 389 (66%) and 163 (28%) identified as gay and bisexual respectively, 318 (55%) had health care coverage. The HIV prevalence in the sample was 41% (n=196), and 52% of those infected were virally suppressed (Table 1). HIV incidence over the study period was 9.6% (characteristics associated with seroconversion were published previously).(38) The retention analysis revealed that those who were not retained were less likely to be HIV positive via both self-report and via laboratory testing (p=0.01 and .p=0.004), more likely to be straight or "other" sexual orientation (p= 0.02) and were slightly younger, median 21 years (IQR 19–24) vs. 23 years (IQR 21–25) (p=0.0001) at baseline. These measures were controlled for in the multivariate analyses. No differences were found in bridging, other socio-demographic factors, social-environmental factors, or social support factors. The productive seed analysis revealed no differences in HIV status, viral suppression, economic hardship, sexual orientation, criminal justice involvement, the use of hook-up apps, number of sex partners, and age at baseline between productive seeds and unproductive seeds.

### Network Characteristics

The mean effective size was 4.9 (SD 2.17) at baseline and decreased by an average of 0.21 (SD 2.9) over the study period. Compared to those with low bridging, those with a high

bridging (i.e. those with less network stability) had a median degree of 7 (IQR 6,8) versus 4 (IQR 3,4), retained an average of 14% (SD 16%) of their network connections versus 22% (SD 27%), were approximately the same age (mean age 24 (SD 3.1) vs. 23 (3.2)), and reported slightly more condomless sex partners (mean 1 (SD 1.2) vs. 0.5 (SD 0.6)). The mean network size was 5.3 (SD 2.3) at baseline and 4.9 (SD 2) at both Waves 2 and 3. The mean density was 0.48 (SD 2.0) at baseline and 0.33 (SD 2.6) at Waves 2 and 3. Respondents retained an average of 1.40 (SD 1.23) network members between baseline and Wave 2, and 1.14 (SD 1.05) between Wave 2 and Wave 3. Bridging remained stable among 381 (64%) of respondents and degree remained stable among 396 (67%) of respondents over the 18-month study period.

### Social-Environmental Factors, HIV Risk, and Bridging

After adjusting for all other variables in the model, the logistic regression estimates showed that having concurrent partners (OR 3.09; 95% CI 1.99–4.83), the number of male and transgender partners (OR 1.35; 95% CI 1.18–1.54) and sex drug use (OR 1.57; 95% CI 1.01–2.44) were positively associated with bridging **(Table 2).** Age (OR 0.96; 95% CI 0.92–0.99) and being HIV positive versus negative were inversely associated with bridging (OR 0.81; 95% CI 0.65–1.00). In contrast, the conditional logit model showed that within-respondent changes in economic hardship (OR 2.58; 95% CI 1.12–5.91) and exposure to violence (OR 1.54; 95% CI 1.08–2.21) were both associated with changes in bridging, as was a change in the number of sex partners over the past 6 months (OR 2.97; 95% CI 1.97–4.46).

### Social-Environmental Factors, HIV Risk, and Network Size

The logistic regression with network size as an outcome showed similar results to the logistic regression with bridging as an outcome, while the conditional models had differing results. After adjusting for all other variables in the model, the logistic regression estimates showed that having concurrent partners (OR 3.13; 95% CI 1.98–4.85) and the number of male and transgender partners (OR 1.31; 95% CI 1.21–1.54) were positively associated with network size, and age was inversely associated (OR 0.96; 95% CI 0.92–1.00) (Table 3). The conditional logit model, however, showed that after holding all other covariates fixed, within-respondent changes in sexual orientation (OR 11.34; 95% CI 1.57–81.78), the use of hook-up applications (OR 3.19; 95% CI 0.99–10.25), and the number of sex partners over the past 6 months (OR 2.72; 95% CI 1.26–5.87) were associated with changes in network size.

