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Understanding structural factors of place for HIV prevention
among adolescent and young men who have sex with men in the U.S.

By

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Doctor of Philosophy

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By

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MPH, Columbia University, 2011
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An abstract of
A dissertation submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
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Abstract

Understanding structural factors of place for HIV prevention
among adolescent and young men who have sex with men in the U.S.

By Veronica C. Lee

Adolescent and young gay, bisexual, and other men who have sex with men (AYMSM) are at high risk for HIV. Understanding the role of structural place-based factors in AYMSM's access and utilization of HIV prevention and testing services may help with informing effective HIV prevention interventions for this population. This dissertation utilized online-based HIV behavioral surveillance data from an age- and geographically-diverse sample of AYMSM to investigate the following multilevel relationships:

In Aim 1, we examined the relationship between urban-rural residence and sexual identity disclosure, to anyone and to health care providers, by perceptions of neighborhood tolerance of gay and bisexual individuals. Among AYMSM who perceived their neighborhoods to be tolerant, we observed a consistent pattern of less disclosure to anyone for AYMSM residing in suburban, small and medium metropolitan, and rural areas compared to AYMSM residing in urban areas. Regardless of neighborhood tolerance perception, AYMSM in non-urban areas were less likely to disclose to providers compared to their urban counterparts.

In Aim 2, we explored the relationships between two place-based factors, area disadvantage and local racial/ethnic spatial concentration, and receipt of free condoms by AYMSM's race/ethnicity. Overall, free condom receipt was low. We observed different relationships by race/ethnicity. Receipt was associated with residing in the high disadvantaged areas compared to the less disadvantaged areas among White and Hispanic AYMSM, adjusting for individual- and area-level covariates. Among White AYMSM, those residing in areas with high concentrations of racial/ethnic minorities, compared to those in areas with high concentrations of White residents, were more likely to have received free condoms. No meaningful associations were observed among Black AYMSM.

In Aim 3, we explored the relationships between the same structural place-based factors from Aim 2 and having ever tested for HIV by race/ethnicity. Overall, only half of AYMSM reported ever testing for HIV. Different patterns by race/ethnicity were observed. Residing in high disadvantaged areas was associated with increased HIV testing for White and Hispanic AYMSM. Residing in areas with highest concentrations of racial/ethnic minorities was associated with increased HIV testing for White AYMSM and decreased testing for Hispanic AYMSM. No meaningful associations were observed among Black AYMSM.

Taken together, these findings suggest that contextual factors within AYMSM's residential environments may a play a role in their HIV prevention access and utilization. Understanding how these contextual features affect AYMSM, and how these relationships may differ based on sexual identity-related stigma and race/ethnicity, is critical to effective HIV prevention for AYMSM.

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Chapter 1 Background and significance

Epidemiology of HIV among gay, bisexual, and other men who have sex with men

Gay, bisexual, and other men who have sex with men (MSM) in the U.S. have been disproportionately affected by HIV. They comprise 4% of the adult male population (1), but they account for two thirds of all new HIV diagnoses, with approximately 27,000 new diagnoses each year (2). HIV incidence estimates, based on analytic epidemiological studies, range from 0.7 to 6.5 infections per 100 person-years (3). Trend analyses show that HIV diagnoses among MSM have been stable since 2010, whereas diagnoses due to heterosexual sexual contact has decreased over this same period. (2). Nested within this larger disparity are disparities by race/ethnicity, whereby Black and Hispanic/Latinx MSM have been, and continue to be, disproportionately affected by HIV (3–5).

Within MSM, those in adolescence and young adulthood represent the most vulnerable. Gay, bisexual, and other adolescent and young men who have sex with men (AYMSM) aged 13 to 24 years composed 17% of all new HIV diagnoses in the U.S. and 81% of all new diagnoses among those aged 13 to 24 years in 2018 (2). The incidence of HIV among AYMSM has been approximately 6,000 new infections per year over the past 5 years (2), and estimates from analytic epidemiological studies range from 2.85 to 6.5 per 100 person-years (3). Surveillance data show HIV incidence had decreased from 2014 to 2018, by 3%, among AYMSM; however, HIV incidence has increased by 6% among MSM in the subsequent age group (6).

Similar to adult MSM, Black and Hispanic/Latinx AYMSM have been disproportionately affected by HIV. In 2018, Black AYMSM accounted for 48% new HIV diagnoses among AYMSM aged 13 to 24 years, followed by Hispanic/Latinx (31%) and White AYMSM (15%) (2). HIV incidence estimates reflect this racial/ethnic disparity as well, with higher incidence, up to 10-fold, among Black and Hispanic AYMSM compared to White AYMSM (7–10). In a four-year cohort study of Black and White MSM residing in Atlanta, the incidence of HIV was 10.9

infections per 100 person-years among Black AYMSM aged 18 to 24 years, compared to 0.9 infections per 100 person-years among White AYMSM (7). Garofalo et al. observed a cumulative incidence of 10.83% among Black AYMSM, 5.17% among Hispanic AYMSM, and 1.67% among White AYMSM in their cohort study of AYMSM aged 16 to 20 years in Chicago (8).

Low condom use and HIV testing among AYMSM

One key challenge for HIV prevention among AYMSM is the low level of condom use. Correct and consistent condom use is highly effective in the prevention of HIV and other sexual transmitted infections (STIs). When used consistently, condoms have a 71% effectiveness in preventing the transmission of HIV through anal intercourse among men who have sex with men (MSM) (11). However, behavioral surveillance data among high school-aged AYMSM show that almost half (52%) reported not using a condom the last time they had engaged in anal intercourse (12) and a meta-analysis of sexual risk behaviors among younger AYMSM reported a similar estimate (50%) (13). Reported condomless anal intercourse (CAI) in the past year among older AYMSM has ranged from 62%, from online-based behavioral surveillance (14), to 73%, from venue-based surveillance (15).

A second critical challenge is the low levels of HIV testing. Nearly half of AYMSM living with HIV infection were unaware of their HIV status in 2018 (2), and AYMSM are more likely than adult MSM to have diagnosed HIV infection (16). Diagnosis of HIV is critical for linking individuals with HIV to care and treatment, which can then reduce the risk of onward transmission, and for linking individuals who test negative to HIV prevention services and counseling. HIV testing is strongly associated with older age (17) among MSM. Based on surveillance data, only 15% of high school-aged AYMSM had ever tested for HIV (12). For older AYMSM, estimates for having tested in the past year range from 45%, among those aged 15 to 24 years from online-based surveillance (18), to 79%, among those aged 18 to 24 years from venue-based surveillance (19). Trend analyses of online- and venue-based surveillance show that HIV testing among AYMSM has not increased over time (18,20).

There are also differences in undiagnosed HIV infection and HIV testing by race/ethnicity and urban-rural geography. Black and Hispanic/Latinx AYMSM report higher levels of testing compared to White AYMSM (21,22) but are less likely to be aware of their HIV infection, and therefore less likely to be linked to care early in their HIV infection (22). In 2018, 51% of Hispanic AYMSM had undiagnosed HIV infection, followed by 44% among Black and 43% among White AYMSM (2). For urban-rural differences, previous studies, primarily conducted among MSM 18 years and older, have found that HIV testing was less likely among those residing in rural, compared to urban, areas, after adjusting for individual-level demographic, socioeconomic, and HIV risk factors (23). Of the few studies that have examined testing among AYMSM less than 18 years of age, only two have included rural AYMSM, and both studies did not observe an association between urban-rural residence and HIV testing, though this may have been due to small sample size of rural participants (21,24).

Challenges in HIV prevention and testing access and utilization among AYMSM

Individual-level

Addressing low levels of condom use and HIV testing among AYMSM is essential for reducing HIV risk and incidence in this population. However, our understanding of how best to reach this population with effective HIV prevention and testing interventions is limited. Reaching AYMSM is challenging given the complex factors related to their younger age and sexual minority identity, in addition to minority racial and ethnic identities for AYMSM of color.

The intersection of these identities may mean that AYMSM are especially vulnerable to HIV risk due to their limited knowledge about sexual health and HIV prevention (25,26); limited resources to access HIV prevention tools or services (27); developing cognitive ability to accurately assess and perceive their HIV risk (26,28); and anticipated or experienced stigma related to their sexual minority status or having HIV (29–31).

Structural-level

Contextual features of AYMSM's residential environment may also play a role in their access and utilization of HIV prevention and testing services. Place-based factors, such as those within a neighborhood, have been studied for their effects on health among adolescents and young adults (32,33). Within HIV, the role of "neighborhood effects" on HIV risk and access to HIV-related services has received much attention as well. The HIV epidemic in the U.S. has been geographically patterned, and areas of high HIV prevalence and incidence have been characterized by high levels of socioeconomic disadvantage and economic and racial segregation (34,35). This has highlighted the role of structural drivers in the prevention of HIV at the population-level. Structural factors, or those relating to the physical, social, material, and policy features of an environment, shape the distribution of resources and barriers, and thereby impede or facilitate an individual's efforts to avoid HIV infection (35–38).

Neighborhood disadvantage and racial residential segregation are two structural factors that have been linked to individual-level risk behaviors and have been examined as the drivers of the disparities in HIV by race/ethnicity and economic status (34,39). Among AYMSM, previous studies, though few, have found associations between neighborhood disadvantage and segregation with sexual risk behaviors, like CAI and early sexual initiation (38,40,41), HIV testing (38,42), and linkage and retention in HIV care and treatment (43). Among AYMSM, racial segregation, most commonly operationalized as concentration of Black residents within a neighborhood, has been associated with HIV testing and testing intentions (42). Black racial concentration at the neighborhood-level has also been associated with higher rates of new HIV diagnoses (44) and late HIV diagnoses (45) among adult men.

The urbanicity or rurality of AYMSM's residential environment is also a structural factor in HIV prevention among AYMSM. The geography of where AYMSM live, whether urban or rural, can shape their access and utilization of health services, as well as their decisions to disclose their sexual identity. Compared to urban areas, rural areas have less access to health services given few primary care providers and health facilities per capita and less access to health insurance (46,47). For sexual minority individuals residing in rural areas, these barriers may be further compounded by sexual identity-related stigma due to their gay, bisexual, or other minority sexual identity. There may also be fewer HCPs who are LGBT-friendly and knowledgeable about LGBT health in small towns and rural areas (48,49). This stigma, whether perceived, experienced, or anticipated, can influence AYMSM's decision to seek health services and whether they disclosure their sexual identities to a health care provider. Disclosure of sexual identity to a health care provider has been repeatedly linked to increased counseling on sexual health and HIV prevention and uptake of STI and HIV testing (21,26,30,50).

Relevance for AYMSM

Given these challenges, it is critical to understand the multilevel relationships between these place-based factors and HIV prevention among AYMSM. Despite attention to place-correlates of HIV risk behaviors, our understanding of place-based correlates and HIV prevention access and uptake, among AYMSM especially, is limited (35). These challenges have long been recognized, and structural HIV prevention interventions, such as the expansion of HIV testing services and the provision of free condoms, have been implemented at the community- and neighborhood-levels (51,52). Assessing these multilevel relationships can elucidate which AYMSM benefit, or not, from structural HIV prevention interventions implemented at the community- or neighborhood-levels. Additionally, understanding how structural place-based factors affect HIV prevention behaviors, access, and utilization can help us to better tailor HIV prevention efforts and understand how best to deliver combination HIV prevention given the structural barriers AYMSM face in their residential environments. Biomedical and behavioral HIV prevention will not succeed without also addressing these structural barriers to AYMSM's access and utilization (36,37,53).

Dissertation Goal and Specific Aims

The overarching goal of this dissertation was to utilize a multilevel approach to explore the association between structural place-based factors in the residential environment and HIV prevention among gay, bisexual, and other AYMSM. The specific aims are:

> <u>Aim 1</u>: To examine the cross-sectional association between urban-rural residence and sexual identity disclosure, to anyone and to health care providers specifically, by perceptions of neighborhood tolerance for minority sexual identities among AYMSM aged 15 to 24 years with HIV-negative or HIV-unknown status.

> <u>Aim 2</u>: To examine the separate, cross-sectional associations between area-level disadvantage and local racial/ethnic spatial concentration with receipt of free condoms by race/ethnicity among AYMSM aged 15 to 24 years with HIV-negative or HIV-unknown status.
>
> > Aim 2.1: To assess multiplicative and additive interaction between the place-based factors, area disadvantage and local racial/ethnic spatial concentration, and AYMSM's race/ethnicity on receipt of free condoms.

> <u>Aim 3</u>: To examine the separate, cross-sectional associations between area-level disadvantage and local racial/ethnic spatial concentration with having ever tested for HIV by race/ethnicity among AYMSM aged 15 to 24 years with HIV-negative or HIV-unknown status.
>
> > Aim 3.1: To assess multiplicative and additive interaction between the place-based factors, area disadvantage and local racial/ethnic spatial concentration, and AYMSM's race/ethnicity on having ever tested for HIV

Chapter 2 Urban-rural residence and sexual identity disclosure among adolescent and young adult men who have sex with men

ABSTRACT

Background: Sexual identity disclosure to a health care provider (HCP) has been linked with increased HIV and STI testing among gay, bisexual, and other adolescent and young men who have sex with men (AYMSM). Structural place-based factors, like urban-rural residence and sexual identity-related stigma, may influence AYMSM's decision to disclose their sexual identities, including to HCPs, and their overall utilization of health care. We assessed the relationship between these place-based factors and disclosure, to anyone and to HCP specifically, by perceived neighborhood tolerance of gay and bisexual individuals.

Methods: We used individual-level data for AYMSM aged 15 to 24 years from the 2017-2019 cycles of the American Men's Internet Survey (AMIS), an annual internet-based survey of HIV risk, prevention, and testing behaviors. Disclosure to anyone and to HCP were binary variables. Urban-rural residence was classified into urban, suburban, small and medium metro (SMM), or rural and identified based participants' ZIP Code. Perceived neighborhood tolerance was measured as tolerant, neutral, or intolerant. Generalized estimating equations were used to estimate odds ratios (ORs) of the residence and disclosure relationships which were stratified by tolerance level.

Results: Sexual identity disclosure was consistently high regardless of where AYMSM resided. Disclosure to HCP was lower. There was a consistent pattern of less disclosure to anyone among AYMSM residing in suburban (OR 0.93, 95% confidence interval (CI) 0.65, 1.34), SMM (OR 0.67, 95% CI 0.48, 0.93), and rural (OR 0.51, 95% CI 0.31, 0.82) areas compared to urban AYMSM, among those who perceived their neighborhoods to be tolerant. For disclosure to HCP, this same pattern was observed, with AYMSM in rural areas (OR 0.64, 95% CI 0.47, 0.87) being least likely to have disclosed compared to AYMSM in urban areas. Greater overall disclosure was associated with residing in SMM areas, compared to urban areas, among AYMSM who were neutral about their neighborhood's tolerance and with residing in suburban areas among AYMSM who perceived their neighborhoods to be intolerant.

Conclusion: Urban-rural residence and sexual identity-related stigma may play an important role in AYMSM's sexual identity disclosure. Further research is needed to understand how these environments shape AYMSM's disclosure overall and to HCPs specifically to their facilitate access and utilization of HIV prevention services.

INTRODUCTION

Adolescent and young men who have sex with men (AYMSM) face complex and multilevel barriers in accessing and utilizing health care services. Compared with their non-sexual minority peers and with older men who have sex with men (MSM), AYMSM are more likely to have unmet medical and mental health needs and lower levels of accessing health services (54,55). This gap between unmet need and utilization is especially concerning because AYMSM are disproportionately affected by certain adverse health outcomes, such as HIV and sexually transmitted infections (STIs) (3,17,18,56–58) and may be more likely to engage in risky health behaviors like smoking and alcohol and substance use (48). Because adolescent and young adulthood are critical phases of human development that shape health and overall wellbeing during adulthood (28), understanding the barriers this vulnerable population faces in health care access and utilization is critical.

However, data on AYMSM's access and utilization of health care are limited. Based on nationally-representative data, males aged 18 to 24 years in the U.S. are least likely to have a usual place to go for medical care compared to males of other age groups and to females of all ages; three out of 10 males in this age group did not have a usual place for care in 2017 (59). A 2010-2016 trend analysis of a nationally-representative sample of children, adolescents, and young adults found that declines in insurance coverage and access to care began at 10 to 14 years or age. Young adults, aged 19 to 25 years, were most likely to be uninsured and least likely to have a usual source of preventive care, to have a doctor visit in the past year, and to have delayed needed health care due to cost (60). Studies on health care utilization among lesbian, gay, bisexual, and transgender (LGBT) populations have observed that LGBT individuals may be less likely to use preventive health services than their non-sexual minority peers (48,61,62) and more likely to experience stigma related to their sexual identity (48,50,63,64). In addition to their age and minority sexual identity, AYMSM who have minority racial and ethnic identities, especially those who are Black or Hispanic, face further intersectional vulnerability. An analysis of the U.S. National Health Interview Survey found that among adolescents aged 10 to 17 years, Black and Hispanic adolescents were less likely to have a usual place for preventive care and have a well-child checkup than White adolescents (65). Among adult MSM, these racial and ethnic disparities in access and utilization have been observed as well (5,66). A cohort study of Black and White adult MSM in Atlanta found having health insurance explained much of the disparity in HIV incidence rates between the two groups (7).

Based on Andersen's Behavioral Model for Health Service Use, there are predisposing, enabling, and need conditions that operate at the individual and contextual levels that lead one to utilize, or not, health services (67,68). The contextual level represents the circumstances and environment of health care access, and these factors are measured at an aggregate level that can range from a family unit to the community to national-level systems (67). Predisposing conditions are the demographic and social characteristics of an individual or contextual environment, as well as beliefs or norms around health and health care access. Enabling conditions are those factors related to financing and the organization of health care, or more broadly, the resources available in the area that facilitate use of health services (69). At an individual-level, this may mean having transportation to get to care, having the financial resources to pay for care, and having a regular provider of care. At a contextual level, enabling conditions can span from the community-level to the national-level; examples of these factors include national-level health policies, community-level financial resources available to pay for health services, and the structural organization of health services, such as distribution of health facilities and health care providers (HCPs). Individual-level need conditions represent the individual's perceived need for health care and the evaluated need, as assessed by a HCP. Contextual-level need conditions include the health-related measures of the physical environment (e.g. clean air and water) and population-level indicators of health (e.g. rates of mortality, cardiovascular disease, or HIV).

For AYMSM, younger age and minority sexual identity are defining predisposing factors that impede their access to health care. They may lack the financial resources to travel to and/or pay for health services (54,70). Additionally, navigating the administrative process of health care systems and health insurance to engage and remain in health care is also a major challenge, especially for this age group given their cognitive development of planning and abstract thinking skills (27). Privacy and confidentiality concerns in health care are also a critical concern. In a nationally-representative study of adolescents and young adults aged 11 to 21 years, participants with a minority sexual identity reported not seeking medical care when needed due to not wanting their parents to know and fearing what the doctor would say or do if they had to disclose their sexual identity (54). Another study found that AYMSM who had primary care providers would rather refuse prevention services rather than risk disclosure of their sexual identity to parents, due to the provider or to insurance explanation of benefits documentation (27). Additionally, given their younger age, AYMSM may perceive themselves to be in good health and at low risk for adverse health outcomes, making the perceived need for health care low (63).

Sexual identity-related stigma at the individual and contextual levels is another predisposing factor that poses a considerable barrier for AYMSM in accessing health care. As conceptualized by Link and Phelan, stigma represents the co-occurrence of labeling, stereotyping, separation, status loss, and discrimination in a context where power dynamics exist (71). Regarding sexual identity, this stigma may represent the anticipated, enacted, or perceived negative experiences AYMSM may have due to their minority sexual identity. AYMSM may experience unequal treatment in their everyday interactions, such as at home, school, or work, and there may also be societal conditions that constrain their opportunities, resources, and well-being (72). Regarding health care, AYMSM may have internalized negative feelings about their gay or bisexual identities, fear disclosing their sexual identity to HCPs, or anticipate poor treatment in health care settings (63,64,73). In their qualitative study of healthcare preferences among gay and bisexual individuals in four cities in the U.S., Martos et al. found that stigma was most often associated with participants' preferences for seeking lesbian, gay, or bisexual (LGB) HCPs, with whom they could speak openly about their sexual identities and behaviors (74).

As such, sexual identity disclosure to HCPs may play an important role in AYMSM's engagement with health care. Sexual identity disclosure is the disclosure of one's sexual identity as gay, bisexual, or other non-heterosexual identity to others and is an important milestone in the sexual identity development of AYMSM (30,75). The decision to disclosure, to whom, and to what extent may be shaped by norms in their physical and social environments around gay and bisexual identities, especially if there are expectations of and/or experiences of stigma against sexual minority identities (29,30,76).

Patient-provider communication around sexual identity, including sexual identity disclosure, is an enabling factor that may play a significant role in AYMSM's engagement with health services. Given their high vulnerability to sexual health risks and low levels of health care utilization, discussion of same-sex behaviors between AYMSM and their providers is critical in ascertaining their risk behaviors, necessary screening and testing, and appropriate prevention counseling and is therefore recommended by the American Academy of Pediatricians (77). Among adult MSM, sexual identity disclosure to HCP has been associated with higher levels of positive health behaviors and increased use of health services (26,50,78–82), such as HIV testing (79), STI screenings, such as for gonorrhea and syphilis (81,82), and receipt of recommended vaccines, such as for Hepatitis A and B (81,82). The few studies that have examined sexual identity disclosure in patient-provider relationships among AYMSM have also found positive associations between sexual identity disclosure to HCPs and increased HIV testing and HIV prevention counseling, compared to AYMSM whose providers were not aware of their sexual identity (21,26).

The geography of where AYMSM live, whether urban or rural, can shape their access and utilization of health services. Compared to urban areas, rural areas have less access to health services given few primary care providers and health facilities per capita and less access to health insurance (46,47), despite having higher burdens of disease (83) and mortality (84). This growing disparity between rural and urban health outcomes in the U.S. has been included as a top health disparity concern in Healthy People 2020 (85). For sexual minority individuals, these barriers are further compounded by the lack of HCPs who are LGBT-friendly and knowledge about LGBT health (48,49).

Urban-rural geography may also influence AYMSM's decisions to disclose their sexual identity in general and to HCPs specifically. AYMSM residing in suburban, small metropolitan, and rural neighborhoods may have less access to LGBT community and resources, as compared to their urban counterparts. AYMSM face sexual identity-related stigma in every environment, but urban areas may have a more LGBT-friendly culture compared to non-urban areas. Studies examining urban-rural differences among adult MSM have found MSM in rural were less likely to have disclosed their sexual identity to their primary care providers than MSM in urban areas (79,86).

However, the relationship between urban-rural residence and sexual identity disclosure among AYMSM has been understudied. We have limited information regarding sexual identity disclosure patterns by urban-rural residence and sexual identity disclosure in general for AYMSM less than 18 years of age, as this information has not been collected in venue- and school-based behavioral surveillance systems that include AYMSM (12,19). Online-based behavioral surveillance among MSM, as a complementary approach to venue-based surveillance, has been successful in recruiting participants less than 18 years of age and who reside in diverse urban-rural residential environments (18). Given these strengths, we utilized data from an online-based sample of AYMSM and explored the relationship between urban-rural residence and sexual identity disclosure among AYMSM. The specific aims were to:

- Describe patterns of sexual identity disclosure and disclosure to a HCP by urban-rural residence
- Examine the association between urban-rural residence and sexual identity disclosure to anyone by perception of neighborhood sexual identity-related stigma.
- Among those who have disclosed their sexual identity to anyone, examine the association between urban-rural residence and disclosure to HCP by perception of neighborhood sexual identity-related stigma.

METHODS

Study Design

Data sources

Individual-level data were from the 2017 to 2019 cycles of the American Men's Internet Survey (AMIS). AMIS is an annual cross-sectional, internet-based survey of HIV risk behaviors, HIV prevention, and access to HIV-related health services among gay, bisexual, and other MSM, with the aim of collecting at least 10,000 completed surveys from eligible MSM. The survey's methodology has been previously detailed (14). Briefly, men were eligible to participate if they were 15 years of age or older, reside in the U.S., reported ever having oral or anal sex with a man or identify as gay or bisexual, and were able to complete the survey in English. Participants were recruited online through convenience sampling in two ways. First, advertisements (ads) for a survey on men's sexual health were placed as banner ads on a variety of websites and social media applications. Men who clicked on these ads were taken to the survey website to be screened for eligibility and undergo the informed consent process.