### Social-Environmental Factors, HIV Risk, and Density

The logistic regression model with density as an outcome showed that, after adjusting for all other variables in the model, having a sexual orientation of straight was positively associated with density (OR 8.08; 95% CI 2.84–23.01) and experiencing both residential transience and insufficient resources was inversely associated with density (OR 0.20; 95% CI 0.04–0.89) (Table 4). The conditional model could not be calculated for density, as there was too little variation within respondents to estimate the model.

## DISCUSSION

We found that bridging among YBMSM was positively associated with HIV risk in the between-respondent analysis. Those with high bridging in the between-respondent analysis were more likely to have concurrent partners, more likely to have more male or transgender partners, use drugs or alcohol before or during sex, and less likely to be older and HIV positive. The within-respondent analysis, however, showed that respondents who increased their number of male or transgender partners, experienced increasing instances of friends or family members getting robbed or attacked, and had increasing economic hardship were more likely to have higher bridging than they did at baseline. Equivalently, respondents who decreased these factors were more likely to have lower bridging.

The analyses with network size as an outcome, conversely, did not show any associations with adverse social-environmental factors in either the between or within respondent analyses indicating that the bridging and network size metrics may be measuring different constructs. Similar to above, those with large network size in the between-respondent analysis were more likely to have concurrent partners, more likely to have more male or transgender partners and less likely to be older. The within-respondent analysis, however, showed that respondents who increased their number of male or transgender partners, used hook-up apps or had concurrent partners were more likely to have a larger network size than they did at baseline. Equivalently, respondents who decreased these factors were more likely to have smaller network size. Sexual orientation was also associated with network-size, however only marginally, and the confidence intervals were large. Finally, while density could only be assessed in the between-respondent analysis, the analysis showed that those with more dense networks were more likely to be straight and less likely to experience social economic hardship. The differences in these results indicate that structural social network metrics (such as bridging and density) may be more heavily impacted by social-environment factors than network size.

These findings corroborate previous literature that provides the basis for our hypothesis about the causal pathway between the social-environment and HIV risk. It has been proposed that adverse social-environmental factors cause change in the composition of one's network, leading to poor health outcomes.(11) Likewise, bridging has been associated with increased HIV transmission.(16) Our findings provide evidence of the link between social-environmental factors, bridging, and HIV risk. Future studies should examine whether a sequential link exists between these three factors.

Having a close friend or relative being robbed or attacked was the most frequently reported exposure to community violence, and it was also the most strongly associated exposure to community violence metric with bridging in the conditional logit model. Chronic exposure to stressful events may be more detrimental to health and resiliency than acute exposure.(39) Chronic or sustained exposure to violence within a social network may lead to chronic stress because it can create a prolonged state of apprehension about whether and when negative or violent events will occur. McEwan and Gianaros note that this apprehension can result in, chronic dysregulation of physiological systems that are normally involved in adaptation to environmental challenge, which then can undermine health.(39)

We did not find any associations between protective factors, such as having an emotionally supportive mother figure, feeling close to the gay community and/or Black community, religion, or membership in a gay family or house ball and bridging. We also did not find any associations between CJI and bridging. It may be that CJI causes individuals to rely on each other, hence increasing their social resources. This explanation is inline with the theory of moral economies which explains how unfavorable situations can render social capital through reciprocity.(40) The positive association that we found between bridging and having limited economic resources coupled with the theory of moral economies suggests that micro-economic structural interventions may help alleviate the negative implications of bridging.(41)

The high rates of exposure to community violence coupled with the association between community violence and bridging underscore the increased need for violence prevention resources geared towards sexual minorities of color. Sexual minorities experience CJI more often than straight individuals of their same age and SES,(42) and this was compounded by high rates of violence in Chicago during the study period. Since 2010, Chicago has experienced an increase in violent crime, with rates well above the United States average.(43) Chicago has a long history of place-based health disparities due to ethno-racial segregation and disinvestment in areas where the majority of Black Chicagoans reside.(44) These areas consequently also experience the most violent crime. In addition, our rates of exposure to violence are likely underestimated because the Lifetime Exposure to Violence Probe instrument does not assess exposure to police brutality, excessive policing, or inter-partner violence.(32) Future studies should collect these additional sources of violence to assess the impact of a broader range of violence exposure to better inform intervention.

Our findings appear to counter previous literature linking bridging and high social capital.(15) However, much of the previous literature surrounding bridging and social capital was among populations with higher SES than our population.(45) It may be possible that among our sample, the association between bridging and higher rates of multiple anal sex partners, condomless sex, group sex, and transactional sex indicates that bridging is advantageous in terms of social resources. Perhaps those who engage in more sexual activity with more partners are benefiting from these relationships by gaining access to resources (both monetary and emotional) that are not measured in our survey. This possibility aligns with Social Exchange Theory that views social behavior as a series of exchanges in which individuals attempt to maximize their rewards and minimize costs, where rewards and costs include gratification and opportunity in addition to monetary considerations.(14) Future research should assess this possibility.

Our study is limited in that much of the data are self-report, including the elicited network members. Thus, there could be concern about missing data within the network. Network data, however, are rarely complete,(46) and our rigorous network matching methodology allowed us to link individuals who did not name one another, increasing the completeness of the network. There were some differences in those who were lost to follow-up and those who were retained. However, these differences are not specific to this study(47) and efforts have been made to control for these factors in the analysis. Despite these limitations, this study is the first to examine bridging as a factor related to both the social-environment and

HIV risk among YBMSM. Providing social support to those with high exposure to community violence and social economic hardship may be beneficial for mitigating the impact of the social environment on HIV risk. Family support interventions may also mitigate risk as maternal communication about sex with males has been positively associated with routine HIV testing among YBMSM.(3)

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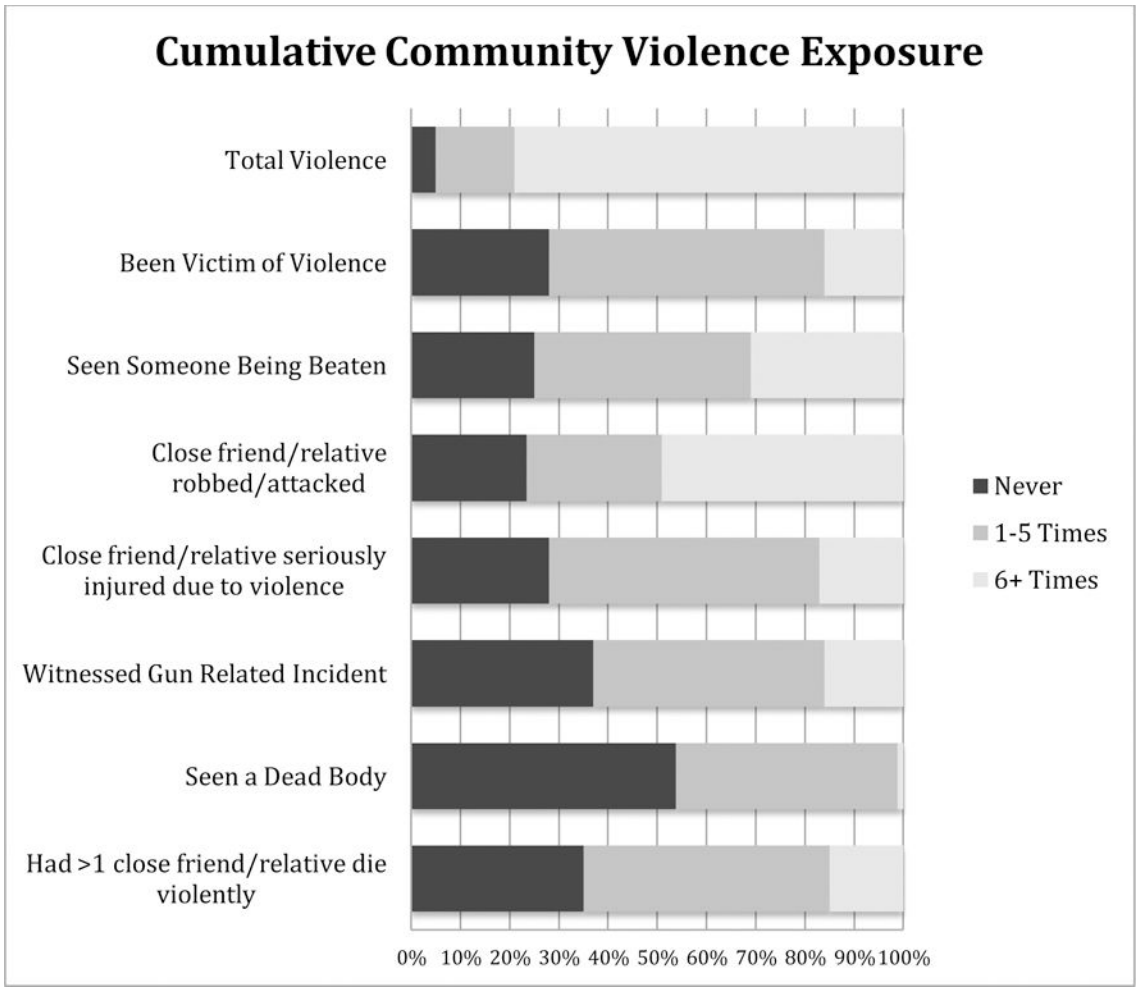