Second, participants were also recruited through emailing participants of previous cycles who had consented to be contacted for potential participation in future studies. Men who were eligible and provide consent are then immediately directed to the self-administered survey, which was completed on a computer or mobile device. AMIS asked questions along the following domains: demographics, sexual behavior, stigma, HIV testing history, STIs, and utilization of HIV prevention services. The survey also collected participants' ZIP Code of residence. Participants did not receive incentives for study participation. Survey data were collected using encrypted HIPAA-compliant survey software and stored on an access-restricted secure data server, administered by SurveyGizmo (Boulder, CO, USA).

The area unit of analysis was the ZIP Code Tabulation Area (ZCTA), the U.S. Census Bureau's areal approximation of the U.S. Postal Service's ZIP Code system. Using participants' ZIP Code, we identified their respective ZCTA, and ZCTA-level characteristics were abstracted from the American Community Survey (ACS), using the five-year estimates for 2014-2018.

For our analyses, participants were eligible if they reported being 15 to 24 years age, HIV-negative or unknown status, and resided in the 50 states of the U.S. Given our aim of examining the relationship between urban-rural residence and sexual identity disclosure, we excluded participants who did not report a ZIP Code due to housing instability; resided in U.S. territories; and reported ZIP Codes associated with military bases, as indicated by Army Post Office (APO) or Fleet Post Office (FPO). Based on these criteria, there were 10,981 participants eligible for analyses.

Measures

Our outcomes were sexual identity disclosure overall and to a HCP specifically. Participants were asked, "Have you ever told anyone that you are attracted to or have sex with men?" and responses were categorized as yes/no. Among participants who reported disclosing their sexual identity to anyone, they were asked if they had told a HCP they are attracted to or have sex with men. Disclosure to HCP was also measured as yes/no variable.

Urban-rural residence, the exposure, was classified as urban, suburban, small and medium metro (SMM), and rural based on the participant's ZIP Code. These classifications were based on the National Center for Health Statistics (NCHS) 2013 urban-rural classification scheme (87) which considers population size and the U.S. Office of Management and Budget's

(OMB) delineation of metropolitan and nonmetropolitan areas. For our study, urban areas were defined as large central metro areas, or areas in metropolitan statistical areas (MSAs) with a population of 1 million or more. Suburban areas were large fringe metro areas, or those areas in MSAs with 1 million or more population that did not qualify as large central metro areas. Medium metro areas are those in MSAs that have a population size of 250,000 to 999,999, and small metro areas have populations of less than 250,000. Non-metropolitan areas are divided into micropolitan statistical areas, 10,000-49,999 population, and areas with less population are considered noncore areas. For our analysis, non-metropolitan areas were classified as rural.

We examined covariates at the individual- and area-levels in our analysis for effect modification and for potential confounding. Individual-level covariates included age, race/ethnicity, sexual identity, level of education, health insurance status, and having seen a HCP in the past year. There were three sexual identity-related stigma covariates. Experienced stigma due to sexual identity was ascertained by asking participants about having ever experienced the following: being called names or insulted; receiving poorer service at restaurants, retail outlets, or other businesses; being treated unfairly at work or school; being denied or provided with lower quality health care, and being physically attacked or injured. These yes/no questions were then categorized into no, one, or two or more experiences. For sexual identity-related stigma in health care, participants were asked about anticipated and experienced stigma related to health care (73): whether they were afraid to go to health care services because someone may learn they have sex with men; whether they avoided going to health care services because someone may learn they have sex with men; whether they had heard HCPs gossiping about them because they had sex with men; and whether they felt they were not treated well in a health center because someone knew they had sex with men. These were measured as yes/no and then summed to create a sexual identity-related stigma in health care score. Perceived neighborhood tolerance for gay and bisexual individuals was also measured. Participants were asked to evaluate their neighborhood's tolerance of gay and bisexual individuals by rating their level of agreement with the statement, “Most people in my area are tolerant of gays and bisexuals.” Possible response ranged from strongly agree to strongly disagree with a neutral option and were then collapsed into three levels: agree, neutral, and disagree. For the ZCTA-level covariates, we considered region of country, percent of adults aged 15 years or older who had less than a high school degree, percent of individuals with health insurance, median household income, and percent of households with a same-sex couple.

Statistical Analyses

We first described the study population by presenting their demographic, socioeconomic, and health-related characteristics by their disclosure status and residence. To examine the exposure and outcome associations, we conducted multilevel, multivariable modeling using generalized estimating equations (GEE) with a binomial distribution and logit link and an exchangeable correlation structure, which accounted for clustering by ZCTA. Subjects with missing data for the outcome and/or covariates were excluded from the analyses. Our modeling strategy first examined the unadjusted association between exposure and outcome and then proceeded to examine interaction between urban-rural residence and perceived neighborhood tolerance perception on the multiplicative scale (interaction-only model). In the fully adjusted model, we adjusted for individual-level (age, race/ethnicity, education, sexual identity, and experienced sexual identity-related stigma) and ZCTA-level covariates (region, median household income, percent with less than a high school education, and percent of same-sex households) to address potential confounding. For the residence and disclosure to a HCP association, the models were adjusted for the same covariates, in addition to health insurance status, seeing a HCP in the past year, and sexual identity-related stigma in health care. These covariates were selected based on their associations with sexual identity disclosure, overall and to HCPs specifically, from previous literature (30,50,63,74,78,88,89). We also examined collinearity among the covariates, and the ZCTA-level percent of individuals with health insurance was not included in the models due to collinearity issues.

Missing data and sensitivity analyses

There were 10,023 participants who had disclosed their sexual identity, and 28% (2,787) did not respond to the subsequent question asking whether they had disclosed their sexual identity to a HCP, the second outcome of interest. We did not find any meaningful differences between those who responded and those who did not by age, education, or sexual identity. Those who were missing disclosure to HCP data had a higher proportion of missing for health insurance status (16% versus 10%) and having seen a health provider in the past year (13% versus 4%), compared to those who did not have missing data. There were 4,105 participants (41%) who were missing data on at least one covariate.

We conducted sensitivity analyses to assess the impact of the missingness in disclosure to a HCP. Multiple imputation (MI) using chained equations was used to impute the missing outcome data in two ways. We conducted multiple imputation to impute the missing values for the outcome as well as covariates that had missingness and then conducted the regression analyses on the imputed data for the outcome and covariates. Since the missingness was primarily in the outcome, we explored a second method of imputing only the outcome using the auxiliary variables of having ever tested for HIV and STIs for the study population and then regressed the imputed outcome over the observed data for the covariates. When compared to the model estimates from the complete-case analysis, there were no meaningful differences across the three methods, and as such, the results from the complete-case regression analyses are presented.

All analyses were conducted using SAS 9.4 (Carey, NC, USA). AMIS was reviewed and approved by the Emory University Institutional Review Board.

RESULTS

Participant and ZCTA characteristics

There was a total of 10,981 participants aged 15 to 24 years of age who reported HIV-negative or unknown status who were eligible for our analysis (Table 2.1). The mean age was 20 years (standard deviation (SD): 2.5), and 58% were White, non-Hispanic (NH), 6% Black, non-Hispanic, and 24% Hispanic (Table 1). Almost three-fourths of the participants (72%) were homosexual, or gay, and 23% were bisexual. Participants largely resided in SMM areas (34%) and in urban areas (32%). Sexual identity disclosure was high, with 91% reporting they had disclosed they had sex with men to anyone. Notably, 53% of those who had not disclosed their sexual identity were bisexual. Among those who had disclosed and responded, 49% were had disclosed their identity to a HCP.

There were 6,185 ZCTAs represented amongst the participants (Table 2.2). A third of the ZCTAs was in SMM areas, followed by urban (28%), suburban (24%), and rural (14%). Overall, 38% of ZCTAs were in the South. Urban ZCTAs were the most racially and ethnically diverse, with residents of color accounting for 45% (interquartile range (IQR): 26%, 71%) of the population, compared to 101% (IQR: 4, 23) in rural areas and about 22% in suburban (23%, IQR: 12, 40) and SMM areas (21%, IQR: 11, 38). Suburban ZCTAs had the lowest median percentage of individuals with less than a high school degree (7%, IQR: 4, 11). Suburban areas also had the highest median household income (MHI) (USD $82,000) and the lowest proportion of households living in poverty (7%, IQR: 5, 12). In comparison, rural areas had the highest median proportion of individuals with less than a high school degree (13%, IQR: 8, 18), the lowest median MHI (USD $50,000), and the highest median proportion of households living in poverty (16%, IQR: 12, 21). The median percentage of same-sex households was 0.2% in the ZCTAs represented. This was largest in urban ZCTAs (0.4%, IQR: 0.2, 0.7) and lowest in rural ZCTAs (0.01%, IQR: 0, 0.3).

Table 2.1 Characteristics of participants aged 15 to 24 years reporting HIV-negative or HIV-unknown status by sexual identity disclosure status, AMIS 2017-2019

	Total		Not disclosed		Disclosed		Among disclosed:					
							Missing		Disclosed to HCP		Not disclosed to HCP	
	n	%[*]	n	%	n	%	n	%	n	%	n	%
	10,981		768		10,023		2,786		3,693		3,544	
Age (years)												
15-17	1,684	15.3	153	19.9	1,500	15.0	480	17.2	763	20.7	257	7.3
18-20	4,415	40.2	342	44.5	4,004	39.9	1,110	39.8	1,647	44.6	1,247	35.2
21-24	4,882	44.5	273	35.5	4,519	45.1	1,196	42.9	1,283	34.7	2,040	57.6
Mean (SD)	20	2.5	19	2.4	20	2.5	20	2.5	19	2.4	21	2.3
Sexual identity												
Homosexual or gay	7,889	71.8	201	26.2	7,584	75.7	2,126	76.3	2,575	69.7	2,883	81.3
Bisexual	2,544	23.2	407	53.0	2,101	21.0	592	21.2	946	25.6	563	15.9
Heterosexual	154	1.4	100	13.0	48	0.5	-[†]	-	-	-	-	-
Other	170	1.5	7	0.9	145	1.4	-	-	61	1.7	62	1.7
Race/ethnicity												
White, NH	6,415	58.4	384	50.0	5,935	59.2	1,645	59.0	2,160	58.5	2,130	60.1
Black, NH	641	5.8	60	7.8	566	5.6	119	4.3	224	6.1	223	6.3
Other/multiple race	1,076	23.9	81	29.4	969	23.5	288	23.9	354	24.1	327	22.5
Hispanic	2,625	9.8	226	10.5	2,353	9.7	666	10.3	890	9.6	797	9.2
Education												
< HS diploma	1,680	15.3	149	19.4	1,500	15.0	454	16.3	784	21.2	262	7.4
HS diploma or equivalent	2,856	26.0	243	31.6	2,565	25.6	689	24.7	1,069	28.9	807	22.8
Some college or technical degree	4,143	37.7	232	30.2	3,834	38.3	1,020	36.6	1,271	34.4	1,543	43.5

[*] Percentages may not equal 100% due to missing data.
[†] Numbers below 50 not shown

College degree or postgraduate education	2,120	19.3	122	15.9	1,966	19.6	564	20.2	503	13.6	899	25.4
Education on track	9,802	89.3	664	86.5	8,973	89.5	2,519	90.4	3,300	89.4	3,154	89.0
Region												
Northeast	1,843	16.8	106	13.8	1,705	17.0	450	16.2	589	15.9	666	18.8
Midwest	2,282	20.8	156	20.3	2,082	20.8	566	20.3	799	21.6	717	20.2
South	4,286	39.0	324	42.2	3,897	38.9	1,114	40.0	1,512	40.9	1,271	35.9
West	2,570	23.4	182	23.7	2,339	23.3	656	23.5	793	21.5	890	25.1
Rural / Urban												
Urban	3,513	32.0	219	28.5	3,230	32.2	911	32.7	1,054	28.5	1,265	35.7
Suburban	2,526	23.0	190	24.7	2,292	22.9	637	22.9	880	23.8	775	21.9
Small/med Metro	3,784	34.5	266	34.6	3,450	34.4	957	34.4	1,283	34.7	1,210	34.1
Rural	1,158	10.5	93	12.1	1,051	10.5	281	10.1	476	12.9	294	8.3
Health insurance												
Uninsured	3,268	29.8	171	22.3	3,071	30.6	341	12.2	1,411	38.2	1,319	37.2
Private	4,425	40.3	307	40.0	4,026	40.2	1,460	52.4	1,150	31.1	1,416	40.0
Public only	1,228	11.2	92	12.0	1,105	11.0	308	11.1	423	11.5	374	10.6
Other/multiple	736	6.7	59	7.7	660	6.6	224	8.0	212	5.7	224	6.3
HCP visit in past year	8,543	77.8	532	69.3	7,914	79.0	1,960	70.4	2,825	76.5	3,129	88.3

Table 2.2 Characteristics of participant ZCTAs by urban-rural residence classification, AMIS 2017-2019

	Total	Urban	Suburban	Small/Med Metro	Rural
	%	%	%	%	%
N =	6,185	1,743	1,508	2,065	869
Region					
Northeast	18.1	16.1	27.7	27.7	12.2
Midwest	21.7	15.7	22.4	22.4	32.1
South	38.4	33.9	37.6	37.6	42.2
West	21.8	34.4	12.3	12.3	13.5
			Median (IQR)		
Population					
Race/ethnicity					
Persons of color	25.3 (12.1, 48.1)	45.2 (26.4, 71.5)	23.0 (12.1, 40.3)	21.3 (10.7, 38.1)	10.5 (4.3, 22.9)
Black, NH	4.8 (1.5, 13.4)	7.4 (3.1, 18.2)	5.0 (1.7, 12.8)	4.4 (1.4, 12.4)	1.4 (0.4, 5.0)
Hispanic	8.1 (3.6, 19.3)	16.1 (6.8, 34.6)	7.9 (3.7, 15.6)	6.6 (3.3, 15.5)	3.6 (1.6, 8.8)
Less than high school diploma or equivalent (among adults 25+ years)	9.2 (5.4, 15.1)	9.7 (5.1, 17.6)	7.1 (4.5, 11.3)	9.2 (5.5, 14.4)	12.6 (8.3, 17.9)
Has health insurance	92.6 (88.3, 95.4)	92.0 (87.0, 95.2)	94.3 (90.4, 96.5)	92.5 (88.5, 95.1)	91.7 (87.6, 94.2)
Households					
Same-sex household	0.2 (0.1, 0.5)	0.4 (0.2, 0.7)	0.2 (0.1, 0.4)	0.2 (0.0, 0.5)	0.01 (0.0, 0.3)
Median household income (2019 USD)	63,000 (49,000, 84,000)	67,000 (51,000, 89,000)	82,000 (64,000, 105,000)	58,000 (47,000, 71,000)	50,000 (42,000, 57,000)
Living in poverty	11.9 (7.1, 18.8)	12.5 (7.6, 20.4)	7.5 (4.7, 11.9)	13.1 (8.2, 20.0)	16.2 (11.7, 21.4)
Gini index	0.43 (0.40, 0.47)	0.45 (0.41, 0.49)	0.42 (0.39, 0.45)	0.44 (0.40, 0.57)	0.44 (0.41, 0.47)

Participant characteristics by urban-rural residence

AYMSM in rural (mean 20 years, SD 2.4) and suburban areas (mean 20 years, SD 2.5) were slightly younger than AYMSM residing in urban (mean 20 years, SD 2.5) and SMM areas (mean 20 years, SD 2.4) (Table 2.3). The proportions of AYMSM who were homosexual or gay and bisexual were similar across the residence areas, with approximately 72% of participants reporting being gay and 23-25% reporting being bisexual. Participants residing in urban and suburban areas were more racially and ethnically diverse than participants residing in small/medium metropolitan and rural areas. AYMSM of color accounted for half of the participants in urban areas, whereas in rural areas, they accounted for 27%. A third of AYMSM in rural areas did not have health insurance, compared to 29% for urban AYMSM and around 30% for AYMSM residing in suburban and SMM areas. Between 78% and 79% of AYMSM in urban, suburban, and SMM areas reported visiting a HCP in the past year; 74% of rural AYMSM reported visiting a HCP in the past year. Levels of sexual identity disclosure were similarly high across the residence areas, with 92% among urban AYMSM and approximately 91% in the other three residence areas. Of those who had disclosed their sexual identity, 36% of AYMSM residing in urban areas were out to a HCP, and this was lower among AYMSM in suburban (31%), SMM (32%), and rural (25%) areas.

Sexual identity-related stigma by urban-rural residence and disclosure status

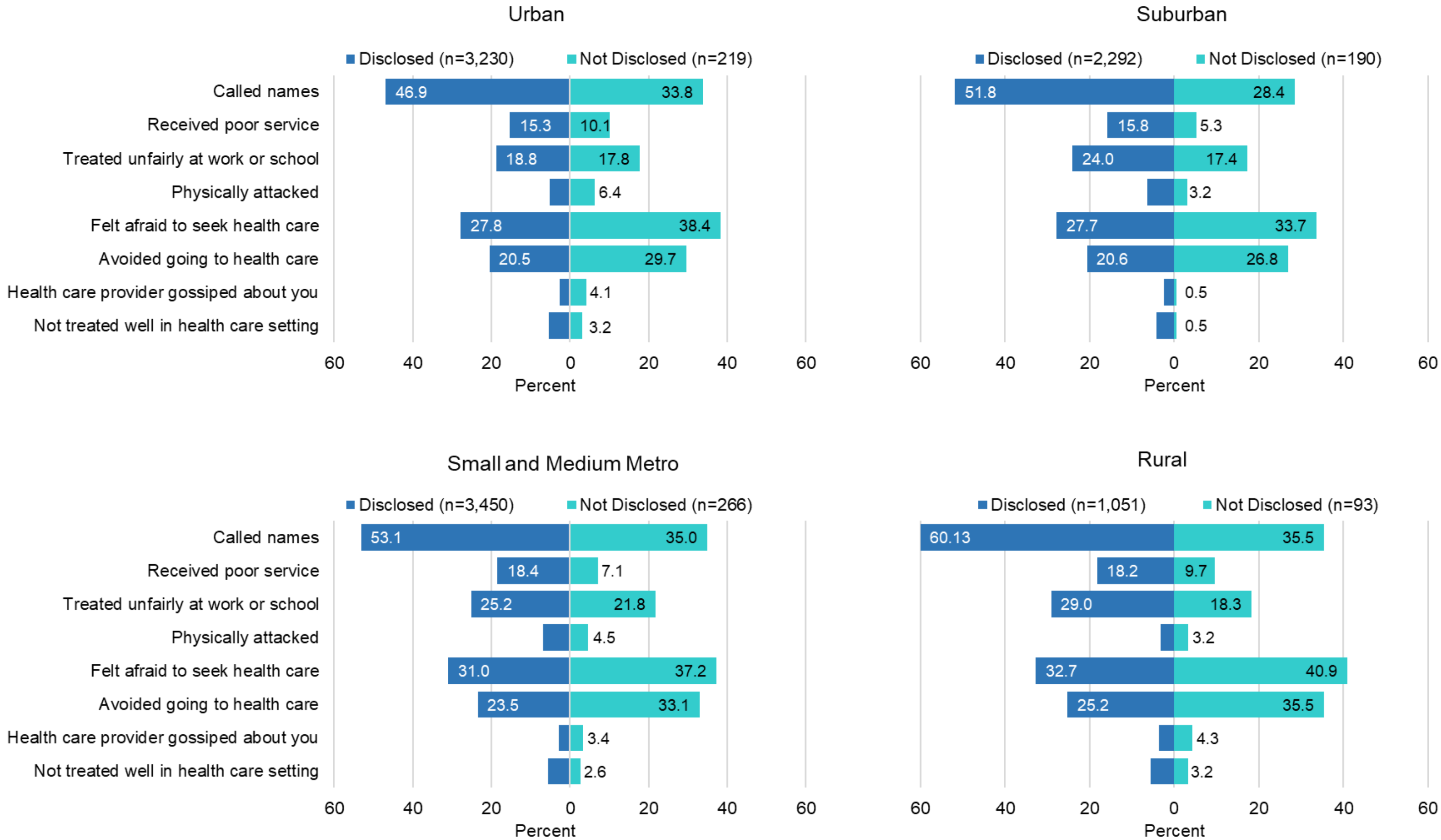
Overall, participants reported experiencing high levels of stigma related to their sexual identity, with 55% reporting one or more experiences of stigma in the past year (Table 2.3). There were differences in perceived neighborhood tolerance of gay and bisexual individuals across the residence categories. AYMSM in urban and suburban areas were more likely to report that their neighborhood was tolerant, at 69% and 62% respectively, compared to 51% of AYMSM in SMM areas and 34% of AYMSM in rural areas. Regarding experienced stigma, rural AYMSM reported the highest proportion of having one or more experiences of stigma due to their sexual identity in the past year, at 61%; this was 51% among urban AYMSM, 55% among suburban AYMSM, and 57% among SMM AYMSM. Being called names or insulted was the most common stigma experience across residence areas and disclosure status, ranging from 47% among AYMSM who had disclosed in urban areas to 60% among those who had disclosed in rural areas (Figure 2.1). Experiencing a physical attack or being injured because someone knew or assumed they had sex with men was reported by 6% of participants overall (data not shown). Regarding the health care-related stigma domains, AYMSM who had not disclosed their sexual identity to anyone reported higher levels of fearing and avoiding health care across all residence categories. Approximately a third of the AYMSM who had not disclosed in SMM (33%) and rural areas (35%) did not seek health services because they worried someone could learn they had sex with men.