**Figure 1.**
Cumulative Community Violence Exposure among Young African-American MSM in Chicago (n=505)

**Table 1.**

Baseline demographics, behavioral characteristics, and HIV serostatus among Young African-American MSM in Chicago, uConnect (n=591), 2013–2016

| | n (%) |
|---|---|
| **Age at interview, median (IQR)** | 23 (20,25) |
| **Insured** | 318 (55) |
| **Sexual Orientation** | |
| Gay | 389 (66) |
| Bisexual | 163 (28) |
| Straight | 22 (4) |
| **Social-Environment Factors** | |
| **Residential Transience (previous year)** | 124 (25) |
| **Not enough resources for basic needs (previous 6 months)** | 254 (43) |
| **CJI in lifetime**[a] | 273 (46) |
| **CJI exposures (count)**[b] | |
| 1 | 104 (39) |
| 2 | 59 (22) |
| 3+ | 107 (39) |
| **Father Figure present** | 369 (62) |
| **Father figure emotionally supportive** | 167 (46) |
| **Mother Figure present** | 534 (90) |
| **Mother figure emotionally supportive** | 364 (68) |
| **Felt close to gay community** | 130 (22) |
| **Felt close to Black community** | 275 (47) |
| **Member of house ball community** | 92 (16) |
| **Member of gay family** | 178 (30) |
| **Felt religion was important** | 296 (50) |
| **Used hook-up application**[c] | 197 (33) |
| **HIV Risk Factors** | |
| **Sex drug use (previous year)** | 142 (24) |
| **Transactional sex (previous year)** | 68 (12) |
| **Group sex (previous year)** | 118 (20) |
| **Number of male sex partners (previous 6 months) (median, IQR)**[d] | 2 (1,3) |
| **Total number of sex partners (previous 6 months) (median, IQR)**[e] | 3 (1,4) |
| **Any condomless male sex partners (previous 6 months)** | 288 (49) |
| **Concurrency (previous 6 months)** | 249 (42) |
| **HIV Seropositive**[f] | 196 (41) |
| **Suppressed viral load**[g] | 95 (52) |

[a] Includes jail/parole

[b] % among those with CJI

[c] Of those who use the internet

[d] Obtained from network elicitation

[e] Obtained from general questionnaire

[f] Of those with an HIV lab result (n=483)

[g] % among HIV+ aware

**Table 2.**

Logistic regression and conditional logit models showing adjusted associations between bridging and social-environmental factors and HIV risk among Young African-American MSM in Chicago, uConnect, 2013–2016