Table 2.3 Characteristics of participants aged 15-24 years and reporting HIV-negative or unknown status by residence, AMIS 2017-2019

	Urban		Suburban		Small and Medium Metro		Rural	
	n	%	n	%	n	%	n	%
	3,513		2,526		3,784		1,158	
Age (years)								
15-17	438	12.5	488	19.3	538	14.2	220	19.0
18-20	1,302	37.1	1,086	43.0	1,535	40.6	492	42.5
21-24	1,773	50.5	952	37.7	1,711	45.2	446	38.5
Mean (SD)	20	2.5	20	2.5	20	2.4	20	2.4
Sexual identity								
Homosexual	2,541	72.3	1,788	70.8	2,733	72.2	827	71.4
Heterosexual	45	1.3	39	1.5	57	1.5	13	1.1
Bisexual	796	22.7	594	23.5	869	23.0	285	24.6
Other	64	1.8	35	1.4	57	1.5	14	1.2
Race/ethnicity								
White, NH	1,688	48.1	1,464	58.0	2,444	64.6	819	70.7
Black, NH	229	6.5	174	6.9	198	5.2	40	3.5
Other/multiple race	1,122	31.9	594	23.5	739	19.5	170	14.7
Hispanic	395	11.2	245	9.7	335	8.9	101	8.7
Education								
< HS diploma	432	12.3	484	19.2	531	14.0	233	20.1
HS diploma or equivalent	827	23.5	730	28.9	975	25.8	324	28.0
Some college or technical degree	1,310	37.3	855	33.8	1,540	40.7	438	37.8
College degree or postgraduate education	888	25.3	403	16.0	683	18.0	146	12.6
Education on track	3159	89.9	2257	89.4	3368	89.0	1018	87.9
Health insurance								
Uninsured	1,003	28.6	749	29.7	1,130	29.9	386	33.3
Private	1,500	42.7	979	38.8	1,544	40.8	402	34.7
Public only	423	12.0	229	9.1	423	11.2	153	13.2
Other/multiple	232	6.6	176	7.0	253	6.7	75	6.5
HCP visit in past year	2,747	78.2	1,990	78.8	2,944	77.8	862	74.4
Perceived neighborhood tolerance								
Tolerant	2,429	69.1	1,564	61.9	1,945	51.4	392	33.9
Neutral	575	16.4	481	19.0	850	22.5	282	24.4
Intolerant	359	10.2	371	14.7	854	22.6	441	38.1
Stigma experiences								
None	1,676	47.7	1,093	43.3	1,576	41.6	437	37.7

1	992	28.2	724	28.7	1,079	28.5	332	28.7
2+	813	23.1	663	26.2	1,088	28.8	377	32.6
Disclosed sexual identity	3,230	91.9	2,292	90.7	3,450	91.2	1,051	90.8
Out to HCP among disclosed								
Missing	911	25.9	637	25.2	957	25.3	281	24.3
Yes	1,265	36.0	775	30.7	1,210	32.0	294	25.4

Figure 2.1 Sexual identity-related stigma experiences among participants by residence and disclosure status, AMIS 2017-2019



Relationship between urban-rural residence and sexual identity disclosure (to anyone)

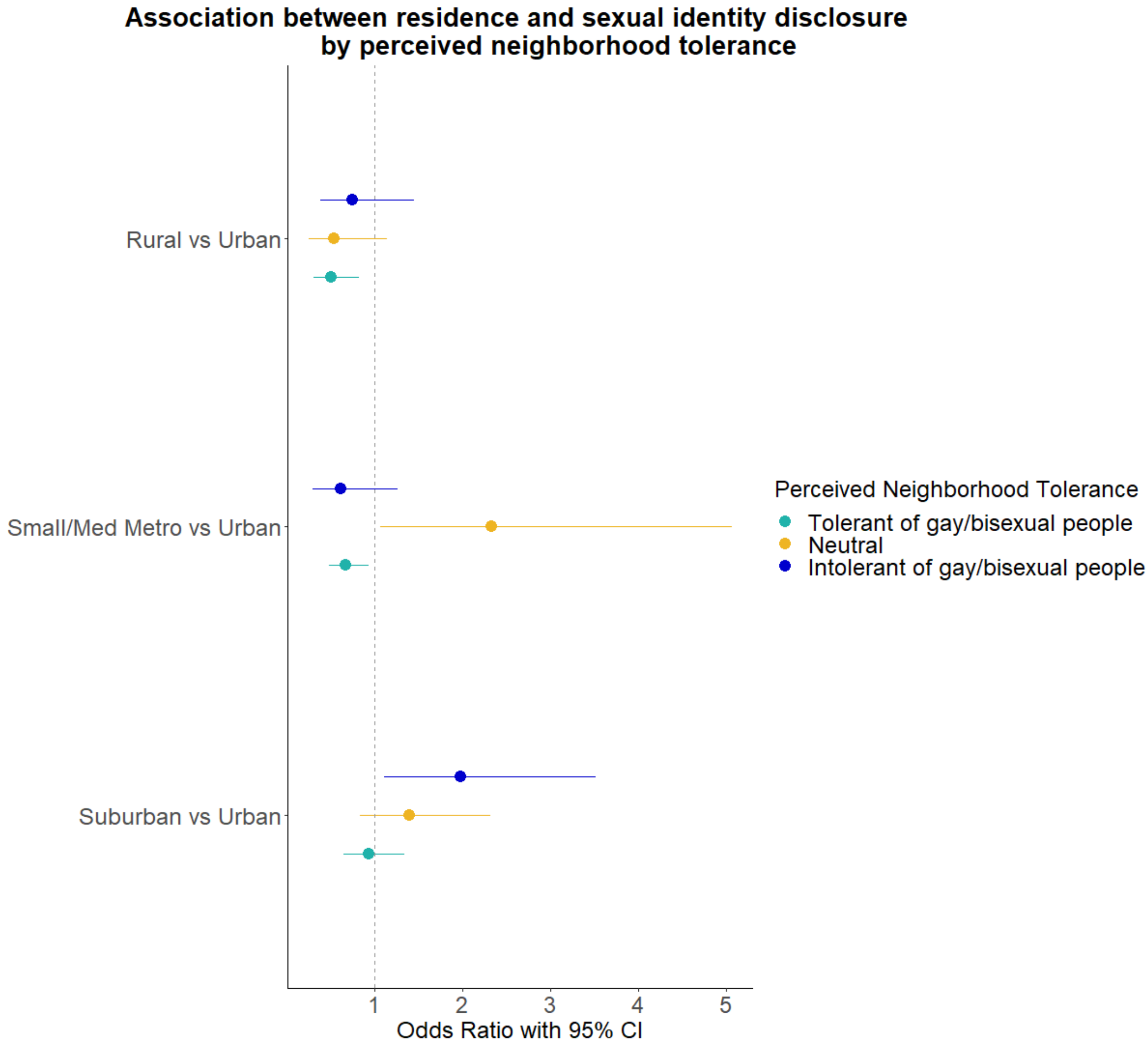
In our unadjusted model, AYMSM residing in non-urban areas were less likely to have disclosed their sexual identity than AYMSM in urban areas (Table 2.4). AYMSM in rural areas were least likely to have disclosed their sexual identity, with a 22% lower odds of disclosure compared to AYMSM in urban areas (odds ratio (OR): 0.78, 95% confidence interval (CI): 0.67, 1.02). AYMSM residing in suburban areas had a 17% lower odds of disclosure (OR 0.83, 95% CI 0.60, 1.01), and AYMSM in SMM areas were more similar to their urban counterparts in their levels of disclosure, with an OR of 0.89 (95% CI 0.73, 1.07).

In the interaction-only model, we observed differences between urban-rural residence and disclosure across the different perceived neighborhood tolerance groups. Among those that perceived their neighborhood to be tolerant, AYMSM residing in the non-urban areas were less likely to have disclosed their sexual identity compared to those in urban areas, with AYMSM in rural areas almost half as likely to have disclosed (OR 0.55, 95% CI 0.36, 0.85). Among those that perceived their neighborhood to be intolerant, AYMSM had similar levels of disclosure in suburban areas compared to urban areas (OR 0.96, 95% CI 0.60, 1.54), whereas AYMSM in SMM and rural areas were more likely to have disclosed their sexual identity (OR 1.22, 95% CI 0.81, 1.85 and OR 1.46, 95% CI 0.89, 2.38 respectively). For AYMSM who were neutral, those living in the three non-urban areas were more likely to have disclosed their sexual identity than their urban counterparts. The OR comparing AYMSM in SMM to those in urban areas was 1.62 (95% CI 1.11, 2.38), and 1.46 (95% CI 0.89, 2.38) comparing rural to urban AYMSM.

In the fully adjusted model that accounted for confounding from individual-level and area-level covariates and the interaction term, the pattern of less disclosure in the three non-urban areas compared to the urban areas among those who perceived their neighborhood to be tolerant remained (Figure 2.1). AYMSM in rural areas were still half as likely as AYMSM in urban areas to have disclosed their sexual identity (OR 0.51, 95% CI 0.31, 0.82). AYMSM in SMM areas were more likely to have disclosed than rural but less likely than urban AYMSM (OR

0.67, 95% CI 0.48, 0.93). Among those that perceived their neighborhood to be intolerant, the OR comparing disclosure between suburban and urban AYMSM was 1.98 (95% CI 1.11, 3.52), which crossed the null from the interaction-only model. In contrast, AYMSM in SMM and rural areas were less likely to have disclosed their sexual identity, with ORs of 0.62 (95% CI 0.30, 1.26) and 0.75 (95% CI 0.39, 1.45) respectively, after adjusting for confounding. This was different than what was observed in the interaction-only model, where they were more likely than urban AYMSM to have disclosed. AYMSM who were neutral about their neighborhood's tolerance level remained more likely to have disclosed their sexual identity if they resided in suburban (OR 1.39, 95% CI 0.84, 2.31) and SMM (OR 2.33, 95% CI 1.07, 5.07) areas compared to urban AYMSM. Those who resided in rural areas were approximately half as likely to have disclosed as urban AYMSM (OR 0.54, 95% CI 0.26, 1.14), and this was also a change in direction from the interaction-only model. There was evidence of multiplicative interaction ($p = 0.06$).

Figure 2.2 Association between residence and sexual identity disclosure by perceived neighborhood tolerance among AYMSM aged 15-24 years who report HIV-negative or unknown status, AMIS 2017-2019



	Tolerant		Neutral		Intolerant	
	aOR*	95% CI	aOR	95% CI	aOR	95% CI
Rural vs Urban	0.51	(0.31, 0.82)	0.54	(0.26, 1.14)	0.75	(0.39, 1.45)

All models clustered by ZCTA.
* aOR: Adjusted odds ratio. Models were adjusted for individual-level variables of race, age, education, sexual identity, and experiences of stigma and ZCTA-level variables of region, median household income, percent with less than high school education, and percent of same-sex households.

Small/Med Metro vs Urban	0.67	(0.48, 0.93)	2.33	(1.07, 5.07)	0.62	(0.30, 1.26)
Suburban vs Urban	0.93	(0.65, 1.34)	1.39	(0.84, 2.31)	1.98	(1.11, 3.52)

Table 2.4 Associations between urban-rural residence and sexual identity disclosure by perceived neighborhood tolerance among AYMSM aged 15-24 years who report HIV-negative or unknown status, AMIS 2017-2019

	Model 1: Unadjusted		Model 2: Interaction only		Model 3: Fully adjusted*	
	OR	95% CI	OR	95% CI	OR	95% CI
Rural	0.78	(0.67, 1.02)	-		-	
Small/Med Metro	0.89	(0.73, 1.07)	-		-	
Suburban	0.83	(0.60, 1.01)	-		-	
Urban	Ref					
Tolerant neighborhood perception						
Rural	-		0.55	(0.36, 0.85)	0.51	(0.31, 0.82)
Small/Med Metro	-		0.74	(0.56, 0.97)	0.67	(0.48, 0.93)
Suburban	-		0.78	(0.58. 1.05)	0.93	(0.65, 1.34)
Urban	-		Ref		Ref	
Neutral neighborhood perception						
Rural	-		1.54	(0.90, 2.63)	0.54	(0.26, 1.14)
Small/Med Metro	-		1.62	(1.11, 2.38)	2.33	(1.07, 5.06)
Suburban	-		1.20	(0.79, 1.83)	1.39	(0.84, 2.31)
Urban	-		Ref		Ref	
Intolerant neighborhood perception						
Rural	-		1.46	(0.89, 2.38)	0.75	(0.39, 1.44)

All models clustered by ZCTA.

* Adjusted for individual-level variables of race, age, education, sexual identity, and experiences of stigma and ZCTA-level variables of region, median household income, percent with less than high school education, and percent of same-sex households.

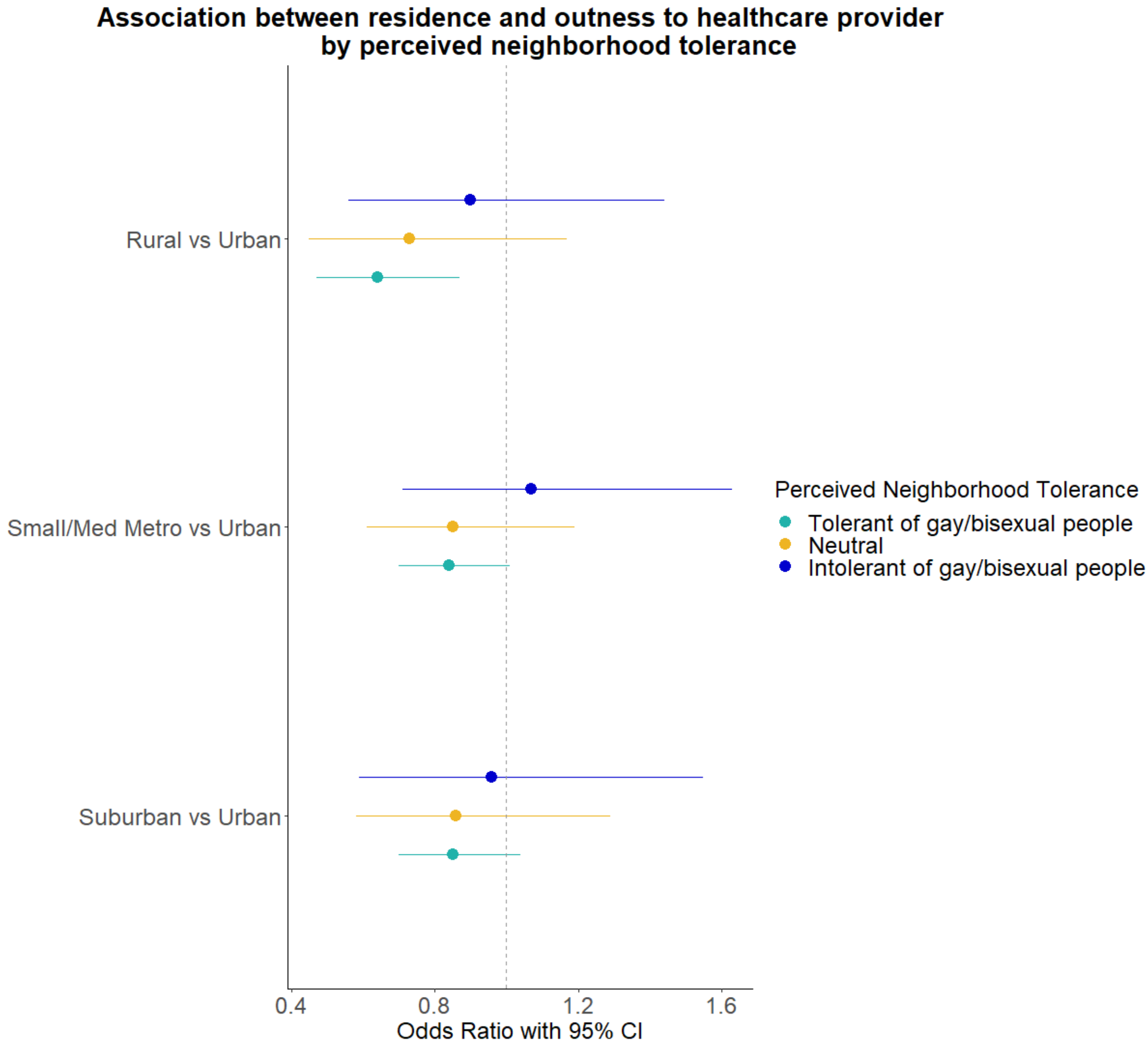
Small/Med Metro	-	1.22	(0.81. 1.85)	0.62	(0.30, 1.26)
Suburban	-	0.96	(0.60, 1.54)	1.98	(1.11, 3.52)
Urban	-	Ref		Ref	
p-value for interaction term		0.01		0.06	

Relationship between urban-rural residence and sexual identity disclosure to HCP

In the unadjusted model, AYMSM residing in non-urban areas were less likely to have disclosed their sexual identity to a HCP than AYMSM in urban areas (Table 2.5). AYMSM in rural areas were half as likely to be out (OR 0.52, 95% CI 0.44, 0.62) as urban AYMSM. For suburban AYMSM, the OR was 0.74 (95% CI 0.65, 0.85), and this estimate was similar when comparing AYMSM in SMM and urban areas (OR 0.78, 95% CI 0.70, 0.88).

In the interaction-only model, we observed differences in the associations among residence areas and disclosure to HCP, though only the relationships among those who perceived tolerance in their neighborhoods were meaningful. Among those who perceived their neighborhood to be tolerant of gay and bisexual individuals, AYMSM in rural areas were half as likely to urban AYMSM to be out to a HCP (OR 0.52, 95% CI 0.40, 0.67). AYMSM in suburban (OR 0.76, 95% CI 0.65, 0.89) and SMM areas (OR 0.77, 95% CI 0.67, 0.90) were also less likely to be out to a HCP. Among those who perceived their neighborhood to be intolerant, being out to a HCP was similar among AYMSM in SMM and urban areas (OR 1.07, 95% CI 0.77, 1.49) but less among AYMSM in suburban (OR 0.91, 95% CI 0.62, 1.33) and rural areas (OR 0.79, 95% CI 0.54, 1.16). In the fully adjusted model (Figure 2.3), the associations among those who perceived tolerance in their neighborhoods were attenuated, and only the rural-urban comparison remained (OR 0.64, 95% CI 0.47, 0.87). For those that perceived their neighborhoods to be intolerant or were neutral, these estimates did not meaningfully change after adjustment. There was no evidence of multiplicative interaction (p = 0.92).

Figure 2.3 Association between residence and sexual identity disclosure to health care provider by perceived neighborhood tolerance among AYMSM aged 15-24 years who report HIV-negative or unknown status, AMIS 2017-2019



	Tolerant		Neutral		Intolerant	
	aOR*	95% CI	aOR	95% CI	aOR	95% CI
Rural vs Urban	0.64	(0.47, 0.87)	0.73	(0.45, 1.17)	0.90	(0.56, 1.44)

All models clustered by ZCTA.

* aOR: Adjusted odds ratio. Models were adjusted for individual-level variables of race, age, education, sexual identity, health insurance status, having seen a healthcare provider in the past year, experienced sexual identity-related stigma, sexual identity-related stigma in health care, and ZCTA-level variables of region, median household income, percent with less than high school education, and percent of same-sex households.

Small/Med Metro vs Urban	0.84	(0.70, 1.01)	0.85	(0.61, 1.19)	1.07	(0.71, 1.63)
Suburban vs Urban	0.85	(0.70, 1.04)	0.86	(0.58, 1.29)	0.96	(0.59, 1.55)

Table 2.5 Associations between urban-rural residence and sexual identity disclosure by perceived neighborhood tolerance among AYMSM aged 15-24 years who report HIV-negative or unknown status, AMIS 2017-2019

	Model 1: Unadjusted		Model 2: Interaction-only		Model 3: Fully Adjusted*	
	OR	95% CI	OR	95% CI	OR	95% CI
Rural	0.52	(0.44, 0.62)	-		-	
Small/Med Metro	0.78	(0.70, 0.88)	-		-	
Suburban	0.74	(0.65, 0.85)	-		-	
Urban	Ref					
Tolerant neighborhood perception						
Rural	-		0.52	(0.40, 0.67)	0.64	(0.47, 0.87)
Small/Med Metro	-		0.77	(0.67, 0.90)	0.84	(0.70, 1.01)
Suburban	-		0.76	(0.65, 0.89)	0.85	(0.70, 1.04)
Urban	-		Ref		Ref	
Neutral neighborhood perception						
Rural	-		0.74	(0.52, 1.07)	0.73	(0.45, 1.17)
Small/Med Metro	-		1.02	(0.79, 1.32)	0.85	(0.61, 1.19)
Suburban	-		0.79	(0.58, 1.06)	0.86	(0.58, 1.29)
Urban	-		Ref		Ref	
Intolerant neighborhood perception						
Rural	-		0.79	(0.54, 1.16)	0.90	(0.56, 1.44)
Small/Med Metro	-		1.07	(0.77, 1.49)	1.07	(0.71, 1.63)

All models clustered by ZCTA

* Adjusted for individual-level variables of race, age, education, sexual identity, health insurance status, having seen a healthcare provider in the past year, experienced sexual identity-related stigma, sexual identity-related stigma in health care, and ZCTA-level variables of region, median household income, percent with less than high school education, and percent of same-sex households

Suburban	-	0.91	(0.62, 1.33)	0.96	(0.59, 1.55)
Urban	-	Ref		Ref	
p-value for interaction		0.23		0.92	

Sensitivity Analyses

In our sensitivity analyses for the residence and disclosure to HCP association, the estimates from the two regression models (one with the imputed outcome and covariate data and one with the imputed outcome data only) were not meaningfully different from the estimates from the complete-case analysis (Table 2.6).

Table 2.6 Sensitivity analyses for association between urban-rural residence and disclosure to health care providers, AMIS 2017-2019

	Complete Case			MI – Full			MI – Y only		
	OR	SE	95% CI	OR	SE	95% CI	OR	SE	95% CI
Suburban, Tolerant	0.85	0.09	(0.70, 1.04)	0.85	0.07	(0.71, 1.00)	0.88	0.08	(0.73, 1.04)
Suburban, Neutral	0.86	0.18	(0.58, 1.29)	0.90	0.18	(0.56, 1.25)	0.94	0.21	(0.54, 1.35)
Suburban, Intolerant	0.96	0.24	(0.59, 1.55)	0.81	0.14	(0.53, 1.09)	0.88	0.16	(0.57, 1.19)
SMM, Tolerant	0.84	0.08	(0.70, 1.01)	0.89	0.07	(0.75, 1.04)	0.88	0.08	(0.73, 1.03)
SMM, Neutral	0.85	0.15	(0.61, 1.19)	1.02	0.18	(0.67, 1.37)	1.07	0.20	(0.67, 1.47)
SMM, Intolerant	1.07	0.23	(0.71, 1.63)	0.93	0.12	(0.69, 1.16	0.92	0.14	(0.64, 1.20)
Rural, Tolerant	0.64	0.10	(0.47, 0.87)	0.73	0.11	(0.52, 0.94)	0.67	0.10	(0.46, 0.87)
Rural, Neutral	0.73	0.18	(0.45, 1.17)	0.92	0.18	(0.57, 1.26)	0.99	0.21	(0.58, 1.41)
Rural, Intolerant	0.90	0.22	(0.56, 1.44)	0.85	0.16	(0.54, 1.17)	0.75	0.17	(0.42, 1.07)

MI – Full: Multiple imputation (MI) of all missing data for the outcome and covariates
MI – Y only: MI of missing data for the outcome (outness to HCP) only
SMM: Small and medium metropolitan area

DISCUSSION

In this analysis, we examined the relationship between residence and sexual identity disclosure among AYMSM. Among this study population, sexual identity disclosure to anyone was consistently high and sexual identity disclosure to a HCP was consistently low across the urban-rural residence categories. Of AYMSM who had not disclosed their sexual identity to anyone, half were bisexual. Experienced and anticipated sexual identity-related stigma was high, regardless of disclosure status. We observed a consistent pattern of less disclosure to anyone among AYMSM residing in suburban, SMM, and rural areas compared to urban AYMSM, among those who perceived their neighborhoods to be tolerant. For disclosure to HCP, this same pattern was observed, with AYMSM in rural areas being least likely to have disclosed compared to AYMSM in urban areas. Greater overall disclosure was associated with residing in SMM areas, compared to urban areas, among AYMSM who were neutral about their neighborhood's tolerance and with residing in suburban areas among AYMSM who perceived their neighborhoods to be intolerant.

Our findings add to the existing knowledge regarding sexual identity disclosure patterns among AYMSM. Few studies have examined the various urban-rural residential environments in which AYMSM reside, as previous studies have primarily focused on AYMSM residing in large metropolitan areas. Our findings regarding less disclosure overall and to HCP specifically among AYMSM in rural areas compared to urban AYMSM are consistent with the literature, of MSM residing in rural areas experiencing higher levels of stigma, be less likely to disclose their sexual identity, and be less likely to utilize health services (23,30,50,78,86,90) The higher levels of fearing and avoiding health care out of concern their sexual identity may be disclosed among AYMSM who have not disclosed reflect the barriers of stigma and privacy and confidentially AYMSM face that previous studies have also observed (27,63). The lower levels of sexual identity disclosure among AYMSM who were bisexual, also present in the literature (30,75,88), reflects the heterogeneity in identity formation among this population and how the disclosure process and disclosure to HCPs may be different for AYMSM with bisexual identities.

The heterogeneous relationships between urban-rural residence and disclosure to anyone by neighborhood tolerance perception has not previously been observed in the literature. The increased likelihood of disclosure among AYMSM in SMM and suburban ZCTAs, compared to urban ZCTAs, among those who had neutral or intolerant neighborhood perceptions was contrary to our expectations. We expected to observe a similar pattern of less disclosure in the non-urban areas, as with those who had tolerant neighborhood perceptions. One possible explanation is that those who are more out, or open, about their minority sexual identity may be more likely to report experiencing or perceive sexual identity-related stigma in their environments, particularly if there is less acceptance of LGBT individuals. In our study, there were higher levels of reported experienced stigma among those who had disclosed compared to those who had not in each urban-rural residence category. The positive association between being out and increased experiences of discrimination has been observed previously (30). The pattern of less disclosure in non-urban areas among AYMSM who perceived their neighborhoods to be tolerant of gay and bisexual individuals reflects the complexities of sexual identity formation (75) and identity integration, or the acceptance and commitment to their sexual identity (91). AYMSM may perceive their neighborhoods to be tolerant but may face sexual identity-related stigma in other contexts, such as within their school or family, and this may inform their decision to disclose and/or influence whether they feel comfortable with others knowing their identities (29,91). Additionally, the lack of meaningful associations observed between urban-rural residence and disclosure to HCP may indicate that individual perceptions of neighborhood tolerance may be too broad, and therefore insufficient, to represent the sexual identity-related stigma constructs in their residential environment that would influence disclosure in a health care setting.