| | Logistic Regression Model (n=546) | | | Conditional Logit Model n=144 (obs=288) | | |
|---|---|---|---|---|---|---|
| | OR * | 95% C.I. | p-value | OR * | 95% C.I. | p-value |
| **Mother emotionally supportive** | 0.86 | 0.63–1.19 | 0.38 | 0.50 | 0.17–1.48 | 0.21 |
| **Age** | **0.96** | **0.92–0.99** | **0.017** | - | - | - |
| **Sexual Orientation Gay** | | | | | | |
| Gay | Ref. | | | Ref | | |
| Bisexual | 1.27 | 0.96–1.68 | 0.10 | 1.21 | 0.18–7.99 | 0.85 |
| Straight | 1.26 | 0.66–2.41 | 0.49 | 5.37 | 0.67–43.30 | 0.11 |
| **Used hook-up application** | 1.12 | 0.84–1.49 | 0.44 | 1.76 | 0.52–5.98 | 0.91 |
| **Economic Hardship Scale** | | | | | | |
| None | Ref. | | | Ref. | | |
| Residential transience or insufficient resources | 0.74 | 0.54–1.03 | 0.07 | **2.58** | **1.12–5.91** | **0.025** |
| Residential transience and insufficient resources | 0.69 | 0.46–1.04 | 0.08 | 3.00 | 0.95–9.52 | 0.062 |
| **Friend/family robbed or attacked** | 0.99 | 0.95–1.04 | 0.72 | **1.54** | **1.08–2.21** | **0.018** |
| **Condomless anal sex (previous 6 months)** | 0.79 | 0.57–1.08 | 0.13 | 0.96 | 0.39–2.33 | 0.92 |
| **Concurrent sex partners (previous 6 months)** | **3.09** | **1.99–4.83** | **<0.001** | 2.52 | 0.93–6.85 | 0.07 |
| **# male/transgender partners (previous 6 months)** | **1.35** | **1.18–1.54** | **<0.001** | **2.97** | **1.97–4.46** | **<0.001** |
| **Transactional Sex** | 1.15 | 0.76–1.74 | 0.52 | 1.82 | 0.52–6.35 | 0.35 |
| **Sex Drug Use** | **1.57** | **1.01–2.44** | **0.045** | 2.38 | 0.83–6.84 | 0.11 |
| **Any Group Sex** | 1.23 | 0.84–1.79 | 0.28 | 1.64 | 0.30–8.88 | 0.57 |
| **STI Diagnosis** | 1.14 | 0.83–1.57 | 0.43 | 0.59 | 0.19–1.79 | 0.35 |
| **Self-Report HIV Status** | | | | | | |
| Negative | Ref. | | | Ref. | | |
| Positive | **0.81** | **0.65–1.00** | **0.05** | 3.65 | 0.35–37.72 | 0.27 |
| Never tested | 1.12 | 0.78–1.59 | 0.55 | 0.30 | 0.08–11.12 | 0.52 |
| **Wave** | - | - | - | 1.09 | 0.72–1.65 | 0.69 |

OR indicates Odds Ratio, C.I. indicates Confidence Interval

* Odds ratios are adjusted for all variables for which estimates are presented.

**Table 3.**

Logistic regression and conditional logit models showing adjusted associations between degree and social-environmental factors and HIV risk among Young African-American MSM in Chicago, uConnect, 2013–2016

| | Logistic Regression Model (n=546) | | | Conditional Logit Model n=132 (obs=264) | | |
|---|---|---|---|---|---|---|
| | OR * | 95% C.I. | p-value | OR * | 95% C.I. | p-value |
| **Mother emotionally supportive** | 0.84 | 0.59–1.19 | 0.32 | | | |
| **Age** | **0.96** | **0.92–1.00** | **0.034** | - | - | - |
| **Sexual Orientation Gay** | | | | | | |
| Gay | Ref. | | | Ref. | | |
| Bisexual | 1.29 | 0.95–1.75 | 0.102 | 0.97 | 0.25–3.72 | 0.97 |
| Straight | 1.40 | 0.75–2.61 | 0.30 | **11.34** | **1.57–81.78** | **0.016** |
| **Used hook-up application** | 1.11 | 0.81–1.52 | 0.51 | **2.83** | **1.22–6.57** | **0.015** |
| **Economic Hardship Scale** | | | | | | |
| None | Ref. | | | Ref. | | |
| Residential transience or insufficient resources | 0.84 | 0.59–1.21 | 0.35 | 1.27 | 0.60–2.71 | 0.53 |
| Residential transience and insufficient resources | 0.71 | 0.44–1.51 | 1.15 | 0.97 | 0.43–2.19 | 0.94 |
| **Friend/family robbed or attacked** | 0.99 | 0.94–1.04 | 0.65 | 0.85 | 0.54–1.35 | 0.50 |
| **Condomless anal sex (previous 6 months)** | 0.79 | 0.53–1.17 | 0.24 | 0.99 | 0.48–2.02 | 0.98 |
| **Concurrent sex partners (previous 6 months)** | **3.13** | **1.98–4.95** | **<0.001** | 2.25 | 0.86–5.86 | 0.098 |
| **# male/transgender partners (previous 6 months)** | **1.31** | **1.12–1.54** | **0.001** | **2.72** | **1.26–5.87** | **0.01** |
| **Transactional Sex** | 1.23 | 0.77–1.98 | 0.38 | | | |
| **Sex Drug Use** | 1.48 | 0.93–2.34 | 0.097 | **3.19** | **0.99–10.25** | **0.05** |
| **Any Group Sex** | 1.08 | 0.68–1.71 | 0.74 | 1.01 | 0.31–3.28 | 0.98 |
| **STI Diagnosis** | 1.03 | 0.69–1.53 | 0.90 | 0.74 | 0.24–2.29 | 0.60 |
| **Self-Report HIV Status** | | | | | | |
| Negative | Ref. | | | Ref. | | |
| Positive | 0.80 | 0.61–1.04 | 0.09 | 2.42 | 0.51–11.44 | 0.27 |
| Never tested | 1.19 | 0.81–1.75 | 0.38 | 0.06 | 0.001–6.62 | 0.24 |
| **Wave** | - | - | - | 1.23 | 0.84–1.80 | 0.28 |

OR indicates Odds Ratio, C.I. indicates Confidence Interval

* Odds ratios are adjusted for all variables for which estimates are presented.

**Table 4.**

Logistic regression model showing the adjusted associations between density and social-environmental factors and HIV risk among Young African-American MSM in Chicago, uConnect, 2013–2016

| | Logistic Regression Model (n=546) | | |
|---|---|---|---|
| | OR * | 95% C.I. | p-value |
| **Mother emotionally supportive** | 1.25 | 0.47–3.31 | 0.66 |
| **Age** | 0.94 | 0.84–1.05 | 0.28 |
| **Sexual Orientation Gay** | | | |
| Gay | Ref. | | |
| Bisexual | 1.83 | 0.63–5.38 | 0.27 |
| Straight | **8.08** | **2.84–23.01** | **<0.001** |
| **Used hook-up application** | 0.78 | 0.30–2.08 | 0.63 |
| **Economic Hardship Scale** | | | |
| None | Ref. | | |
| Residential transience or insufficient resources | 0.85 | 0.32–2.26 | 0.74 |
| Residential transience and insufficient resources | **0.20** | **0.04–0.89** | **0.035** |
| **Friend/family robbed or attacked** | 1.11 | 0.96–1.29 | 0.16 |
| **Condomless anal sex (previous 6 months)** | 1.67 | 0.54–5.21 | 0.38 |
| **Concurrent sex partners (previous 6 months)** | 1.15 | 0.49–2.70 | 0.75 |
| **# male/transgender partners (previous 6 months)** | 1.40 | 0.95–2.07 | 0.09 |
| **Transactional Sex** | 1.19 | 0.28–5.04 | 0.81 |
| **Sex Drug Use** | 0.70 | 0.21–2.30 | 0.56 |
| **Any Group Sex** | 1.89 | 0.46–7.72 | 0.38 |
| **STI Diagnosis** | 1.39 | 0.41–4.69 | 0.60 |
| **Self-Report HIV Status** | | | |
| Negative | Ref. | | |
| Positive | 1.36 | 0.52–3.58 | 0.53 |
| Never tested | 0.70 | 0.18–2.76 | 0.61 |

OR indicates Odds Ratio, C.I. indicates Confidence Interval

* Odds ratios are adjusted for all variables for which estimates are presented.