Our study has several important limitations. First, this study utilizes a convenience sampling approach, and therefore, data from AMIS are not generalizable to AYMSM in the US or all AYMSM who access the internet. Because recruitment for AMIS is conducted through online ads on websites and social media applications, the study population is likely skewed toward AYMSM who are more open about their gay and bisexual identities, and there is a potential for selection bias. However, online-based recruitment has been effective in recruiting a broader population, such as MSM who do not attend venues, including AYMSM who are less than 21 years of age, and who reside in non-urban areas (30). Second, participants' residence was determined by their ZIP Codes and proxied by their ZCTAs. ZCTAs can vary widely in their population sizes and land areas and may not accurately represent the participants' contextual environment. However, ZCTAs and ZIP codes have been frequently used in public health research to capture area-level information, given participants' knowledge of their ZIP code, public availability of the data, and interpretability of ZIP code for public health action by policymakers and the public (92,93). Third, we did not have information regarding the length of residence in the reported ZIP Code. It is possible that participants were only exposed to their neighborhood environment for short period of time, and this may introduce bias. However, though young adulthood is a highly mobile period due to education, employment, housing, or family-related issues, approximately 6% to 8% of young adults move to different counties (94). Fourth, there may be uncontrolled confounding due to spatial stratification processes that have led LGBT individuals in the U.S. to reside in urban areas, as reflected by their concentration in urban areas in the county. There may also be stratification by age, as our population includes those less than 18 years of age, and their place of residence was determined by their parents/guardians. Fifth, we did not observe any meaningful associations between residence and sexual disclosure overall and to a HCP by perceived neighborhood tolerance, and this may be due to a lack of statistical power to detect multiplicative interaction. Sixth, subjects with missing covariate and outcome data were excluded from our analyses and may have biased our results, especially with the high proportion of missingness in disclosure to HCP. However, those with missing outcome data were not meaningfully different than those with data regarding demographic and SES characteristics, and our sensitivity analyses utilizing multiple imputation of missing outcome and covariate data did not meaningfully change our model estimates.

Conclusion

AYMSM experience complex and multi-level barriers in accessing and utilizing health services due to their age and minority sexual identity, and the patient-provider relationship is critical in AYMSM's engagement with and receipt of comprehensive health care. It is therefore critical to understand the contextual- and individual-level factors that shape AYMSM's decision to their sexual identity to HCPs and to explore the heterogeneity of these relationships by urban-rural residence. The high levels of anticipated stigma reported by AYMSM suggest an urgent need for health care that is LGBT-inclusive and knowledgeable about LGBT health. Further, the high levels of non-disclosure among AYMSM with bisexual identities must be further examined to understand how non-disclosure affects their health behaviors and outcomes. Areas for future research include clarifying the potential mechanisms by which contextual factors affect AYMSM's disclosure to HCP and assessing the role of anticipated stigma in AYMSM's health care access and utilization.

Chapter 3 Area disadvantage and local racial/ethnic concentration and receipt of free condoms among adolescent and young men who have sex with men

ABSTRACT

Background: Adolescent and young men who have sex with men (AYMSM) report low levels of condom use, despite being disproportionately affected by HIV. The role of place-based factors in AYMSM's condom access is not well understood. We explored the relationship between two structural place-based factors, socioeconomic disadvantage and local racial/ethnic spatial concentration, and AYMSM's receipt of free condoms.

Methods: We used individual-level data from the 2016-2019 cycles of the American Men's Internet Survey (AMIS). Participant-reported ZIP Codes were used to identity their ZIP Code Tabulation Area (ZCTA), and ZCTA data were abstracted from the American Community Survey. Demographic and socioeconomic indicators were used to construct neighborhood disadvantage index and the Index of Concentration at the Extremes (ICE) for race/ethnicity, to measure local spatial concentration of racial/ethnic minority groups, or people of color (POC). Multilevel modeling was conducted to estimate prevalence ratios (PRs). Multiplicative and additive interaction between the exposures and race and ethnicity was also assessed.

Results: Overall, 47% of AYMSM reported receiving free condoms. Receipt was associated with residing in the highest disadvantaged compared to the least disadvantaged ZCTAs for White (PR 1.10, 95% confidence interval (CI) 1.01, 1.20) and Hispanic (PR 1.24, 95% CI 1.07, 1.45) AYMSM, adjusting for individual- and area-level factors. For Black AYMSM, no meaningful associations were observed. Residing in ZCTAs with high POC concentration was associated with increased free condom receipt for White (PR 1.13, 95% CI 1.02, 1.24) but not Hispanic and Black AYMSM. Multiplicative, but not additive, interaction was observed for area disadvantage.

No interaction, multiplicative or additive, was observed for local racial/ethnic spatial concentration and race/ethnicity.

Conclusions: Different patterns of associations between these structural place-based factors and receipt of free condoms by race/ethnicity suggest that condom access may differ for White, Black, and Hispanic AYMSM within the same socioeconomic and demographic residential environments. Structural-level interventions to increase the availability and accessibility of condoms should consider contextual factors, like area-level socioeconomic and demographic characteristics, along with HIV prevalence and incidence, in identifying where to target condom distribution interventions.

INTRODUCTION

Adolescent and young men who have sex with men (AYMSM) are at high risk for HIV. AYMSM account for nearly a fifth of new HIV diagnoses in the U.S., with approximately 6,500 new diagnoses (2). HIV incidence estimates for this population have ranged from 2.85 to 6.5 per 100 person-years (3).

Black and Hispanic AYMSM have been disproportionately affected by HIV. In 2018, Black AYMSM accounted for nearly half of new HIV diagnoses (48%) among males aged 13 to 24 years, followed by Latino (31%) and White AYMSM (15%) in 2018 (2). HIV incidence estimates, from longitudinal studies, reflect this racial/ethnic disparity as well, with higher incidence, up to 10-fold, among Black and Hispanic AYMSM compared to White AYMSM (7–10).

Correct and consistent condom use is highly effective in the prevention of HIV and other sexual transmitted infections (STIs). When used consistently, condoms have a 70.5% effectiveness in preventing the transmission of HIV through anal intercourse among men who have sex with men (MSM) (11). Therefore, interventions that promote the availability of condoms and counseling on their correct and consistent use have been and continue to be an essential part of comprehensive HIV prevention (95,96), and condom distribution programs are one of CDC’s high impact HIV prevention strategies (51).

Low levels of condom use among AYMSM is a critical challenge for HIV prevention. Behavioral surveillance data among high school-aged AYMSM show that almost half (52%) reported not using a condom the last time they had engaged in anal intercourse (12) and a meta-analysis of sexual risk behaviors among younger AYMSM reported a similar estimate (50%) (13). Reported condomless anal intercourse (CAI) in the past year among older AYMSM has ranged from 62%, from online-based behavioral surveillance (14), to 73%, from venue-based surveillance (15).

AYMSM's inconsistent or no condom use has been linked to individual- and neighborhood-level factors. Individual-level correlates include low risk perception of contracting HIV or STIs (26,97); challenges discussing HIV and STI status and negotiating condom use with partners (98); alcohol and drug use during sex (25); and peer attitudes and social norms regarding condom use (97,98). Though studies examining multilevel relationships have been few, studies have observed associations between neighborhood-level factors and condom use after adjusting for individual-level factors. In one study of AYMSM in the Detroit area, residing closer to a HIV/AIDS service organization and in neighborhoods with higher levels of disadvantage was associated with increased condom use (38,40). Among a sample of AYMSM in New York City, higher neighborhood concentrations of same-sex couples was linked to increased consistent condom use (41). Heterogeneity by race/ethnicity has also been observed in the multilevel relationships; Frye et al. found that less physical disorder and less social disorganization were associated with less HIV-discordant CAI among Black but not White MSM in New York City (99).

Limited access to condoms is a structural barrier to AYMSM's condom use. Accessing condoms presents a multistep process for AYMSM to navigate, and there may be challenges at each step. AYMSM have reported challenges with knowing where to buy condoms, identifying which type to buy, whether they can afford them, and feeling embarrassed about purchasing them (97). Additionally, the cost of condoms may be prohibitive, especially for younger AYMSM, those less than 18 years of age who do not frequent venues, and AYMSM residing in areas with less access to free condoms (97).

Structural interventions to increase the availability of and access to condoms have been implemented by health departments, community-based organizations, HIV/AIDS service organization, and clinics to reach populations at high risk for HIV (51). Community-level condom distribution programs have been effective in reducing HIV risk through increased condom use (51,100–102). A systematic review examining condom cost and condom use among MSM observed a direct positive relationship between receipt of free condoms and increased use (102), and a meta-analysis of community-based condom distribution interventions in the U.S. estimated a 12% decrease in self-reported condomless sex due to condom distribution interventions that made condoms free and widely available within the community (103). School-based condom distribution programs have also been linked to increased condom use (104). Although the effectiveness of these program in reducing HIV and STI incidence has been mixed (103,104) and effectiveness has not been specifically examined among AYMSM, condom distribution interventions that address structural barriers related to condom availability and accessibility could improve AYMSM's condom access.

Given these links between place-based factors and condom use among AYMSM, it is important to understand how place-based factors affect condom access and which AYMSM have received free condoms. Based on previous research that has identified differences in condom use by race/ethnicity, examining these multilevel relationships with AYMSM's condom access by race/ethnicity is warranted. In this study, we aimed to explore how place-based structural factors, area-level disadvantage and local racial/ethnic spatial concentration, in AYMSM's residential environment impact AYMSM's receipt of free condoms and examined these relationships by AYMSM's race/ethnicity.

METHODS

Study Design

Data sources

All individual-level data were from the 2016 to 2019 cycles of the American Men's Internet Survey (AMIS). AMIS is an annual cross-sectional, internet-based survey of HIV risk behaviors, HIV prevention, and access to HIV-related health services among gay, bisexual, and other MSM, with the aim of collecting at least 10,000 completed surveys from eligible MSM. The survey's methodology has been previously detailed (14). Briefly, men were eligible to participate if they are 15 years of age or older, reside in the U.S., report ever having oral or anal sex with a man or identify as gay or bisexual, and were able to complete the survey in English. Participants were recruited online through convenience sampling in two ways. First, advertisements, or "ads," for a survey on men's sexual health were placed as banner ads on a variety of websites and social media applications. Second, participants were also recruited through emailing participants of previous cycles who had consented to be contacted for potential participation in future studies. Men who were eligible and provided consent were then directed to the self-administered survey, which could be completed on a computer or mobile device. AMIS asked questions in the following domains: demographics, sexual behavior, HIV testing history, and utilization of HIV prevention services. The survey also collected participants' ZIP Code of residence. Participants did not receive incentives for study participation. Survey data were collected using encrypted HIPAA-compliant survey software and stored on an access-restricted secure data server, administered by SurveyGizmo (Boulder, CO, USA).

Demographic and socioeconomic area-level data were abstracted from the American Community Survey (ACS), using the five-year estimates for 2014-2018, for the ZIP Code Tabulation Area (ZCTA). ZCTAs are the U.S. Census Bureau's areal approximations of the U.S. Postal Service's ZIP Code system (105). Participants' reported ZIP Code were linked to their respective ZCTA, and UDS Mapper ZIP Code to ZCTA Crosswalk (106) was used to resolve ZIP Code-ZCTA discrepancies. The locations of HIV testing sites in the U.S. were downloaded from the CDC's National Prevention Information Network Service Finder tool as of 2019.

Measures

Outcome assessment

The outcomes for this analysis was receipt of free condoms in the past year, and this was measured as a binary variable. Participants were asked if they had received free condoms in the past year, not including those given to them by a friend, relative, or sex partner.

Exposure assessment

To measure neighborhood disadvantage, we adapted the Neighborhood Deprivation Index created by Messer et al (107). We first examined the following ZCTA-level sociodemographic factors: percent of population aged 25 years and older with less than a high school degree or equivalent; percent of population aged 16 years and older who were unemployed; percent of population living in poverty; percent of males in professional occupations; percent of population in the labor force; percent of home ownership; percent of single female-headed households; percent of crowded households; percent of low income households (households income less than $30,000 per year); and percent of households receiving government assistance such as food stamps. We utilized principal components analysis (PCA), a data reduction technique, to determine which variables to retain in the final index, using an orthogonal rotation (varimax) on the full set of variables. There were three factors with an eigenvalue greater than one, and the first factor explained much of the variance (variance factor 1 = 5.46, variance factor 2 = 1.36, variance factor 3 = 1.15). The 7 variables that fit within the first factor were retained, and these were percent with less than a high school degree or equivalent; percent who were unemployed; percent in poverty; percent of low income households; percent of households receiving government assistance, percent of single female-headed households, and percent of home ownership. The factor loadings were high, with a variance factor was 4.68. The retained variables were used to construct a standardized continuous neighborhood disadvantaged score that was categorized into quintiles, with quintile 1 (Q1) representing the least disadvantage neighborhoods and quintile 5 (Q5) the most disadvantaged neighborhoods.

To measure local racial/ethnic spatial concentration, we used the Index of Concentration at the Extremes (ICE) at the ZCTA level. ICE, primarily used in the social sciences, was initially conceived to measure the extremes of poverty and affluence (108) and has recently been used in public health, specifically in surveillance, to capture spatial social polarization of deprivation and privilege as represented by race and income (109,110). ICE is related to but not the same as racial residential segregation, which compares two spatial scales, such as local neighborhoods and the broader region in which they are situated, simultaneously. ICE is a useful metric because it can simultaneously reflect both extremes, provide the directional tendency, and be utilized locally, such as within a ZCTA, while avoiding issues of multicollinearity that frequently occur when separate measures of race/ethnicity and socioeconomic status are included in the model (110) ICE is calculated as:

$$ICE_i = \frac{A_i - P_i}{T_i}$$

A_i is the number of White, non-Hispanic residents in the i^{th} ZCTA, P_i is the number of non-White (Black, Asian) or Hispanic residents, and T_I is the total population. The range of this index is -1 to 1, where -1 indicates that all individuals in the neighborhood are White, non-Hispanic; 0 indicates that there are equal proportions of White, non-Hispanic and POC individuals; and 1 indicates that all persons are POC. ICE values were categorized into quintiles, where Q1 represented ZCTAs with the highest concentration of White, non-Hispanic individuals and Q5 the ZCTAs with the highest concentration of POC individuals.

Covariate assessment

We examined the following individual-level covariates: age, sexual identity, education, sexual identity disclosure, sexual identity-related stigma, health insurance, a health care provider visit in the past year, condomless anal intercourse (CAI) in the past year, STI testing, and STI diagnosis in the past year. Education was measured as a binary variable that indicated whether the participant's education was on track relative to their age. Participants were asked about their highest level of education attainment but were not asked if they were currently in school. Since the study population included high school-aged AYMSM, this education on track variable was created to capture their educational status. CAI and STI diagnosis were used to indicate AYMSM's HIV risk. Having heard of PrEP represented AYMSM's awareness of HIV prevention. Area-level covariates included urban-rural residence and region of the country. Urban-rural residence classification was based on the National Center for Health Statistics Urban-Rural Classification Scheme (87).

Statistical Analysis

The research questions of interested examined the relationship between the two area-level exposures, area disadvantage and local racial/ethnic spatial concentration, and HIV testing. We describe the study population by their individual- and ZCTA-level characteristics by area disadvantage and local racial/ethnic spatial concentration and present the prevalence of ever having tested for HIV stratified by the disadvantage and ICE quintiles for the three race/ethnic groups. For the multivariable analysis, we conducted multilevel modeling with a modified Poisson approach (111) to estimate prevalence ratios and used generalized estimating equations with an exchangeable correlation structure to account for clustering by ZCTA. Subjects with missing data for the outcome and/or covariates were excluded from the analyses. Area disadvantage and ICE and their relationships with the outcome were examined separately. Our modeling strategy fit a series of models: (i) unadjusted without interaction, (ii) exposure X race interaction-only model, (iii) fully adjusted model adjusting for individual- and area-level covariates with exposure x race interaction. For the models with interaction, we assessed multiplicative interaction with the generalized score test statistic and its p-value and additive interaction with the relative excess risk due to interaction (RERI) from the relative risk model (112). A RERI calculated using risk ratios ($RERI_{RR}$) indicates the direction of the additive interaction, whether positive or negative, but not the relative magnitude of the interaction. To address confounding, we adjusted for the following individual- and area-level covariates based on prior literature (35,41,97,113): age in years; sexual identity; educational status; sexual identity disclosure; health insurance; health care provider visit in the past one year; CAI; STI testing and diagnosis in the past year; having ever tested for HIV; having heard of PrEP; urban-rural residence; and region of the country. Multicollinearity was assessed by examining condition indices (greater than 35) and variance decomposition factors (two or more greater than 0.5). Since these criteria were not met, all covariates were retained in the final model. The findings presented focus on the comparisons between the extremes - the most (Q5) and least (Q1) disadvantaged ZCTAs and the highest POC concentration (Q5) and highest White concentration ZCTAs (Q1).

We did not include Asian and Pacific Islander participants and participants who reported their race/ethnicity as Other or Multiracial in the regression analyses. The small sample size of Asian and Pacific Islander participants would produce unreliable estimates, and the heterogeneity of the Other/Multiracial category precluded us from making meaningful interpretations about the exposure-outcome relationships for this group.

Descriptive and regression analyses were conducted using SAS 9.4 (Carey, NC, USA). Calculation of distance to the nearest HIV testing site was conducted using R 3.6.2 (Vienna, Austria). AMIS was reviewed and approved by the Emory University Institutional Review Board.

RESULTS

Participant characteristics

There were 12,032 AYMSM aged 15 to 24 years who were included in our study. Overall, 47% of participants reported receiving free condoms (Table 3.1). AYMSM in the most disadvantaged ZCTAS had a mean age of 21 years (SD 2.4), were 11% Black and 33% Hispanic, and resided primarily in urban areas (45%). In comparison, AYMSM in the least disadvantaged ZCTAs were younger (mean age 20 years, SD 2.5), predominantly White (78%), and more likely to reside in suburban areas (49%). Among AYMSM in the most disadvantaged ZCTAs, 11% reported not having any health insurance, compared to 5% among AYMSM in the least disadvantaged ZCTAs. Having seen a health care provider in the past year was high in both groups. AYMSM in the most disadvantaged ZCTAs reported higher levels of CAI (67%) and STI diagnosis (10%) in the past year than AYMSM in the least disadvantaged ZCTAs, among whom 59% reported CAI and 7% an STI diagnosis. AYMSM in the most disadvantaged ZCTAs reported higher levels of STI testing in the past year (38%) and having ever tested for HIV (61%). AYMSM in the least disadvantaged ZCTAs reported less STI testing in the past year (31%), and less than half (47%) had ever been tested for HIV. Approximately two-thirds (67%) of AYMSM in the most disadvantaged ZCTAs and 55% of AYMSM in the least disadvantaged ZCTAs had heard of PrEP. Receipt of free condoms was reported by 53% of AYMSM in the most disadvantaged ZCTAs and 45% of AYMSM in the least disadvantaged ZCTAs.

By ICE, AYMSM who resided in ZCTAs with the highest concentration of POC individuals (Q5) were correspondingly, more racially and ethnically diverse, with 54% Hispanic and 14% Black, whereas AYMSM who resided in ZCTAs with the highest concentration of White individuals (Q1) were 91% White, 7% Hispanic, and 1% Black. Among AYMSM in the highest POC concentration ZCTAs, 67% identified as gay and 25% were bisexual, whereas 72% of AYMSM in the highest White concentration ZCTAs identified as gay and 22% as bisexual. AYMSM in the highest POC concentration ZCTAs primarily resided in the South (45%) and

West (33%) and in urban areas (57%). AYMSM in the highest White concentration ZCTAs were largely from the Midwest (43%) and Northeast (30%) and resided in rural (35%) and small and medium metropolitan (34%) areas. Across both groups, AYMSM were similar in age (mean age of 20 years). Among AYMSM in the highest POC concentration ZCTAs, 88% were on track with their education, and 13% reported being uninsured. For AYMSM in the highest White concentration ZCTAs, 90% were on track with education, and 7% did not have health insurance. AYMSM in the highest White concentration ZCTAs reported a higher percentage of having seen a HCP in the past year (78%) than AYMSM in the highest POC concentration ZCTAs (73%).

CAI in the past year was similarly high in both groups (63% among AYMSM in the highest White concentration ZCTAs and 66% among AYMSM in the highest POC concentration ZCTAs). Being diagnosed with a STI in the past year was 11% among AYMSM in the highest POC concentration ZCTAs and 6% among AYMSM in the highest White concentration ZCTAs. AYMSM in the highest POC concentration ZCTAs reported higher levels of STI testing in the past year (38%) and having ever been tested for HIV (59%) than AYMSM in the highest White concentration ZCTAs with 26% having tested for STIs in the past year and 42% having ever been tested for HIV. Seven out of 10 AYMSM in the highest POC concentration ZCTAs had heard of PrEP (72%), compared to 67% among AYMSM in the highest White concentration ZCTAs. Receipt of free condoms was similar across both groups, reported by 58% of AYMSM in the highest POC concentration ZCTAs and 54% of AYMSM in the highest White concentration ZCTAs.

Table 3.1 Characteristics of participants aged 15-24 years and reporting HIV-negative or unknown status by area disadvantage and local racial/ethnic spatial concentration, AMIS 2016-2019

	Total		Area Disadvantage				ICE-POC*			
			Q1 (least)		Q5 (most)		Q1 (highest White)		Q5 (highest POC)	
	n	%	n	%	n	%	n	%	n	%
	12,032		2,122		2,804		1,757		2,586	
Age (years)										
15-17	1,810	15.0	454	21.4	281	10.0	376	21.4	353	13.7
18-20	4,665	38.8	878	41.4	1,060	37.8	741	42.2	955	36.9
21-24	5,557	46.2	790	37.2	1,463	52.2	640	36.4	1,278	49.4
Mean (SD)	20	2.5	20	2.5	21	2.4	20	2.4	20	2.5
Race/ethnicity										
White, non-Hispanic	7,982	66.3	1,656	78.0	1,523	54.3	1,590	90.5	784	30.3
Black, non-Hispanic	762	6.3	80	3.8	303	10.8	23	1.3	352	13.6
Hispanic	3,067	25.5	353	16.6	927	33.1	116	6.6	1,387	53.6
Sexual identity										
Gay or homosexual	8,662	72.0	1,546	72.9	1,969	70.2	1,260	71.7	1,730	66.9
Heterosexual	160	1.3	25	1.2	42	1.5	27	1.5	41	1.6
Bisexual	2,612	21.7	442	20.8	647	23.1	381	21.7	656	25.4
Other	145	1.2	25	1.2	39	1.4	18	1.0	45	1.7
Region										
Northeast	2,115	17.6	573	27.0	455	16.2	525	29.9	369	14.3

Percentages may not equal 100% due to missing data.

* Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

Midwest	2,557	21.3	511	24.1	518	18.5	755	43.0	195	7.5
South	4,649	38.6	616	29.0	1,298	46.3	374	21.3	1,165	45.1
West	2,711	22.5	422	19.9	533	19.0	103	5.9	857	33.1
Residence										
Urban	3,825	31.8	557	26.2	1,250	44.6	108	6.1	1,485	57.4
Suburban	2,781	23.1	1,034	48.7	242	8.6	433	24.6	464	17.9
Small/medium metro	4,091	34.0	466	22.0	1,037	37.0	605	34.4	566	21.9
Rural	1,335	11.1	65	3.1	275	9.8	611	34.8	71	2.7
Education										
Less than high school	1,768	14.7	443	20.9	261	9.3	359	20.4	333	12.9
High school diploma or equivalent	2,889	24.0	508	23.9	633	22.6	451	25.7	651	25.2
Some college/technical degree	4,609	38.3	702	33.1	1,207	43.0	659	37.5	1,034	40.0
College/post-graduate	2,532	21.0	421	19.8	644	23.0	249	14.2	512	19.8
Education on track	10,734	89.2	1,945	91.7	2,457	87.6	1,584	90.2	2,273	87.9
Disclosed sexual identity	11,063	91.9	1,945	91.7	2,587	92.3	1,593	90.7	2,332	90.2
Stigma experiences										
0	5,184	43.1	905	42.6	1,288	45.9	671	38.2	1240	48.0
1	3,496	29.1	640	30.2	777	27.7	522	29.7	731	28.3
2+	3,215	26.7	548	25.8	708	25.2	540	30.7	586	22.7
Health insurance										
Uninsured	1,065	8.9	108	5.1	306	10.9	126	7.2	336	13.0
Private	7,255	60.3	1,383	65.2	1,629	58.1	1,062	60.4	1,339	51.8
Public	1,318	11.0	141	6.6	374	13.3	188	10.7	427	16.5
Other/multiple	902	7.5	147	6.9	222	7.9	123	7.0	173	6.7

Health care provider visit in past year	9,266	77.0	1,711	80.6	2,120	75.6	1,374	78.2	1,879	72.7
Condomless anal intercourse in past year	7,741	64.3	1,257	59.2	1,887	67.3	1,100	62.6	1,693	65.5
STI testing in past year	4,110	34.2	659	31.1	1,055	37.6	456	26.0	977	37.8
STI diagnosis in past year	1,016	8.4	141	6.6	285	10.2	96	5.5	275	10.6
Ever tested for HIV	6,496	53.4	999	47.1	1,711	61.0	740	42.1	1,525	59.0
Heard of PrEP	8,798	73.1	1,175	55.4	1,865	66.5	1,175	66.9	1,865	72.1
Participated in prevention counseling	1,887	15.7	325	15.3	500	17.8	218	12.4	486	18.8
Receipt of free condoms	5,634	46.8	955	45.0	1,491	53.2	955	54.4	1,491	57.7

ZCTA characteristics

Table 3.2 presents the characteristics of the participants' ZCTAs by area disadvantage and ICE. For area disadvantage, ZCTAs in the least disadvantaged quintile (Q1) tended to be in suburban areas (48%) and had a median MHI, at $103,000 (USD) (interquartile range (IQR) $87,000-$122,00). In comparison, ZCTAs in the most disadvantaged quintile (Q5) were predominantly in urban areas (40%) and had a median MHI of $40,000 (IQR $35,00-$46,000). Rural ZCTAs accounted for 15% of the most disadvantaged ZCTAs. The median NDI value ranged from -1.15 (IQR -1.34- -1.01) in the least disadvantaged to 1.35 (IQR 2.83-5.85) in the most disadvantaged.

By ICE, the median ICE value for ZCTAs with the highest concentration of White, non-Hispanic individuals (Q1) was 0.9 (IQR 0.8-0.9), and -0.5 (IQR -0.7- -0.3) in ZCTAs with the highest concentration of POC individuals (Q5). Urban ZCTAs were 55% of those with the highest POC concentration, whereas they were only 5% of the highest White concentration ZCTAs. Overall, the highest POC concentration ZCTAs were less socioeconomically well off than the highest White concentration ZCTAs, with higher levels of poverty, higher percentages of individuals without health insurance, and lower levels of education.

Table 3.2 Characteristics of the Zip Code Tabulation Areas (ZCTAs) by area disadvantage and local racial/ethnic spatial concentration, AMIS 2016-2019

	Total	Area disadvantage		ICE-POC*	
		Q1 (least)	Q5 (most)	Q1 (highest White)	Q5 (highest POC)
	%	%	%	%	%
N =	6,461	1,293	1,292	1,292	1,292
Residence					
Urban	27.6	23.0	40.2	5.1	55.0
Suburban	24.7	47.8	9.5	23.7	18.8
Small and medium metro	32.8	24.6	35.8	35.4	22.1
Rural	14.9	4.6	14.6	35.8	4.1
Region					
Northeast	18.9	29.9	15.5	30.9	13.3
Midwest	22.4	25.9	17.0	42.6	7.8
South	37.8	26.5	48.8	21.1	46.7
West	21.0	17.7	18.7	5.4	32.1
			Median (IQR)		
Disadvantage Score	-0.1 (-0.8-0.6)	-1.2 (-1.3--1)	1.3 (1-1.9)	-0.6 (-1-0)	0.9 (0.2-1.7)
ICE – POC Score	0.4 (0-0.7)	0.7 (0.4-0.8)	-0.2 (-0.7-0.2)	0.9 (0.8-0.9)	-0.5 (-0.7- -0.3)
Individuals					
Less than high school diploma or equivalent	9.2 (5.5-15.1)	4.1 (2.8-5.9)	19.1 (14-26)	7.5 (4.6-11.6)	19.3 (13.1-27)

* Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

Unemployed	5.1 (3.8-7)	3.7 (2.9-4.6)	8.3 (6.4-10.6)	4.2 (3.1-5.8)	7.2 (5.6-9.8)
Health insurance	92.6 (88.3-95.4)	96.3 (94.6-97.7)	87.3 (82-91.5)	94.9 (92.5-96.7)	86.8 (81.6-91.1)
Below poverty	11.9 (7.1-18.9)	4.6 (3.4-5.8)	25.3 (21.4-31.2)	9.2 (5.6-14.5)	20.0 (13.1-27.9)
Households					
MHI (2019 USD)	63,000 (49,000-83,000)	103,000 (87,000-122,000)	40,000 (35,000-46,000)	63,000 (51,000-80,000)	51,000 (39,000-67,000)
Home ownership	67.2 (53.6-77.3)	83 (77.2-87.8)	46.5 (33.8-57.8)	77.8 (71.1-84.1)	51.7 (38.7-62.8)
Single, female-headed	22.2 (14.3-31.7)	10.8 (7.9-13.5)	40.6 (33.6-50.7)	16.8 (11.1-23.4)	33.6 (25-45)
Low income (<$30,000)	23 (15.3-32.1)	11.2 (8.7-13.8)	39.5 (34.5-45.1)	22.1 (15.4-29.9)	30.6 (20.8-41.2)
Household assistance	10.3 (5.6-16.9)	3.7 (2.4-5.1)	23.3 (18.7-29)	9.1 (5.2-14)	18.8 (11.8-27.4)

Prevalence of free condom receipt

Overall, receipt of free condoms ranged from 46% in the least disadvantaged ZCTAs (Q1) to 53% in the most disadvantaged ZCTAs, and prevalence was similar across Q1 to Q4 (Table 3.3). Across ICE quintiles, prevalence was higher in ZCTAs with higher concentrations of POC; 52% of AYMSM in the highest POC concentration ZCTAs reported having received free condoms, compared to 40% of AYMSM in the highest White concentration ZCTAs. When stratified by race/ethnicity, AYMSM who resided in the most disadvantaged ZCTAs had the highest prevalence of receiving free condoms for White, Black, and Hispanic AYMSM. The pattern of higher levels of receipt among AYMSM in ZCTAs with high and highest POC concentration was observed for all race/ethnic groups.

Table 3.3 Prevalence of condom receipt among AYMSM aged 15 to 24 years who reported HIV-negative or unknown status, stratified by race and area disadvantage and local racial/ethnic spatial concentration, AMIS 2016-2019

	Total		White, non-Hispanic		Black, non-Hispanic		Hispanic	
	n tested / total*	%	n tested / total	%	n tested / total	%	n tested / total	%
Total	5,533 / 11,811	46.8	3,571 / 7,982	44.7	429 / 762	56.3	1,533 / 3,067	50.0
Area disadvantage								
Q1 (least)	962 / 2,114	45.5	748 / 1,676	44.6	46 / 80	57.5	154 / 358	43.0
Q2	955 / 2,138	44.7	643 / 1,564	41.1	52 / 86	60.5	237 / 488	48.6
Q3	1,045 / 2,286	45.7	703 / 1,615	43.5	55 / 113	48.7	267 / 558	47.8
Q4	1,176 / 2,509	46.9	687 / 1,596	43.0	102 / 180	56.7	364 / 733	49.7
Q5 (most)	1,475 / 2,764	53.4	790 / 1,531	51.6	174 / 303	57.4	511 / 930	54.9
ICE-POC†								
Q1 (White, NH)	687 / 1,729	39.7	623 / 1,590	39.2	- ‡	-	53 / 116	45.7
Q2	982 / 2,274	43.2	809 / 1,914	42.3	31 / 58	53.4	142 / 302	47.0
Q3	1,214 / 2,605	46.6	910 / 2,001	45.5	72 / 134	53.7	232 / 470	49.4
Q4	1,279 / 2,485	50.4	829 / 1,708	48.5	122 / 205	59.5	420 / 805	52.2
Q5 (POC)	1,279 / 2,485	51.5	400 / 769	52.0	193 / 342	56.4	686 / 1,374	49.9

* Among those whose race/ethnicity and/or outcome were not missing (missing n = 231)

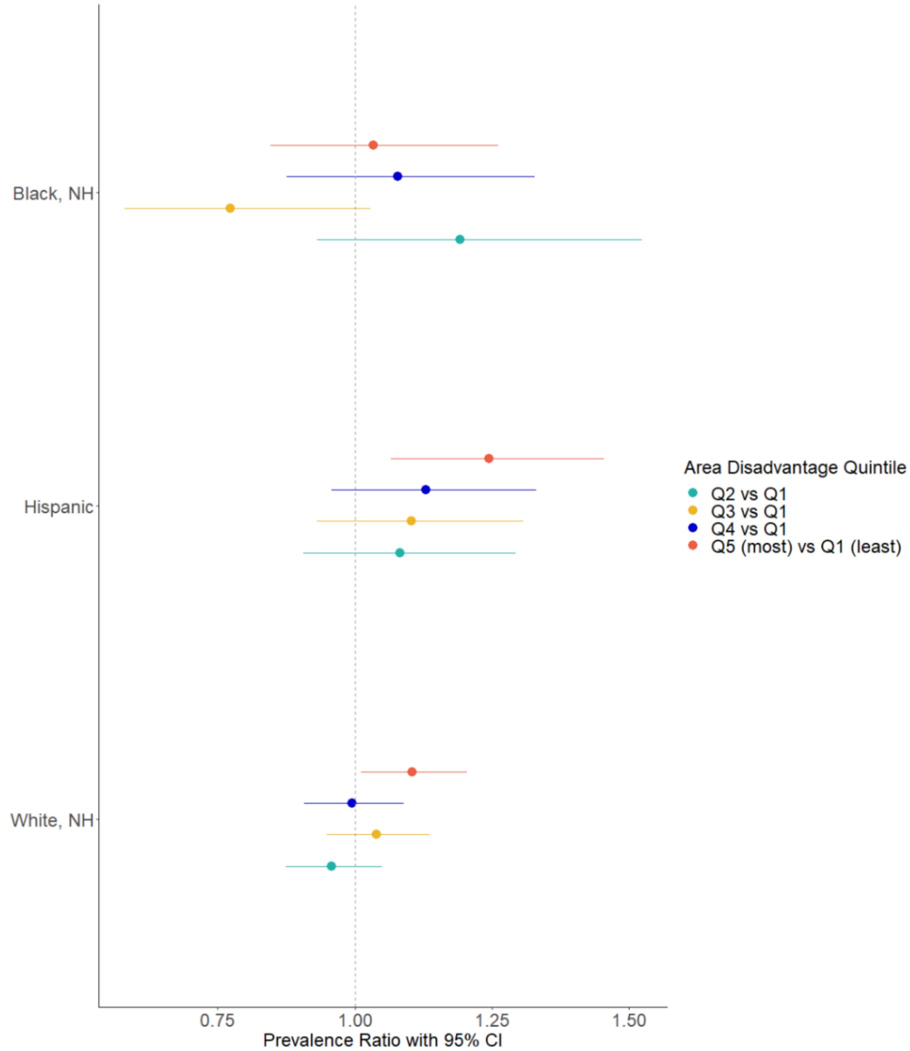
† Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

‡ Denominators < 50 not shown

Relationship between area disadvantage and free condom receipt

In the unadjusted model, AYMSM who resided in ZCTAs with the most disadvantaged were more likely to have received free condoms compared to AYMSM in ZCTAs with the least disadvantage (prevalence ratio (PR) 1.16, 95% confidence interval (CI) 1.09, 1.23) (Table 3.6). In the interaction only model, receipt of condom use was higher in the most disadvantaged ZCTAs, compared to the least disadvantaged ZCTAs, among White (PR 1.10, 95% CI 1.02, 1.19) and Hispanic AYMSM (PR 1.26, 95% CI 1.09, 1.44). Among Black AYMSM, the PR comparing AYMSM in the most and least disadvantaged ZCTAs was 1.01 (95% CI 0.81, 1.25), indicating no association. In the fully adjusted model (Figure 3.1), the associations comparing condom receipt in the most and least disadvantaged ZCTAs remained and were similar to the estimates in the interaction-only model, for White (PR 1.10, 95% CI 1.01, 1.20) and Hispanic (PR 1.24, 95% CI 1.07, 1.45) AYMSM. For Black AYMSM, no meaningful associations were observed between area disadvantage and receipt of free condoms. There was evidence of multiplicative ($p = 0.04$) but not additive interaction, as $RERI_{RR}$ were null for both groups (Table 3.4).

Figure 3.1 Adjusted prevalence ratios (aPRs) and 95% confidence intervals (CI) for the association between area disadvantage and receipt of free condoms by race/ethnicity, AMIS 2016-2019



Area Disadvantage	Black, non-Hispanic		Hispanic		White, non-Hispanic	
	aPR*	95% CI	aPR	95% CI	aPR	95% CI
Q1 (least)	Ref		Ref		Ref	
Q2	1.19	(0.93, 1.52)	1.08	(0.91, 1.29)	0.96	(0.87, 1.05)

Model clustered by ZCTA

* Adjusted for the individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, STI diagnosis in past 12 months, HIV test ever, and heard of PrEP and area-level covariates: residence and region.

Q3	0.77	(0.58, 1.03)	1.10	(0.93, 1.31)	1.04	(0.95, 1.14)
Q4	1.08	(0.88, 1.33)	1.13	(0.96, 1.33)	0.99	(0.91, 1.09)
Q5 (most)	1.03	(0.85, 1.26)	1.24	(1.07, 1.45)	1.10	(1.01, 1.2)

Table 3.4 Regression coefficients and the relative excess risk due to interaction (RERI) for the associations among area disadvantage, race/ethnicity, and receipt of free condoms (interaction models)

	Model 2 (interaction-only model)*					
	Multiplicative		Black, NH		Hispanic	
	β	95% CI	RERI	95% CI	RERI	95% CI
Area disadvantage						
Q5 (most)	0.10	(0.02, 0.17)	-0.09	(-0.38, 0.2)	0.15	(-0.01, 0.31)
Q4	-0.06	(-0.15, 0.02)	0.03	(-0.28, 0.34)	0.19	(0.02, 0.35)
Q3	-0.03	(-0.11, 0.05)	-0.13	(-0.47, 0.21)	0.12	(-0.05, 0.29)
Q2	-0.08	(-0.17, 0)	0.21	(-0.14, 0.56)	0.19	(0.02, 0.37)
Q1 (least)	Ref					
Race/ethnicity						
Black, NH	0.25	(0.04, 0.45)				
Hispanic	-0.02	(-0.16, 0.11)				
White, NH	Ref					
Interaction						
Q5*Black	-0.09	(-0.32,0.15)				
Q4*Black	0.04	(-0.21,0.29)				
Q3*Black	-0.10	(-0.38,0.18)				
Q2*Black	0.18	(-0.09,0.45)				
Q5*Hispanic	0.13	(-0.02,0.29)				
Q4*Hispanic	0.19	(0.02,0.35)				
Q3*Hispanic	0.12	(-0.06,0.29)				
Q2*Hispanic	0.19	(0.02,0.37)				
p-value for interaction	0.15					

	Model 3 (fully adjusted model)†					
	Multiplicative		Black, non-Hispanic		Hispanic	
	β	95% CI	RERI	95% CI	RERI	95% CI
Area disadvantage						
Q5 (most)	0.10	(0.01, 0.19)	-0.06	(-0.33, 0.2)	0.14	(-0.04, 0.31)
Q4	-0.01	(-0.1, 0.09)	0.10	(-0.17, 0.38)	0.13	(-0.05, 0.32)
Q3	0.04	(-0.05, 0.13)	-0.32	(-0.65, 0)	0.06	(-0.13, 0.26)
Q2	-0.04	(-0.13, 0.05)	0.28	(-0.07, 0.63)	0.12	(-0.07, 0.32)

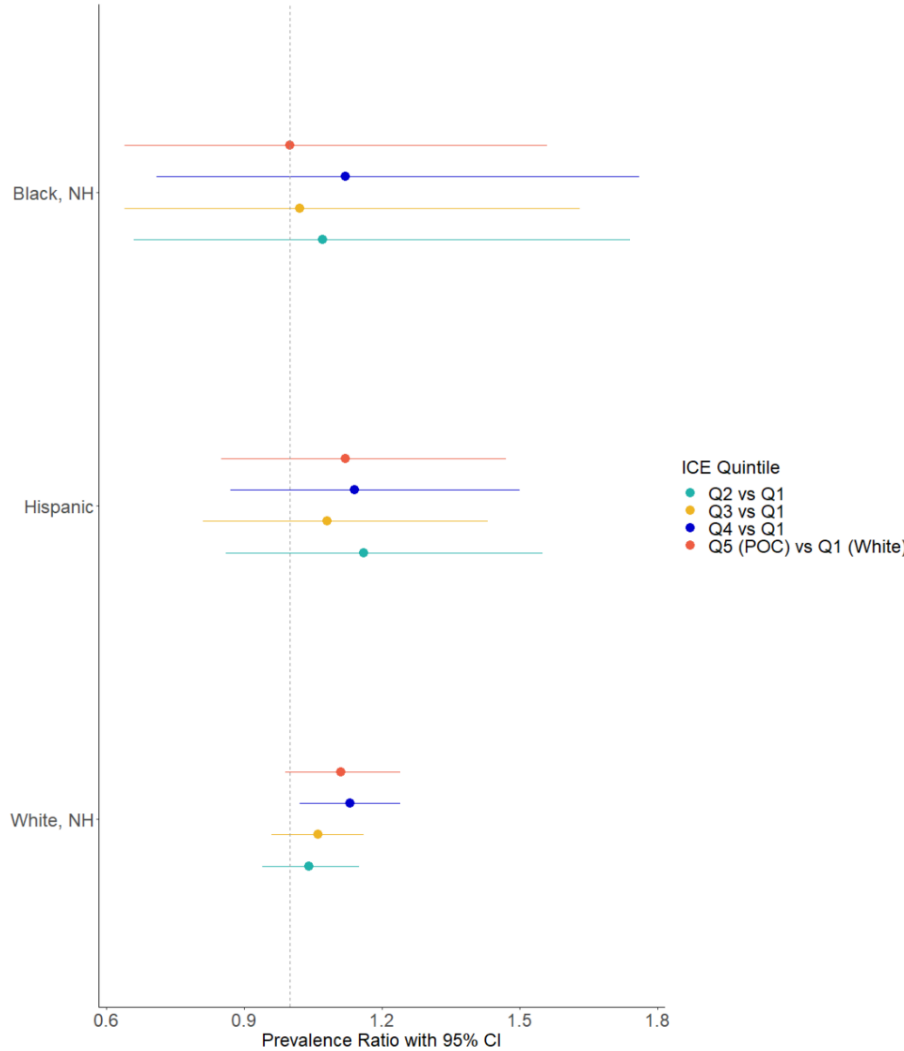
All models clustered by ZCTA.
NH: Non-Hispanic
* Model 2 includes only the exposure and the disadvantage X race/ethnicity interaction term.
† Model 3 is adjusted for individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, STI diagnosis in past 12 months, HIV test ever, and heard of PrEP and area-level covariates: residence and region.

Q1 (least)	Ref	
Race/ethnicity		
Black, NH	0.23	(0.05, 0.41)
Hispanic	-0.01	(-0.17, 0.14)
White, NH	Ref	
Interaction		
Q5*Black	-0.07	(-0.28,0.15)
Q4*Black	0.08	(-0.14,0.3)
Q3*Black	-0.30	(-0.59,0)
Q2*Black	0.22	(-0.04,0.48)
Q5*Hispanic	0.12	(-0.05,0.29)
Q4*Hispanic	0.13	(-0.06,0.31)
Q3*Hispanic	0.06	(-0.13,0.25)
Q2*Hispanic	0.12	(-0.08,0.32)
p-value for interaction	0.04	

Relationship between local racial/ethnic spatial concentration and free condom receipt

In the unadjusted model, AYMSM who resided in ZCTAs with higher POC concentration were more likely to have received free condoms compared to AYMSM who resided in ZCTAs with higher White concentrations (Table 3.6). AYMSM in the highest POC concentration ZCTAs were 29% more likely to have received free condoms than AYMSM in the highest White concentration ZCTAs (PR 1.29, 95% CI 1.19, 1.38). In the interaction-only model, increased free condom receipt was associated with residing in highest POC concentration ZCTAs among White AYMSM (PR 1.28, 95% CI 1.16, 1.41). For Black and Hispanic AYMSM, estimates suggested higher prevalence of free condom receipt among AYMSM in the highest POC concentration ZCTAs but had wide confidence intervals that included the null. In the fully adjusted model (Figure 3.2), among White AYMSM, the association for AYMSM in the highest POC concentration ZCTAs was attenuated (PR 1.11, 95% CI 0.99, 1.24). No meaningful differences were observed by ICE quintile among Black and Hispanic AYMSM, and there was no evidence of multiplicative ($p = 0.91$) or additive interaction (Table 3.5).

Figure 3.2 Adjusted prevalence ratios (aPRs) and 95% confidence intervals (CI) for the association between local racial/ethnic spatial concentration and receipt of free condoms by race/ethnicity, AMIS 2016-2019



ICE-POC*	Black, non-Hispanic		Hispanic		White, non-Hispanic	
	aPR†	95% CI	aPR	95% CI	aPR	95% CI
Q1 (White)	Ref		Ref		Ref	

Model clustered by ZCTA

* Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

† Adjusted for the individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, STI diagnosis in past 12 months, HIV test ever, and heard of PrEP and area-level covariates: residence and region.

Q2	1.07	(0.66, 1.74)	1.16	(0.86, 1.55)	1.04	(0.94, 1.15)
Q3	1.02	(0.64, 1.63)	1.08	(0.81, 1.43)	1.06	(0.96, 1.16)
Q4	1.12	(0.71, 1.76)	1.14	(0.87, 1.5)	1.13	(1.02, 1.24)
Q5 (POC)	1.00	(0.64, 1.56)	1.12	(0.85, 1.47)	1.11	(0.99, 1.24)

Table 3.5 Regression coefficients and the relative excess risk due to interaction (RERI) for the associations among local racial/ethnic spatial concentration, race/ethnicity, and receipt of free condoms (interaction models)

	Model 2 (interaction-only model)*					
	Multiplicative		Black, NH		Hispanic	
	β	95% CI	RERI	95% CI	RERI	95% CI
ICE-POC†						
Q5 (highest White)	0.24	(0.15, 0.34)	-0.08	(-0.6, 0.43)	-0.16	(-0.42, 0.11)
Q4	0.19	(0.11, 0.27)	0.09	(-0.43, 0.61)	-0.06	(-0.32, 0.20)
Q3	0.12	(0.04, 0.21)	0.01	(-0.53, 0.56)	-0.06	(-0.33, 0.21)
Q2	0.07	(-0.01, 0.16)	0.07	(-0.52, 0.67)	-0.04	(-0.33, 0.25)
Q1 (highest POC)	Ref					
Race/ethnicity						
Black, NH	0.22	(-0.17, 0.62)				
Hispanic	0.16	(-0.05, 0.36)				
White, NH	Ref					
Interaction						
Q5*Black	-0.10	(-0.51, 0.31)				
Q4*Black	0.02	(-0.39, 0.44)				
Q3*Black	-0.02	(-0.45, 0.41)				
Q2*Black	0.04	(-0.42, 0.50)				
Q5*Hispanic	-0.05	(-0.29, 0.20)				
Q4*Hispanic	-0.07	(-0.29, 0.15)				
Q3*Hispanic	-0.07	(-0.30, 0.17)				
Q2*Hispanic	-0.05	(-0.29, 0.20)				
p-value for interaction	0.84					

	Model 3 (fully adjusted model)‡					
	Multiplicative		Black, non-Hispanic		Hispanic	
	β	95% CI	RERI	95% CI	RERI	95% CI
ICE-POC						
Q5 (highest White)	0.11	(-0.01, 0.22)	-0.12	(-0.7, 0.47)	0.02	(-0.28, 0.32)

All models clustered by ZCTA.

NH: Non-Hispanic

* Model 2 includes only the exposure and the disadvantage X race/ethnicity interaction term.

† Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

‡ Model 3 is adjusted for individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, STI diagnosis in past 12 months, HIV test ever, and heard of PrEP and area-level covariates: residence and region.

Q4	0.12	(0.02, 0.22)	0.03	(-0.56, 0.61)	0.02	(-0.28, 0.32)
Q3	0.06	(-0.04, 0.15)	-0.03	(-0.63, 0.58)	0.03	(-0.28, 0.34)
Q2	0.04	(-0.06, 0.14)	0.06	(-0.58, 0.69)	0.13	(-0.20, 0.46)
Q1 (highest POC)	Ref					
Race/ethnicity						
Black, NH	0.26	(-0.18, 0.69)				
Hispanic	0.05	(-0.22, 0.32)				
White, NH	Ref					
Interaction						
Q5*Black	-0.11	(-0.56, 0.34)				
Q4*Black	-0.01	(-0.46, 0.45)				
Q3*Black	-0.03	(-0.5, 0.43)				
Q2*Black	0.03	(-0.45, 0.52)				
Q5*Hispanic	0.01	(-0.27, 0.29)				
Q4*Hispanic	0.01	(-0.27, 0.29)				
Q3*Hispanic	0.02	(-0.27, 0.31)				
Q2*Hispanic	0.11	(-0.2, 0.41)				
p-value for interaction	0.91					

Table 3.6 Prevalence ratios (PR) and 95% confidence intervals (CI) for the associations between area disadvantage and local racial/ethnic spatial concentration quintiles and receipt of free condoms by race/ethnicity, AMIS 2016-2019

	Model 1 Unadjusted		Model 2 Interaction only*		Model 3 Fully adjusted†	
	PR	95% CI	PR	95% CI	PR	95% CI
Area Disadvantage						
All						
Q1 (least)	Ref		-		-	
Q2	0.97	(0.91, 1.05)	-		-	
Q3	1.00	(0.93, 1.07)	-		-	
Q4	1.01	(0.94, 1.08)	-		-	
Q5 (most)	1.16	(1.09, 1.23)	-		-	
White, NH						
Q1 (least)	-		Ref		Ref	
Q2	-		0.92	(0.85, 1.00)	0.96	(0.87, 1.05)
Q3	-		0.97	(0.89, 1.05)	1.04	(0.95, 1.14)
Q4	-		0.94	(0.86, 1.02)	0.99	(0.91, 1.09)
Q5 (most)	-		1.10	(1.02, 1.19)	1.10	(1.01, 1.20)
Black, NH						
Q1 (least)	-		Ref		Ref	
Q2	-		1.10	(0.85, 1.43)	1.19	(0.93, 1.52)
Q3	-		0.88	(0.67, 1.15)	0.77	(0.58, 1.03)
Q4	-		0.98	(0.77, 1.24)	1.08	(0.88, 1.33)
Q5 (most)	-		1.01	(0.81, 1.25)	1.03	(0.85, 1.26)
Hispanic						
Q1 (least)	-		Ref		Ref	
Q2	-		1.12	(0.95, 1.30)	1.08	(0.91, 1.29)
Q3	-		1.09	(0.93, 1.27)	1.10	(0.93, 1.31)
Q4	-		1.13	(0.98, 1.31)	1.13	(0.96, 1.33)
Q5 (most)	-		1.26	(1.09, 1.44)	1.24	(1.07, 1.45)
ICE-POC‡						
All						
Q1 (White)	Ref		-		-	

All models clustered by ZCTA
NH: non-Hispanic

* Model 2 includes only the exposure and the disadvantage X race/ethnicity interaction term.
† Model 3 is adjusted for individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, STI dx in past 12 months, HIV test ever, and heard of PrEP and area-level covariates: residence and region.
‡ Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

Q2	1.09	(1.00, 1.18)	-		-	
Q3	1.15	(1.07, 1.24)	-		-	
Q4	1.25	(1.16, 1.34)	-		-	
Q5 (POC)	1.29	(1.19, 1.38)	-		-	
White, NH						
Q1 (White)	-		Ref		Ref	
Q2	-		1.08	(0.99, 1.17)	1.04	(0.94, 1.15)
Q3	-		1.13	(1.04, 1.23)	1.06	(0.96, 1.16)
Q4	-		1.21	(1.11, 1.31)	1.13	(1.02, 1.24)
Q5 (POC)			1.28	(1.16, 1.41)	1.11	(0.99, 1.24)
Black, NH						
Q1 (White)	-		Ref		Ref	
Q2	-		1.12	(0.71, 1.77)	1.07	(0.66, 1.74)
Q3	-		1.11	(0.73, 1.70)	1.02	(0.64, 1.63)
Q4	-		1.24	(0.83, 1.86)	1.12	(0.71, 1.76)
Q5 (POC)	-		1.15	(0.77, 1.72)	1.00	(0.64, 1.56)
Hispanic						
Q1 (White)	-		Ref		Ref	
Q2	-		1.03	(0.81, 1.30)	1.16	(0.86, 1.55)
Q3	-		1.06	(0.85, 1.32)	1.08	(0.81, 1.43)
Q4	-		1.13	(0.92, 1.39)	1.14	(0.87, 1.50)
Q5 (POC)	-		1.10	(0.90, 1.35)	1.12	(0.85, 1.47)

DISCUSSION

Overall, receipt of free condoms in the past year was reported by less than half of AYMSM. We observed different patterns of associations between the place-based structural factors and free condom receipt by race/ethnicity. Increased prevalence of free condom receipt was associated with residing in ZCTAs with the highest disadvantage and in ZCTAs with higher POC concentrations for White AYMSM. For Hispanic AYMSM, residing in ZCTAs with the highest disadvantage was also associated with increased prevalence, and no associations were observed across the ICE levels. For Black AYMSM, no meaningful associations were observed for area disadvantage or local racial/ethnic spatial concentration.

Condoms are an important HIV prevention tool for AYMSM and are a critical component of effective combination prevention for this population. The intersection of AYMSM’s younger age, minority sexual identity, and racial/ethnic identity make AYMSM especially vulnerable to HIV risk due to their limited knowledge, ability, and self-efficacy in accessing HIV prevention tools and services. Therefore, structural interventions that promote access and utilization of HIV prevention behaviors and services, like condom distribution programs, are essential for reducing HIV and STI risk among AYMSM. This study adds to the limited literature on condom access among AYMSM by examining how structural place-based factors are associated with condom access. This multilevel exploration of free condom receipt in a geographically and racially/ethnically diverse sample can provide further insight into which AYMSM have benefitted from free condoms and where structural-level condom interventions should focus.

In our study population, only 47% reported receiving free condoms. This estimate is lower than the 73% reported by AYMSM aged 18 to 24 years in the 2017 National HIV Behavioral Surveillance System (NHBS), which recruits participants through popular venues where MSM gather in major metropolitan areas. The lower estimate we observed may be attributed to the inclusion of younger AYMSM (those who are below 18 years of age) and/or those who do not attend venues in our study population. Contrary to expectations, we found that increased prevalence of free condom receipt was associated with residing in the most disadvantaged ZCTAs for White and Hispanic AYMSM and with residing in ZCTAs with the highest POC concentration for White AYMSM. This aligns with what previous studies, though few, have observed. Bauermeister et al. found that AYMSM living in neighborhoods with higher disadvantage, compared to less disadvantaged neighborhoods, were less likely to report CAI with a HIV serodiscordant partner and more likely to report having tested for HIV (38). Frye et al. examined neighborhood racial/ethnic composition and consistent condom use among MSM residing in New York City and found no association (41). Taken together, these findings may reflect the impact of interventions that have targeted areas of HIV prevalence and incidence, which have also been marked by high socioeconomic disadvantage and high concentrations of minority racial/ethnic groups. We also expected to observe differences by race/ethnicity based on previous research that observed differences by race/ethnicity in the associations between neighborhood-level factors and condom use (99). For Black AYMSM, receipt was similar across disadvantage quintiles, and the lack of association observed may suggest that there may be more relevant barriers to condom access. For local racial/ethnic spatial concentration, it is probable that we were not able to identity differences among Black and Hispanic AYMSM due to similarities in the racial/ethnic composition of the areas in which participants resided. These findings add to our understanding of how these structural place-based factors may not only influence condom use but condom access among AYMSM.

The findings from our study must be interpreted in the context of the study's limitations. First, this study utilizes a convenience sampling approach, and therefore, data from AMIS are not generalizable to AYMSM in the US or all AYMSM who access the internet. Because recruitment for AMIS is conducted through online ads on websites and social media applications, the study population may be more likely to include AYMSM who are more open about their gay and bisexual identities, and outness has been linked to higher and lower levels of engaging in sexual risk behaviors among AYMSM, which may be linked to their receipt of free condoms. Second, participants' residence was determined by their ZIP Codes and proxied by their ZCTAs. ZCTAs can vary widely in their population sizes and land areas and may not accurately represent the participants' contextual environment. However, ZCTAs and ZIP codes have been frequently used in public health research to capture area-level information, given participants' knowledge of their ZIP code, public availability of the data, and interpretability of ZIP code for public health action by policymakers and the public (92,93). Third, we did not have information regarding the length of residence in the reported ZIP Code. It is possible that participants were only exposed to their environment for short period of time, and this may introduce bias. However, though young adulthood is a highly mobile period due to education, employment, housing, or family-related issues, only 6% to 8% of young adults move to different counties (94). Fourth, receipt of free condoms in the past year was based on self-report by AYMSM, and there may be recall bias, resulting in misclassification of the outcome measure. However, this may have been limited because participants were asked about condom receipt, and not use, and self-administered the survey, potentially decreasing social desirability related to condom receipt. Fifth, our study was not designed to examine effect measure modification by race/ethnicity and therefore may be underpowered to detect heterogeneity in these multilevel relationships. Additionally, previous studies have shown that Black MSM tend to be underrepresented in studies with online-based recruitment (114). Finally, there may be uncontrolled and structural confounding due to historical spatial stratification processes that have resulted in the sorting of minority racial/ethnic and sexual identity populations into certain neighborhoods or areas of the U.S so that they could never experience residing in the comparison neighborhoods.

Conclusion

Making condoms available and accessible for AYMSM is essential for reducing their HIV risk. Less than half of AYMSM reported receiving access to free condoms. The different pattern of associations between these structural place-based factors, disadvantage and local racial/ethnic spatial concentration, and receipt of free condoms by race/ethnicity suggest that condom access may differ for different groups despite residing in the same residential environment. Further research is warranted to understand how free condom receipt may be differential for Black and Hispanic compared to White AYMSM within the same socioeconomic and demographic residential environments and to illuminate the specific contextual barriers to condom access for Black and Hispanic AYMSM. Structural-level interventions to increase the availability and accessibility of condoms should consider contextual factors, like area-level socioeconomic and demographic characteristics, along with HIV prevalence and incidence to identify where to target condom distribution interventions.

Chapter 4 Area disadvantage and local racial/ethnic spatial concentration and HIV testing among adolescent and young men who have sex with men

ABSTRACT

Background: HIV testing among AYMSM is low, and testing levels have not increase over time. Structural place-based factors in AYMSM's residential environment, such as area disadvantage and local racial/ethnic spatial concentration, may affect AYMSM's access to HIV testing. In this study, we examined the relationship between these two contextual factors and having ever tested for HIV among AYMSM and how these relationships may differ by race/ethnicity.

Methods: We used individual-level data from the 2016-2019 cycles of the American Men's Internet Survey (AMIS). Participants reported their residential ZIP Code, and ZIP Code Tabulation Area (ZCTA) data were from the American Community Survey. Demographic and socioeconomic indicators were used to construct neighborhood disadvantage index and the Index of Concentration at the Extremes (ICE) for race/ethnicity, to measure local spatial concentration of racial/ethnic minority groups, or people of color (POC). Multilevel modeling was conducted to estimate prevalence ratios (PRs), and multiplicative and additive interaction by race and ethnicity was also assessed.

Results: Overall, 53% of AYMSM reported ever testing for HIV. Residing in the most disadvantaged ZCTAs was associated with increased HIV testing for White (PR 1.08, 95% CI 1.02, 1.14) and Hispanic (PR 1.13, 95% 1.01, 1.26) AYMSM. Residing in ZCTAs with highest POC concentrations was associated with increased HIV testing for White AYMSM (PR 1.17, 95% CI 1.08, 1.26) and decreased testing for Hispanic AYMSM (PR 0.82, 95% 0.69, 0.97). Among Black AYMSM, no meaningful associations were observed.

Conclusions: The findings from our multilevel analysis suggest different associations between these structural place-based factors and HIV testing by race/ethnicity. Future research to understand the multilevel barriers to testing among AYMSM is warranted. Our study also demonstrates how area-level measures can be utilized with HIV behavioral surveillance data to

better understand HIV testing patterns among AYMSM. Given the low levels of testing among AYMSM, HIV testing interventions that focus on AYMSM must be expanded and sustained.

INTRODUCTION

In 2018, nearly half of AYMSM (46%) living with HIV infection were unaware of their HIV status (2). Diagnosis of HIV is critical for linking individuals with HIV to care and treatment, which can then reduce the risk of onward transmission, and for linking individuals who test negative to HIV prevention services and counseling. The U.S. Centers for Disease Control and Prevention (CDC) recommends HIV screening at least annually for sexually-active MSM (115), and diagnosis of HIV infection is one of the four pillars of the national “Ending the HIV Epidemic” initiative (116).

AYMSM have been disproportionately impacted by HIV. They account for 17% of all new HIV diagnoses with approximately 6,000 new infections per year (2). Estimates of HIV incidence from epidemiological studies range from 2.85 to 6.5 per 100 person-years (3). Within this group, Black and Hispanic AYMSM are at even higher risk. Black AYMSM accounted for 48% new HIV diagnoses among AYMSM aged 13 to 24 years, followed by Latino (31%) and White AYMSM (15%) in 2018 (2). HIV incidence estimates reflect this racial/ethnic disparity as well, with higher incidence, up to 10-fold, among Black and Hispanic AYMSM compared to White AYMSM (7–10).

HIV testing among AYMSM is low. Only 15% of high school-aged AYMSM had ever tested for HIV (12), and estimates for having tested in the past year among older AYMSM range from 45%, among those aged 15 to 24 years from online-based surveillance (18), to 79%, among those aged 18 to 24 years from venue-based surveillance (19). Trend analyses of online- and venue-based surveillance show that HIV testing among AYMSM has not increased over time (18,20). By race/ethnicity, Black and Hispanic AYMSM report higher levels of testing compared to White AYMSM (21,22) but are less likely to be aware of their HIV infection, and therefore less likely to be linked to care early in their HIV infection (22). Approximately 51% of Hispanic AYMSM had undiagnosed HIV infection, and this was 44% among Black and 43% among White AYMSM in 2018 (2)

AYMSM may face complex individual- and structural-level barriers in accessing and utilizing HIV testing services. Low risk perception (117,118); not knowing where to get tested or how to travel there (24,119); having limited, or no, financial resources to pay for travel or health services (54,70); lack of health insurance (6), and privacy and confidentiality concerns have been associated with not testing for HIV among AYMSM (24,27). Stigma related to their minority sexual identity and having HIV are also factors in AYMSM's decision to test or not test for HIV. Internalized stigma about their minority sexual identities; fear of disclosing to health care providers and family; and anticipated poor treatment in health care settings have been associated with decreased utilization of health services, including HIV testing (24,64). In addition, the anticipated stigma, of being treated negatively or unfairly, of having HIV has also been linked to decreased HIV testing even after adjusting for age, sexual identity, and risk behaviors (31).

Structural place-based factors in AYMSM's residential environment may also influence AYMSM's access to and utilization of HIV testing services. Previous studies have demonstrated the relationship between place-based factors, such as poverty, physical disorder, and social disorganization, and increased engagement in HIV risk behavior (34,99) and that HIV epidemic in the U.S. has been concentrated in places with high socioeconomic disadvantage, income inequality, and concentrations of minority racial and ethnic populations (34,35,120–123). However, few studies have examined place-based correlates of HIV testing for AYMSM (35). The few studies that have focused or included AYMSM have examined these multilevel relationships have found residing in areas with higher socioeconomic disadvantage, higher proportion of Black/African American residents, and availability of HIV services were associated with HIV testing (38,42).

Given this limited understanding, we aimed to explore how area disadvantage and local spatial concentration of race and ethnicity are linked with HIV testing among AYMSM and how these relationships may be modified by AYMSM's race/ethnicity in a geographically and age diverse sample of AYMSM.

METHODS

Study Design

Data sources

Individual-level data were from the 2016 to 2019 cycles of the American Men's Internet Survey (AMIS). AMIS is an annual cross-sectional, internet-based survey of HIV risk behaviors, HIV prevention, and access to HIV-related health services among gay, bisexual, and other MSM, with the aim of collecting at least 10,000 completed surveys from eligible MSM. The survey's methodology has been previously detailed (14). Briefly, men were eligible to participate if they are 15 years of age or older, reside in the U.S., report ever having oral or anal sex with a man or identify as gay or bisexual, and were able to complete the survey in English. Participants were recruited online through convenience sampling in two ways. First, advertisements, or "ads," for a survey on men's sexual health were placed as banner ads on a variety of websites and social media applications. Second, participants were also recruited through emailing participants of previous cycles who had consented to be contacted for potential participation in future studies. Men who were eligible and provided consent were then directed to the self-administered survey, which could be completed on a computer or mobile device. AMIS asked questions in the following domains: demographics, sexual behavior, HIV testing history, and utilization of HIV prevention services. The survey also collected participants' ZIP Code of residence. Participants did not receive incentives for study participation. Survey data were collected using encrypted HIPAA-compliant survey software and stored on an access-restricted secure data server, administered by SurveyGizmo (Boulder, CO, USA).

Demographic and socioeconomic area-level data were abstracted from the American Community Survey (ACS), using the five-year estimates for 2014-2018, for the ZIP Code Tabulation Area (ZCTA). ZCTAs are the U.S. Census Bureau's areal approximations of the U.S.

Postal Service's ZIP Code system (105). Participants' reported ZIP Code were linked to their respective ZCTA, and UDS Mapper ZIP Code to ZCTA Crosswalk (106) was used to resolve ZIP Code-ZCTA discrepancies. The locations of HIV testing sites in the U.S. were downloaded from the CDC's National Prevention Information Network Service Finder tool as of 2019. Participants were eligible for our analyses if they were reported being 15 to 24 years, reported HIV-negative or unknown status, and resided in the 50 states of the U.S. Given our aim of examining the relationship between neighborhood HIV testing, our analysis excluded participants who did not report a ZIP Code due to housing instability; resided in U.S. territories; and reported ZIP Codes associated with military bases, as indicated by Army Post Office (APO) or Fleet Post Office (FPO). Participants who resided in ZCTAs that had missing information on the ZCTA demographic and socioeconomic characteristics were also excluded.

Measures

Outcome assessment

The outcome for this analysis was having ever tested for HIV. Participants were asked if they had ever been tested for HIV, and this was measured as a binary variable. We also examined a secondary outcome of recent HIV testing, having tested for HIV in the past year, and recent HIV testing was measured as a binary variable.

Exposure assessment

To measure neighborhood disadvantage, we adapted the Neighborhood Deprivation Index created by Messer et al (107). We first examined the following ZCTA-level sociodemographic factors: percent of individuals aged 25 years and older with less than a high school degree or equivalent; percent of individuals aged 16 years and older who were unemployed; percent of individuals with public or private health insurance; percent of individual living in poverty; percent of home ownership; percent of single, female-headed households; percent of low income households (households income less than $30,000 per year); and percent of households receiving government assistance such as food stamps. We utilized principal components analysis (PCA), a data reduction technique, to determine which variables to retain in the final index, using an orthogonal rotation (varimax) on the full set of variables. There were three factors with an eigenvalue greater than one, and the first factor explained much of the variance (variance factor 1 = 5.46, variance factor 2 = 1.36, variance factor 3 = 1.15). The 7 variables that fit within the first factor were retained, and factor loadings were high, with a variance factor was 4.68. The retained variables were used to construct a standardized continuous neighborhood disadvantaged score that was categorized into quintiles, with quintile 1 (Q1) representing the least disadvantage neighborhoods and quintile 5 (Q5) the most disadvantaged neighborhoods.

To measure local racial/ethnic spatial concentration, we used the Index of Concentration at the Extremes (ICE) at the ZCTA level. ICE, primarily used in the social sciences, was initially conceived to measure the extremes of poverty and affluence (108) and has recently been used in public health, specifically in surveillance, to capture spatial social polarization of deprivation and privilege as represented by race and income (109,110). ICE is related to but not the same as racial residential segregation, which compares two spatial scales, such as local neighborhoods and the broader region in which they are situated, simultaneously. ICE is a useful metric because it can simultaneously reflect both extremes, provide the directional tendency, and be utilized locally, such as within a ZCTA, while avoiding issues of multicollinearity that frequently occur when separate measures of race/ethnicity and socioeconomic status are included in the model (110) ICE is calculated as:

$$ICE_i = \frac{A_i - P_i}{T_i}$$

A_i is the number of White, non-Hispanic residents in the i^{th} ZCTA, P_i is the number of non-White (Black, Asian) or Hispanic residents, and T_I is the total population. The range of this index is -1 to 1, where -1 indicates that all individuals in the neighborhood are White, non-Hispanic; 0 indicates that there are equal proportions of White, non-Hispanic and POC individuals; and 1 indicates that all persons are POC. ICE values were categorized into quintiles, where Q1 represented ZCTAs with the highest concentration of White, non-Hispanic individuals and Q5 the ZCTAs with the highest concentration of POC individuals.

Covariate assessment

We examined the following individual-level covariates: age, sexual identity, education, sexual identity disclosure, sexual identity-related stigma, health insurance, a health care provider visit in the past year, condomless anal intercourse (CAS) in the past year, STI testing, and STI diagnosis in the past year. Education was measured as a binary variable that indicated whether the participant's education was on track relative to their age. Participants were asked about their highest level of education attainment but were not asked if they were currently in school. Since the study population included high school-aged AYMSM, this education on track variable was created to capture their educational status. CAI and STI diagnosis were used to indicate AYMSM's HIV risk. Area-level covariates included region of the country, urban-rural residence, density of HIV testing sites (number of sites per 10,000 population), and distance to the nearest HIV testing site, calculated by measuring the Euclidean distance, in meters, from the centroid of the ZCTA to the nearest HIV testing site. Urban-rural residence classification was based on the National Center for Health Statistics Urban-Rural Classification Scheme (87).

Statistical Analysis

The research questions of interested examined the relationship between the two area-level exposures, area disadvantage and local racial/ethnic spatial concentration, and HIV testing. We first describe the study population by their individual- and ZCTA-level characteristics by area disadvantage and local racial/ethnic spatial concentration and present the prevalence of ever having tested for HIV stratified by the disadvantage and ICE quintiles for the three race/ethnic groups. For the multivariable analysis, we conducted multilevel modeling with a modified Poisson approach (111) to estimate prevalence ratios and used generalized estimating equations, with an exchangeable correlation structure and robust variance estimation, to account for clustering by ZCTA. Subjects with missing data for the outcome and/or covariates were excluded from the analyses. Area disadvantage and ICE and their relationships with the outcome were examined separately. Our modeling strategy fit a series of models: (i) unadjusted without interaction, (ii) exposure X race interaction-only model, (iii) fully adjusted model adjusting for individual- and area-level covariates with exposure x race interaction. For the models with interaction, we assessed multiplicative interaction with the generalized score test statistic and its p-value and additive interaction with the relative excess risk due to interaction (RERI) from the relative risk model (112). A RERI calculated using risk ratios ($RERI_{RR}$) indicates the direction of the additive interaction, whether positive or negative, but not the relative magnitude of the interaction. For confounding, we adjusted for individual- and area-level covariates, based on prior literature (21,22,27,35,124): age; sexual identity; educational status, whether on track or not based on age; sexual identity disclosure; experiences of sexual identity-related stigma; health insurance; health care provider visit in the past one year; STI testing and diagnosis in the past year; condomless anal intercourse; urban-rural residence; region of the country; density of HIV testing sites within the ZIP Code; and distance to HIV testing. We also examined the predicted probabilities of ever testing at each exposure quintile by race/ethnicity based on parameters for the fully adjusted model holding all covariates constant at their average. Multicollinearity was assessed by examining condition indices (greater than 35) and variance decomposition factors (two or more greater than 0.5). Since these criteria were not met, all covariates were retained in the final model. The findings presented focus on the comparisons between the extremes - the most (Q5) and least (Q1) disadvantaged ZCTAs and the highest POC concentration (Q5) and highest White concentration ZCTAs (Q1).

We did not include Asian and Pacific Islander participants and participants who reported their race/ethnicity as Other or Multiracial in the regression analyses. The small sample size of Asian and Pacific Islander participants would produce unreliable estimates, and the heterogeneity of the Other/Multiracial category precluded us from making meaningful interpretations about the exposure-outcome relationships for this group.

Descriptive and regression analyses were conducted using SAS 9.4 (Carey, NC, USA). Calculation of distance to the nearest HIV testing site was conducted using R 3.6.2 (Vienna, Austria). AMIS was reviewed and approved by the Emory University Institutional Review Board.

RESULTS

Participant Characteristics

There was a total of 12,032 participants, residing in 6,461 ZCTAs, included in our analysis. Overall, 53% of AYMSM reported ever testing for HIV (Table 4.1). AYMSM in the most disadvantaged ZCTAs (Q5) were slightly older (mean 21 years, standard deviation (SD) 2.4), more likely to be Black (11%) or non-Hispanic (44%), and more likely to reside in urban areas (46%) than AYMSM in the least disadvantaged ZCTAs (Q1). Their mean age was 20 years (SD 2.5), and they were 4% were Black and 17% Hispanic. Approximately half of AYMSM in the least disadvantaged ZCTAs (49%) resided in suburban areas. In each quintile, AYMSM who were gay, or homosexual, were approximately 70% of AYMSM, and bisexual AYMSM represented approximately a fifth. Regarding HIV-related risk, AYMSM in the most disadvantaged ZCTAs reported higher CAI (67% versus 59%) and STI diagnosis (10% versus 7%) in the past year compared to AYMSM in the least disadvantaged ZCTAs.

Regarding local racial/ethnic spatial concentration, AYMSM residing in ZCTAs with the highest concentration of White, non-Hispanic individuals (Q1) were, correspondingly, predominantly White (91%) and gay or homosexual (72%). Approximately a third resided in rural areas (35%) and in small and medium metro areas (34%). In comparison, AYMSM residing in the highest POC concentration ZCTAs (Q5) were 54% Hispanic and 14% Black, 67% were gay, and 57% resided in urban areas. Mean age was similar in both groups (20 years), as was sexual identity disclosure, at or above 90%. AYMSM in the highest POC concentration ZCTAs reported higher levels of being uninsured (13% versus 7%) and lower levels of having a health care provider visit in the past year (73% versus 78%). CAI was similar across the two groups (63% in Q1 and 66% in Q5). Among AYMSM in the highest POC concentration ZCTAs, 38% reported testing for STIs in the past year, and 11% reported receiving a STI diagnosis. In comparison, 26% of AYMSM in the highest White concentration ZCTAs had been tested for STIs and 6% reported a STI diagnosis.

Table 4.1 Characteristics of participants aged 15-24 years and reporting HIV-negative or unknown status by area disadvantage and local racial/ethnic spatial concentration, AMIS 2016-2019

	Total		Area Disadvantage Quintile				ICE-POC Quintile *			
			Q1 (least)		Q5 (most)		Q1 (highest White)		Q5 (highest POC)	
	n	%	n	%	n	%	n	%	n	%
	12,032		2,122		2,804		1,757		2,586	
Age (years)										
15-17	1,810	15.0	454	21.4	281	10.0	376	21.4	353	13.7
18-20	4,665	38.8	878	41.4	1,060	37.8	741	42.2	955	36.9
21-24	5,557	46.2	790	37.2	1,463	52.2	640	36.4	1,278	49.4
Mean (SD)	20	2.5	20	2.5	21	2.4	20	2.4	20	2.5
Race/ethnicity										
White, non-Hispanic	7,982	66.3	1,656	78.0	1,523	54.3	1,590	90.5	784	30.3
Black, non-Hispanic	762	6.3	80	3.8	303	10.8	23	1.3	352	13.6
Hispanic	3,067	25.5	353	16.6	927	33.1	116	6.6	1,387	53.6
Sexual identity										
Gay or homosexual	8,662	72.0	1,546	72.9	1,969	70.2	1,260	71.7	1,730	66.9
Heterosexual	160	1.3	25	1.2	42	1.5	27	1.5	41	1.6
Bisexual	2,612	21.7	442	20.8	647	23.1	381	21.7	656	25.4
Other	145	1.2	25	1.2	39	1.4	18	1.0	45	1.7
Region										
Northeast	2,115	17.6	573	27.0	455	16.2	525	29.9	369	14.3

Percentages may not equal 100% due to missing data.

* Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

Midwest	2,557	21.3	511	24.1	518	18.5	755	43.0	195	7.5
South	4,649	38.6	616	29.0	1,298	46.3	374	21.3	1,165	45.1
West	2,711	22.5	422	19.9	533	19.0	103	5.9	857	33.1
Residence										
Urban	3,825	31.8	557	26.2	1,250	44.6	108	6.1	1,485	57.4
Suburban	2,781	23.1	1,034	48.7	242	8.6	433	24.6	464	17.9
Small/medium metro	4,091	34.0	466	22.0	1,037	37.0	605	34.4	566	21.9
Rural	1,335	11.1	65	3.1	275	9.8	611	34.8	71	2.7
Education										
Less than high school	1,768	14.7	443	20.9	261	9.3	359	20.4	333	12.9
High school diploma or equivalent	2,889	24.0	508	23.9	633	22.6	451	25.7	651	25.2
Some college/technical degree	4,609	38.3	702	33.1	1,207	43.0	659	37.5	1,034	40.0
College/post-graduate	2,532	21.0	421	19.8	644	23.0	249	14.2	512	19.8
Education on track	10,734	89.2	1,945	91.7	2,457	87.6	1,584	90.2	2,273	87.9
Disclosed sexual identity	11,063	91.9	1,945	91.7	2,587	92.3	1,593	90.7	2,332	90.2
Stigma experiences										
0	5,184	43.1	905	42.6	1,288	45.9	671	38.2	1240	48.0
1	3,496	29.1	640	30.2	777	27.7	522	29.7	731	28.3
2+	3,215	26.7	548	25.8	708	25.2	540	30.7	586	22.7
Health insurance										
Uninsured	1,065	8.9	108	5.1	306	10.9	126	7.2	336	13.0
Private	7,255	60.3	1,383	65.2	1,629	58.1	1,062	60.4	1,339	51.8
Public	1,318	11.0	141	6.6	374	13.3	188	10.7	427	16.5
Other/multiple	902	7.5	147	6.9	222	7.9	123	7.0	173	6.7

Health care provider visit in past year	9,266	77.0	1,711	80.6	2,120	75.6	1,374	78.2	1,879	72.7
Condomless anal intercourse in past year	7,741	64.3	1,257	59.2	1,887	67.3	1,100	62.6	1,693	65.5
STI testing in past year	4,110	34.2	659	31.1	1,055	37.6	456	26.0	977	37.8
STI diagnosis in past year	1,016	8.4	141	6.6	285	10.2	96	5.5	275	10.6
Ever tested for HIV	6,496	53.4	999	47.1	1,711	61.0	740	42.1	1,525	59.0

ZCTA Characteristics

Table 4.2 presents the characteristics of the participants' ZCTAs by area disadvantage and ICE. The least disadvantaged ZCTAs (Q1) were largely in suburban areas (48%) and had a median MHI, at $103,000 (USD) (interquartile range (IQR) $87,000-$122,00). In comparison, the most disadvantaged ZCTAs (Q5) were predominantly in urban areas (40%) and had a median MHI of $40,000 (IQR $35,00-$46,000). Rural ZCTAs accounted for 15% of the most disadvantaged ZCTAs, and the median percent of individuals living in poverty was 25%. The density of HIV testing sites was 0 or very low in all ZCTAs. The median distance to the nearest HIV testing site was 5,100 meters (IQR 2,200-22,700) in the most disadvantaged ZCTAs, compared to 13,500 meters (IQR 8,100-20,800) in the least disadvantaged ZCTAs.

Urban ZCTAs were 55% of those with the highest POC concentration, whereas they were only 5% of the highest White concentration ZCTAs. Overall, the highest POC concentration ZCTAs were less socioeconomically well off than the highest White concentration ZCTAs, with higher levels of poverty, higher percentages of uninsured, and lower levels of educational attainment. The median distance to the nearest HIV testing site was 25,200 meters (IQR 13,700-43,100) in the highest White concentration ZCTAs and 5,200 meters (IQR 2,400-10,600) in the highest POC concentration ZCTAs.

Table 4.2 Characteristics of participants' Zip Code Tabulation Areas (ZCTAs) by area disadvantage and local racial/ethnic spatial concentration, AMIS 2016-2019

	Total	Area disadvantage		ICE-POC*	
		Q1 (least)	Q5 (most)	Q1 (highest White)	Q5 (highest POC)
	%	%	%	%	%
N =	6,461	1,293	1,292	1,292	1,292
Residence					
Urban	27.6	23.0	40.2	5.1	55.0
Suburban	24.7	47.8	9.5	23.7	18.8
Small and medium metro	32.8	24.6	35.8	35.4	22.1
Rural	14.9	4.6	14.6	35.8	4.1
Region					
Northeast	18.9	29.9	15.5	30.9	13.3
Midwest	22.4	25.9	17.0	42.6	7.8
South	37.8	26.5	48.8	21.1	46.7
West	21.0	17.7	18.7	5.4	32.1
			Median (IQR)		
Disadvantage Score	-0.1 (-0.8-0.6)	-1.2 (-1.3--1)	1.3 (1-1.9)	-0.6 (-1-0)	0.9 (0.2-1.7)
ICE – POC Score	0.4 (0-0.7)	0.7 (0.4-0.8)	-0.2 (-0.7-0.2)	0.9 (0.8-0.9)	-0.5 (-0.7- -0.3)
Individuals					
Less than high school diploma or equivalent	9.2 (5.5-15.1)	4.1 (2.8-5.9)	19.1 (14-26)	7.5 (4.6-11.6)	19.3 (13.1-27)
Unemployed	5.1 (3.8-7)	3.7 (2.9-4.6)	8.3 (6.4-10.6)	4.2 (3.1-5.8)	7.2 (5.6-9.8)
Health insurance	92.6 (88.3-95.4)	96.3 (94.6-97.7)	87.3 (82-91.5)	94.9 (92.5-96.7)	86.8 (81.6-91.1)

* Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

Below poverty	11.9 (7.1-18.9)	4.6 (3.4-5.8)	25.3 (21.4-31.2)	9.2 (5.6-14.5)	20.0 (13.1-27.9)
Households					
MHI (2019 USD)	63,000 (49,000-83,000)	103,000 (87,000-122,000)	40,000 (35,000-46,000)	63,000 (51,000-80,000)	51,000 (39,000-67,000)
Home ownership	67.2 (53.6-77.3)	83 (77.2-87.8)	46.5 (33.8-57.8)	77.8 (71.1-84.1)	51.7 (38.7-62.8)
Single, female-headed	22.2 (14.3-31.7)	10.8 (7.9-13.5)	40.6 (33.6-50.7)	16.8 (11.1-23.4)	33.6 (25-45)
Low income (<$30,000)	23 (15.3-32.1)	11.2 (8.7-13.8)	39.5 (34.5-45.1)	22.1 (15.4-29.9)	30.6 (20.8-41.2)
Household assistance	10.3 (5.6-16.9)	3.7 (2.4-5.1)	23.3 (18.7-29)	9.1 (5.2-14)	18.8 (11.8-27.4)
HIV testing					
HIV testing service density (site per 10,000 population)	0 (0-0)	0 (0-0)	0 (0-0.1)	0 (0-0)	0 (0-0)
Distance to nearest HIV testing site (meters)	11,267 (4,878-26,471)	13,518 (8,135-20,757)	5,139 (2,216-22,711)	25,182 (13,674-43,120)	5,236 (2,415-10,620)

Table 4.3 Prevalence of having ever tested for HIV among AYMSM aged 15 to 24 years who reported HIV-negative or unknown status, stratified by race/ethnicity and area disadvantage and local racial/ethnic spatial concentration, AMIS 2016-2019

	Total		White, non-Hispanic		Black, non-Hispanic		Hispanic	
	n tested / total *	%	n tested / total	%	n tested / total	%	n tested / total	%
Total	6387 / 11,616	55.0	4,241 / 7,857	54.0	480 / 746	64.3	1,666 / 3,013	55.3
Area disadvantage								
Q1 (least)	987 / 2,047	48.2	777 / 1,621	48.0	51 / 79	64.6	159 / 347	45.8
Q2	1125 / 2,131	52.8	801 / 1,568	51.1	43 / 82	52.4	281 / 481	58.4
Q3	1186 / 2,241	52.9	822 / 1,579	52.1	67 / 110	60.9	297 / 552	53.8
Q4	1408 / 2,485	56.7	895 / 1,586	56.4	115 / 176	65.3	398 / 723	55.1
Q5 (most)	1681 / 2,712	62.0	946 / 1,503	62.9	204 / 299	68.2	531 / 910	58.4
ICE-POC†								
Q1 (White, NH)	732 / 1,700	43.1	660 / 1,562	42.3	- ‡	-	60 / 115	52.2
Q2	1163 / 2,228	52.2	977 / 1,874	52.1	33 / 57	57.9	153 / 297	51.5
Q3	1435 / 2,556	56.1	1,102 / 1,966	56.1	79 / 129	61.2	254 / 461	55.1
Q4	1490 / 2,480	59.1	995 / 1,681	59.2	131 / 193	67.9	441 / 778	56.7
Q5 (POC)	1490 / 2,480	60.1	507 / 774	65.5	225 / 344	65.4	758 / 1,362	55.7

* Among those whose race/ethnicity and/or outcome were not missing (missing n = 416)

† Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

‡ Those with denominators less than 50 not shown

Prevalence of having ever tested for HIV

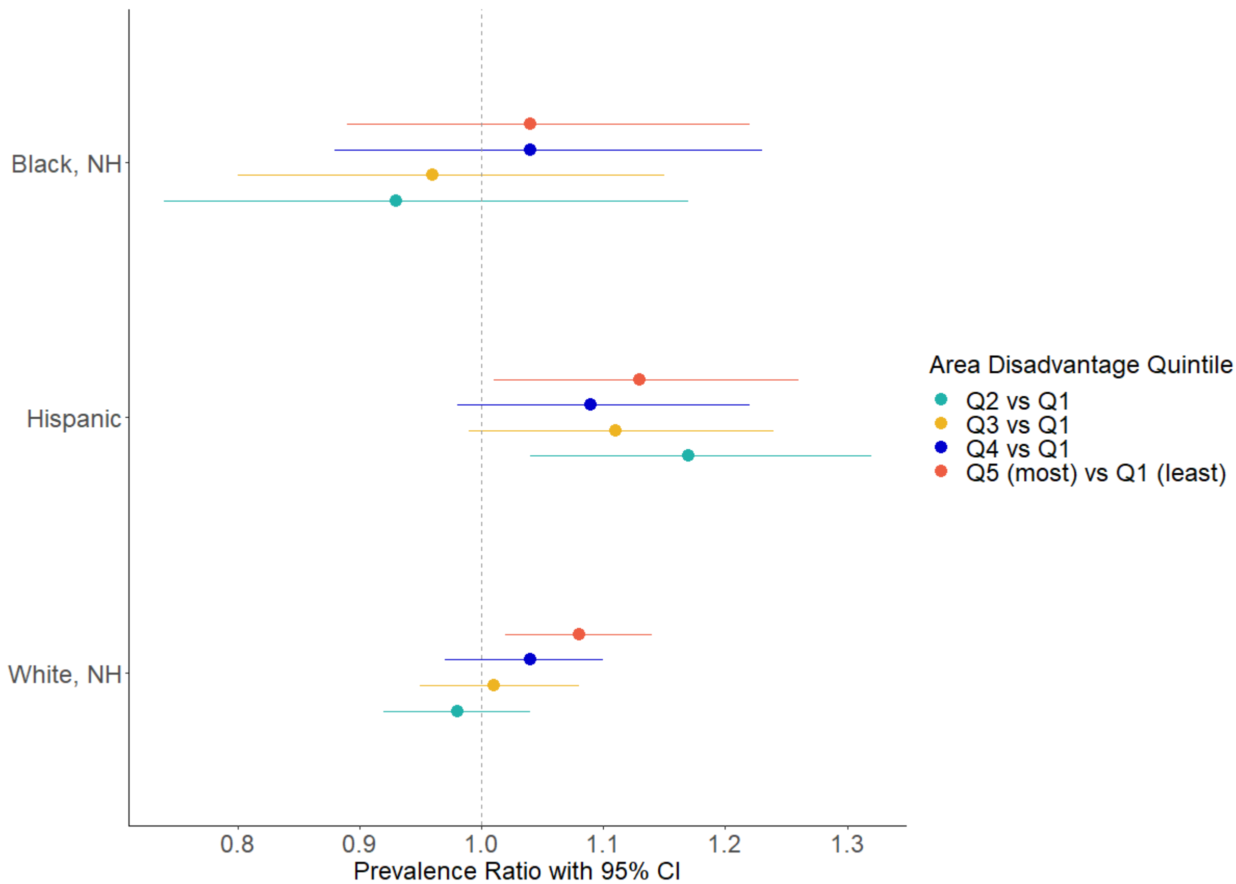
Overall, the prevalence of having ever tested for HIV was highest among AYMSM residing in the most disadvantaged ZCTAs (62%) compared to AYMSM residing in ZCTAs with the least disadvantage (48%) (Table 4.3). By ICE, prevalence of testing was highest among AYMSM residing in the highest POC concentration ZCTAs (60%), compared to 43% among AYMSM in the highest White concentration ZCTAs. Among Black AYMSM, having ever tested was consistently high across all disadvantage quintiles, ranging from 52% (Q2) to 68% (Q5), and ICE quintiles, ranging from 58% (Q2) to 68% (Q4). Among Hispanic AYMSM, testing prevalence was similar across disadvantage quintiles, ranging from 54% (Q3) to 58% (Q2 and Q5), except for Q2 (46%). HIV testing was similar across all ICE quintiles.

Relationship between area disadvantage and HIV testing

In the unadjusted model, AYMSM who resided in ZCTAs with greater disadvantage were more likely to have ever tested for HIV (prevalence ratio (PR) 1.29, 95% confidence interval (CI) 1.22, 1.36) (Table 4.6). In the interaction-only model, we observed increased HIV testing in ZCTAs with higher levels of disadvantage among White and Black AYMSM. Among Hispanic AYMSM, the pattern was mixed, whereby estimates were similar for the most disadvantaged ZCTAs (Q5) (PR 1.28, 95% CI 1.13, 1.46) and the less disadvantaged ZCTAs (Q2) (PR 1.28, 95% CI 1.11, 1.47). In the fully adjusted model (Figure 4.1), residing in the most disadvantaged ZCTAs remained associated, though attenuated, with increased HIV testing among White (adjusted prevalence ratio (aPR) 1.08, 95% CI 1.02, 1.14) and Hispanic (aPR 1.13, 95%: 1.01, 1.26) AYMSM. For Black AYMSM, no associations between neighborhood disadvantage and HIV testing were observed. There was no evidence of multiplicative interaction (p-value 0.20) or additive interaction with area disadvantage and Black race as all $RERI_{RR}$ were null (Table 4.4). The $RERI_{RR}$ estimates for the interaction between disadvantage and Hispanic ethnicity indicated positive interaction, though only the $RERI_{RR}$ for less disadvantage ZCTAs (Q2) was meaningful

($RERI_{RR}$ 0.19, 95% CI 0.05, 0.32). Figure 4.2 shows the predicted probabilities of ever testing by race, and although CIs overlap, these estimates reflect a pattern of higher testing across quintiles among Black AYMSM compared to White AYMSM.

Figure 4.1 Adjusted prevalence ratios (aPR) and 95% confidence intervals (CI) for the association between area disadvantage and having ever tested for HIV by race/ethnicity, AMIS 2016-2019



Area Disadvantage	Black, NH		Hispanic		White, NH	
	aPR*	95% CI	aPR	95% CI	aPR	95% CI
Q1 (least)	Ref		Ref		Ref	
Q2	0.93	(0.74, 1.17)	1.17	(1.04, 1.32)	0.98	(0.92, 1.04)
Q3	0.96	(0.80, 1.15)	1.11	(0.99, 1.24)	1.01	(0.95, 1.08)
Q4	1.04	(0.88, 1.23)	1.09	(0.98, 1.22)	1.04	(0.97, 1.10)
Q5 (most)	1.04	(0.89, 1.22)	1.13	(1.01, 1.26)	1.08	(1.02, 1.14)

Clustered by Zip Code Tabulation Area (ZCTA)
* Adjusted for individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, and STI dx in past 12 months and area-level covariates: HIV testing density per 10,000 population, distance to nearest HIV testing site, residence, and region.

Table 4.4 Regression coefficients and the relative excess risk due to interaction (RERI) for the associations among area disadvantage, race/ethnicity, and ever tested for HIV (interaction models)

	Model 2 (interaction-only model)*					
	Multiplicative		Black, NH		Hispanic	
	β	95% CI	RERI	95% CI	RERI	95% CI
Area disadvantage						
Q5 (most)	0.27	(0.20, 0.34)	-0.22	(-0.50, 0.05)	-0.04	(-0.19, 0.12)
Q4	0.16	(0.09, 0.23)	-0.16	(-0.45, 0.13)	0.02	(-0.13, 0.18)
Q3	0.08	(0.01, 0.16)	-0.18	(-0.50, 0.15)	0.09	(-0.08, 0.25)
Q2	0.06	(-0.01, 0.14)	-0.32	(-0.67, 0.02)	0.20	(0.04, 0.36)
Q1 (least)	Ref					
Race/ethnicity						
Black, NH	0.30	(0.12, 0.48)				
Hispanic	-0.05	(-0.17, 0.08)				
White, NH	Ref					
Interaction of Disadvantage and Race/ethnicity						
Q5*Black	-0.21	(-0.41, 0.00)				
Q4*Black	-0.15	(-0.36, 0.06)				
Q3*Black	-0.15	(-0.40, 0.10)				
Q2*Black	-0.27	(-0.56, 0.02)				
Q5*Hispanic	-0.02	(-0.16, 0.13)				
Q4*Hispanic	0.03	(-0.13, 0.18)				
Q3*Hispanic	0.08	(-0.08, 0.24)				
Q2*Hispanic	0.18	(0.03, 0.34)				
p-value for interaction	0.03					

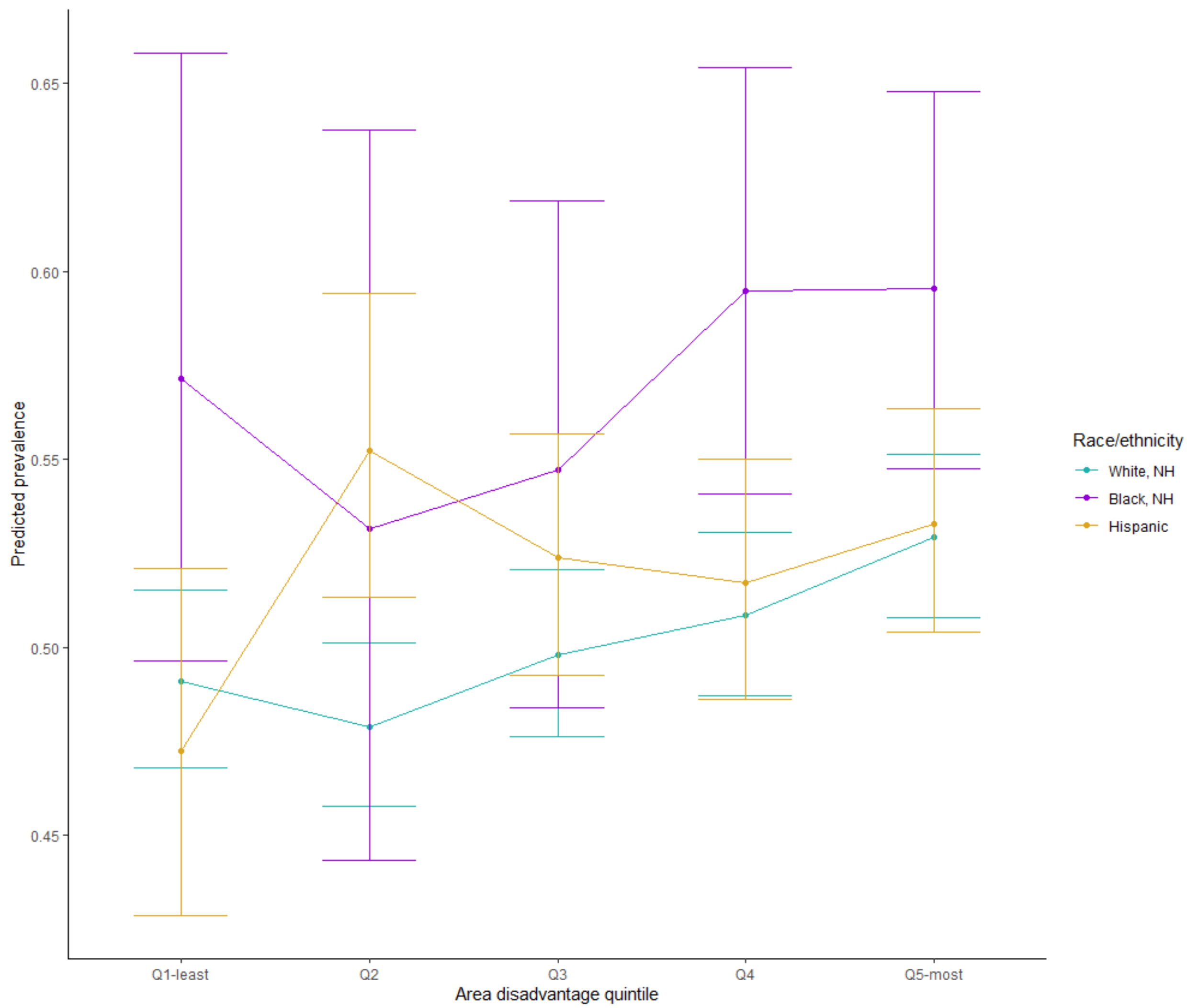
	Model 3 (fully adjusted model)†					
	Multiplicative		Black, NH		Hispanic	
	β	95% CI	RERI	95% CI	RERI	95% CI
Area disadvantage						

All models clustered by Zip Code Tabulation Area (ZCTA)
NH: non-Hispanic

* Model 2 includes only the exposure and the disadvantage X race/ethnicity or ICE X race/ethnicity interaction term.
† Model 3 is adjusted for individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, and STI dx in past 12 months and area-level covariates: HIV testing density per 10,000 population, distance to nearest HIV testing site, residence, and region.

Q5 (most)	0.08	(0.02, 0.13)	-0.03	(-0.23, 0.17)	0.04	(-0.08, 0.17)
Q4	0.04	(-0.03, 0.1)	0.01	(-0.19, 0.22)	0.06	(-0.07, 0.18)
Q3	0.01	(-0.05, 0.08)	-0.06	(-0.28, 0.16)	0.09	(-0.04, 0.21)
Q2	-0.03	(-0.09, 0.04)	-0.06	(-0.32, 0.20)	0.19	(0.05, 0.32)
Q1 (least)	Ref					
Race/ethnicity						
Black, NH	0.15	(0.00, 0.30)				
Hispanic	-0.04	(-0.14, 0.07)				
White, NH						
Interaction of Disadvantage and Race/ethnicity						
Q5*Black	-0.03	(-0.21, 0.14)				
Q4*Black	0.00	(-0.17, 0.18)				
Q3*Black	-0.06	(-0.25, 0.14)				
Q2*Black	-0.05	(-0.28, 0.19)				
Q5*Hispanic	0.05	(-0.08, 0.17)				
Q4*Hispanic	0.06	(-0.07, 0.18)				
Q3*Hispanic	0.09	(-0.04, 0.22)				
Q2*Hispanic	0.18	(0.05, 0.31)				
p-value for interaction	0.20					

Figure 4.2 Predicted prevalence of ever HIV testing by area disadvantage and race/ethnicity, AMIS 2016-2019*

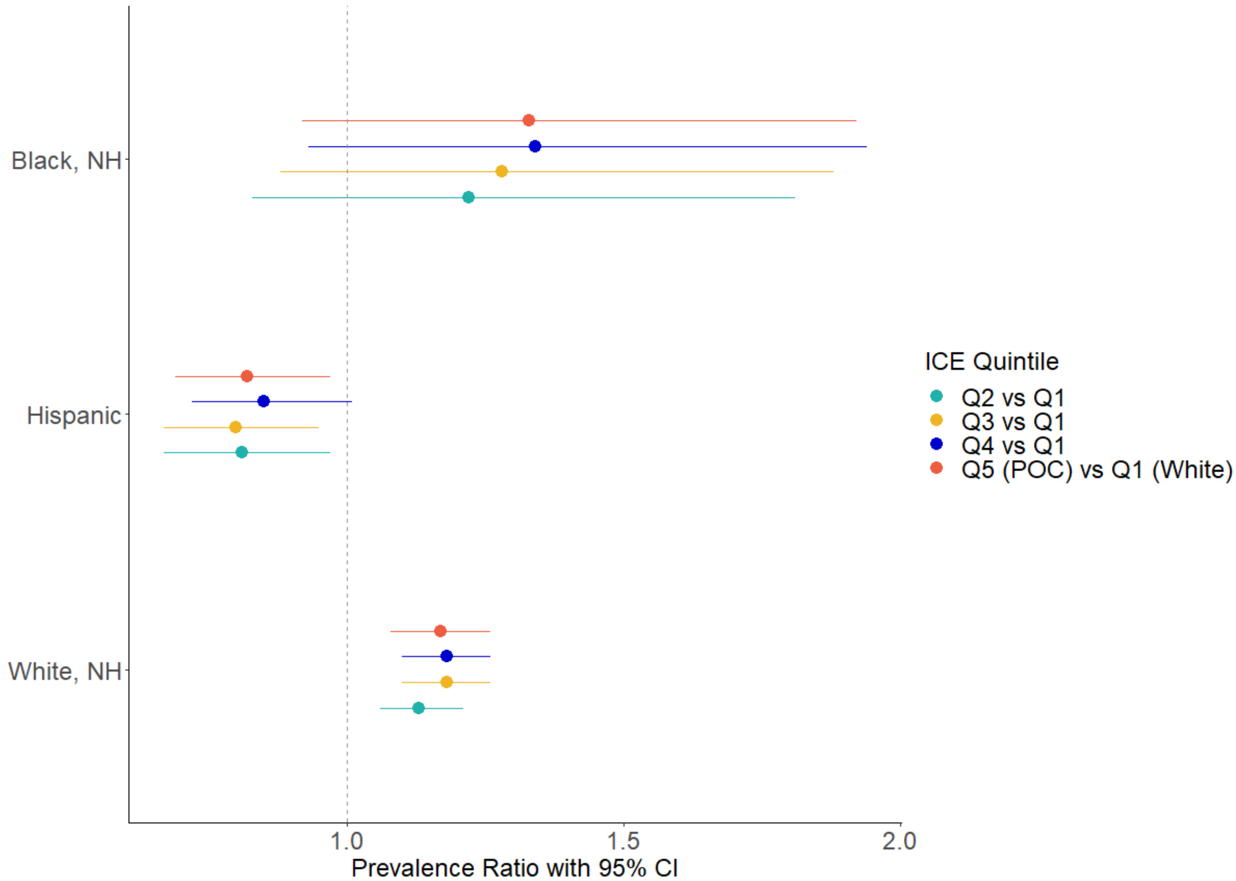


*Predicted probabilities are based on parameters from the fully adjusted model and covariates are held constant at their average. Covariates include age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, STI dx in past 12 months, HIV testing density per 10,000 population, distance to nearest HIV testing site, residence, and region.

Relationship between local racial/ethnic spatial concentration and HIV testing

In the unadjusted model, AYMSM residing in ZCTAs with highest concentrations of POC had increased HIV testing, compared to AYMSM residing in the highest White concentration ZCTAs (PR 1.19, 95% CI 1.15, 1.22) (Table 4.6). In the interaction-only model, the pattern of higher levels of HIV testing in the highest POC concentration ZCTAs was observed among White AYMSM (PR 1.26, 95% CI 1.20, 1.31). Among Black AYMSM, estimates indicated higher levels of testing in ZCTAs with higher POC concentrations (PR 1.14, 95% CI 0.92, 1.42 comparing Q5 to Q1), but these were not meaningful as CIs crossed the null. No associations were observed for Hispanic AYMSM, as estimates were approximately null. In the fully adjusted model (Figure 4.3), the association remained among White AYMSM, though the estimate was attenuated (aPR 1.17, 95% CI 1.08, 1.26). Among Black AYMSM, point estimates moved further from the null but were not meaningful (PR 1.33, 95% CI 0.92, 1.92 comparing Q5 to Q1). For Hispanic AYMSM, residing in the highest POC concentration ZCTAs was associated with decreased HIV testing, compared to those residing in the highest White concentration ZCTAs (aPR 0.82, 95% CI 0.69, 0.97). There was evidence of multiplicative interaction (p-value 0.08), and additive interaction was observed for Hispanic AYMSM only (Table 4.5). The $RERI_{RR}$ point estimates indicated negative additive interaction between residing in ZCTAs with higher POC concentrations and being Hispanic on having ever tested for HIV. For the predicted prevalence (Figure 4.4), there was a pattern of higher testing among Black AYMSM compared to White AYMSM across quintiles, and these differences were meaningful in ZCTAs with high (Q4) and highest POC (Q5) concentrations.

Figure 4.3 Adjusted prevalence ratios (PR) and 95% confidence intervals (CI) for the association between local racial/ethnic spatial concentration and having ever tested for HIV race/ethnicity, AMIS 2016-2019



	Black, NH		Hispanic		White, NH	
ICE-POC*	aPR†	95% CI	aPR	95% CI	aPR	95% CI
Q1 (White)	Ref		Ref		Ref	
Q2	1.22	(0.83, 1.81)	0.81	(0.67, 0.97)	1.13	(1.06, 1.21)
Q3	1.28	(0.88, 1.88)	0.80	(0.67, 0.95)	1.18	(1.10, 1.26)
Q4	1.34	(0.93, 1.94)	0.85	(0.72, 1.01)	1.18	(1.10, 1.26)
Q5 (POC)	1.33	(0.92, 1.92)	0.82	(0.69, 0.97)	1.17	(1.08, 1.26)

Clustered by Zip Code Tabulation Area (ZCTA)
[*] Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).
[†] Adjusted for individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, and STI dx in past 12 months and area-level covariates: HIV testing density per 10,000 population, distance to nearest HIV testing site, residence, and region.

Table 4.5 Regression coefficients and the relative excess risk due to interaction (RERI) for the associations among local racial/ethnic spatial concentration, race/ethnicity, and ever tested for HIV (interaction models)

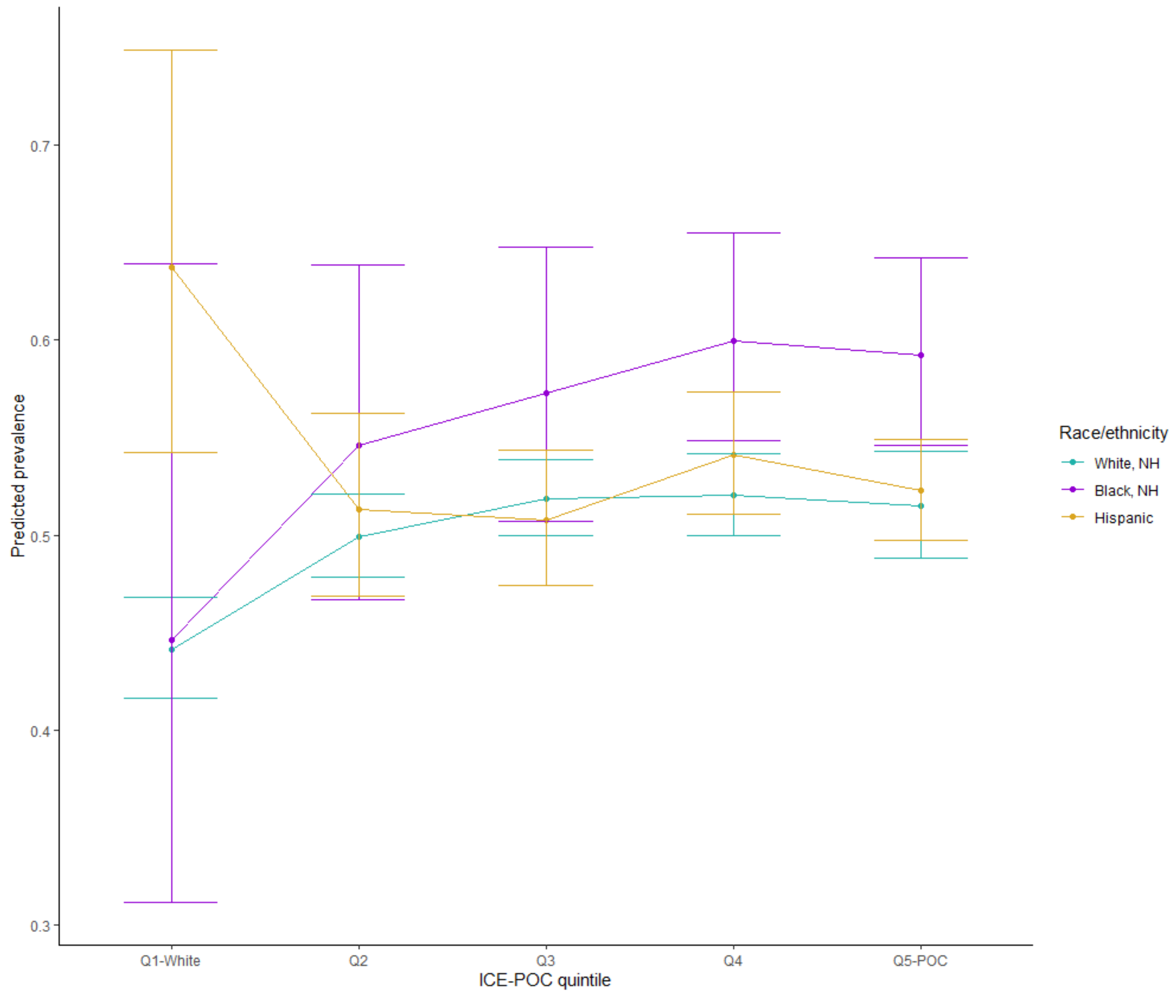
	Model 2 (interaction-only model)[*]					
	Multiplicative		Black, NH		Hispanic	
	β	1.1	RERI	95% CI	RERI	95% CI
ICE-POC[†]						
Q5 (White)	0.23	(0.18, 0.27)	-0.10	(-0.35, 0.15)	-0.21	(-0.33, -0.09)
Q4	0.16	(0.13, 0.20)	0.02	(-0.24, 0.27)	-0.13	(-0.24, -0.01)
Q3	0.13	(0.09, 0.16)	-0.03	(-0.29, 0.22)	-0.11	(-0.23, 0.02)
Q2	0.10	(0.06, 0.13)	-0.02	(-0.30, 0.26)	-0.11	(-0.23, 0.02)
Q1 (POC)	Ref					
Race/ethnicity						
Black, NH	0.10	(-0.12, 0.31)				
Hispanic	0.10	(0.00, 0.19)				
White, NH	Ref					
Interaction of Disadvantage						
Q5*Black	-0.09	(-0.32, 0.13)				
Q4*Black	0.00	(-0.23, 0.22)				
Q3*Black	-0.04	(-0.27, 0.19)				
Q2*Black	-0.02	(-0.28, 0.23)				
Q5*Hispanic	-0.19	(-0.29, -0.08)				
Q4*Hispanic	-0.12	(-0.22, -0.01)				
Q3*Hispanic	-0.10	(-0.21, 0.00)				
Q2*Hispanic	-0.10	(-0.21, 0.01)				
p-value for interaction	0.04					

	Model 3 (fully adjusted model)[‡]					
	Multiplicative		Black, NH		Hispanic	
	β	95% CI	RERI	95% CI	RERI	95% CI
ICE-POC						
Q5 (White)	0.15	(0.08,0.23)	-0.03	(-0.47, 0.41)	-0.43	(-0.68, -0.17)

All models clustered by Zip Code Tabulation Area (ZCTA)
NH: non-Hispanic
[*] Model 2 includes only the exposure and the disadvantage X race/ethnicity or ICE X race/ethnicity interaction term.
[†] Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).
[‡] Model 3 is adjusted for individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, and STI dx in past 12 months and area-level covariates: HIV testing density per 10,000 population, distance to nearest HIV testing site, residence, and region.

Q4	0.16	(0.09,0.23)	0.17	(-0.22, 0.56)	-0.40	(-0.65, -0.14)
Q3	0.16	(0.09,0.23)	0.11	(-0.29, 0.51)	-0.47	(-0.73, -0.21)
Q2	0.12	(0.06,0.19)	0.10	(-0.32, 0.51)	-0.41	(-0.68, -0.15)
Q1 (POC)	Ref					
Race/ethnicity						
Black, NH	0.01	(-0.35, 0.37)				
Hispanic	0.37	(0.20, 0.53)				
White, NH	Ref					
Interaction of Disadvantage						
Q5*Black	0.13	(-0.25, 0.50)				
Q4*Black	0.13	(-0.25, 0.51)				
Q3*Black	0.09	(-0.30, 0.47)				
Q2*Black	0.08	(-0.32, 0.48)				
Q5*Hispanic	-0.35	(-0.53, -0.17)				
Q4*Hispanic	-0.33	(-0.51, -0.15)				
Q3*Hispanic	-0.39	(-0.57, -0.21)				
Q2*Hispanic	-0.34	(-0.53, -0.15)				
p-value for interaction	0.08					

Figure 4.4 Predicted prevalence of ever HIV testing by local racial/ethnic spatial concentration and race/ethnicity, AMIS 2016-2019*



* Predicted probabilities are based on parameters from the fully adjusted model and covariates are held constant at their average. Covariates include age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, STI dx in past 12 months, HIV testing density per 10,000 population, distance to nearest HIV testing site, residence, and region.

Table 4.6 Prevalence ratios (PR) and 95% confidence intervals (CI) for the associations between area disadvantage and local racial/ethnic spatial concentration quintiles and having ever tested by HIV by race/ethnicity, AMIS 2016-2019

	Model 1 Unadjusted		Model 2 Interaction only		Model 3 Fully adjusted*	
	PR	95% CI	PR	95% CI	PR	95% CI
Area Disadvantage						
All						
Q1 (least)	Ref		-		-	
Q2	1.09	(1.02, 1.16)	-		-	
Q3	1.10	(1.03, 1.17)	-		-	
Q4	1.18	(1.11, 1.25)	-		-	
Q5 (most)	1.29	(1.22, 1.36)	-		-	
White, NH						
Q1 (least)	-		Ref		Ref	
Q2	-		1.06	(0.99, 1.14)	0.98	(0.92, 1.04)
Q3	-		1.09	(1.01, 1.17)	1.01	(0.95, 1.08)
Q4	-		1.17	(1.09, 1.26)	1.04	(0.97, 1.10)
Q5 (most)	-		1.30	(1.22, 1.40)	1.08	(1.02, 1.14)
Black, NH						
Q1 (least)	-		Ref		Ref	
Q2	-		0.81	(0.61, 1.07)	0.93	(0.74, 1.17)
Q3	-		0.93	(0.74, 1.18)	0.96	(0.80, 1.15)
Q4	-		1.01	(0.82, 1.23)	1.04	(0.88, 1.23)
Q5 (most)	-		1.06	(0.88, 1.28)	1.04	(0.89, 1.22)
Hispanic						
Q1 (least)	-		Ref		Ref	
Q2	-		1.28	(1.11, 1.47)	1.17	(1.04, 1.32)
Q3	-		1.18	(1.02, 1.36)	1.11	(0.99, 1.24)
Q4	-		1.20	(1.05, 1.38)	1.09	(0.98, 1.22)
Q5 (most)	-		1.28	(1.13, 1.46)	1.13	(1.01, 1.26)
ICE-POC†						
All						
Q1 (White)	Ref		-		-	
Q2	1.09	(1.06, 1.13)	-		-	
Q3	1.13	(1.10, 1.17)	-		-	

All models clustered by ZCTA.

* Model 3 is adjusted for individual-level covariates: age, education, sexual identity, sexual identity disclosure, health insurance, health care provider visit in past 12 months, condomless anal intercourse, STI testing in past 12 months, and STI dx in past 12 months and area-level covariates: HIV testing density per 10,000 population, distance to nearest HIV testing site, residence, and region.

† Local racial/ethnic spatial concentration was measured using the Index of Concentration at the Extremes (ICE) at the ZIP Code Tabulation Area (ZCTA) level, with the extremes as White, non-Hispanic concentration of residents versus non-White, non-Hispanic residents, or people of color (POC).

Q4	1.17	(1.14, 1.21)	-		-	
Q5 (POC)	1.19	(1.15, 1.22)	-		-	
White, NH						
Q1 (White)	-		Ref		Ref	
Q2	-		1.10	(1.06, 1.14)	1.13	(1.06, 1.21)
Q3	-		1.14	(1.10, 1.18)	1.18	(1.10, 1.26)
Q4	-		1.18	(1.14, 1.22)	1.18	(1.10, 1.26)
Q5 (POC)	-		1.26	(1.20, 1.31)	1.17	(1.08, 1.26)
Black, NH						
Q1 (White)	-		Ref		Ref	
Q2	-		1.07	(0.84, 1.38)	1.22	(0.83, 1.81)
Q3	-		1.10	(0.87, 1.38)	1.28	(0.88, 1.88)
Q4	-		1.18	(0.94, 1.47)	1.34	(0.93, 1.94)
Q5 (POC)	-		1.14	(0.92, 1.42)	1.33	(0.92, 1.92)
Hispanic						
Q1 (White)	-		Ref		Ref	
Q2	-		1.00	(0.89, 1.11)	0.81	(0.67, 0.97)
Q3	-		1.03	(0.93, 1.14)	0.80	(0.67, 0.95)
Q4	-		1.05	(0.95, 1.16)	0.85	(0.72, 1.01)
Q5 (POC)	-		1.04	(0.95, 1.14)	0.82	(0.69, 0.97)

DISCUSSION

In this study, we examined the relationship between structural place-based factors, area disadvantage and local racial/ethnic spatial concentration, and having ever tested for HIV among AYMSM. Overall, only half of AYMSM had ever tested for HIV in this study population. This is of public health concern, given this population's high risk for HIV. The findings from our multilevel analysis suggested different associations by race/ethnicity. Residing in areas with high disadvantage and high concentration of POC was associated with greater prevalence of ever testing for HIV for White, non-Hispanic AYMSM. For Hispanic AYMSM, residing in areas with high disadvantage was associated with greater prevalence of ever testing, whereas residing in areas with high concentrations of POC was associated with lower prevalence of ever testing. For Black AYMSM, no associations between these structural place-based factors and HIV were observed.

Over the past two decades, HIV testing initiatives have widely expanded the availability of HIV testing throughout the U.S. (125), and this will continue under the "Ending the HIV Epidemic" initiative. The associations we observed of increased testing among AYMSM in the most disadvantaged and highest POC concentration ZCTAs may reflect efforts to expand HIV testing coverage for high risk populations which have targeted urban and metropolitan areas that have high socioeconomic disadvantage and high concentrations of racial/ethnic populations. Although we expected to observe the reverse, our findings align with previous studies that have found increased testing in neighborhoods with greater disadvantage (38,126) For Black AYMSM, we observed that levels of HIV testing were similar across quintiles and potentially higher compared to White and Hispanic AYMSM. Surveillance data reflect that there have been substantial increases in HIV testing among Black MSM over the past decade (125) and that older Black AYMSM report higher levels of testing (15,118). For Hispanic AYMSM, the different patterns of association for the place-based factors suggest potentially different pathways by which disadvantage and local racial/ethnic spatial concentration affects HIV testing, such as social and cultural norms which have been linked to HIV testing behaviors among adult Hispanic/Latinx MSM (127). To our knowledge, this is first study to explore the relationships between these structural place-based factors and HIV testing among a geographically and age diverse sample of AYMSM.

The findings from our study must be interpreted in the context of the study's limitations. First, this study utilizes a convenience sampling approach, and therefore, data from AMIS are not generalizable to AYMSM in the US or all AYMSM who access the internet. Because recruitment for AMIS is conducted through online ads on websites and social media applications, the study population may be more likely to include AYMSM who are more open about their gay and bisexual identities, and outness has been linked to higher and lower levels of engaging in sexual risk behaviors among AYMSM, which may be linked to their HIV testing behaviors. Second, participants' residence was determined by their ZIP Codes and proxied by their ZCTAs. ZCTAs can vary widely in their population sizes and land areas and may not accurately represent the participants' contextual environment. However, ZCTAs and ZIP codes have been frequently used in public health research to capture area-level information, given participants' knowledge of their ZIP code, public availability of the data, and interpretability of ZIP code for public health action by policymakers and the public (92,93). Third, we did not have information regarding the length of residence in the reported ZIP Code. It is possible that participants were only exposed to their environment for short period of time, and this may introduce bias as their residential environments may be misclassified. However, though young adulthood is a highly mobile period due to education, employment, housing, or family-related issues, only 6% to 8% of young adults move to different counties (94). Fourth, having ever tested for HIV is based on self-report, and there may be misclassification of the outcome measure. However, this may be limited given that testing for HIV is a memorable event particularly given their younger age. Fifth, our study was not designed to examine effect measure modification by race/ethnicity and therefore may be underpowered to detect heterogeneity in these multilevel relationships. Additionally, previous studies have shown that Black MSM tend to be underrepresented in studies with online-based recruitment (114). Finally, there may be uncontrolled and structural confounding due to historical spatial stratification processes that have resulted in the sorting of minority racial/ethnic and sexual identity populations into certain neighborhoods or areas of the U.S so that they could never experience residing in the comparison neighborhoods.

Conclusion

Increasing HIV testing among AYMSM is a critical priority for HIV prevention. Expanding the availability and accessibility of HIV testing among AYMSM is essential in reaching a 90% reduction in HIV infection by 2030. The low level of testing in our study population, despite engagement in risk behaviors, underscores the importance of scaling up and sustaining HIV testing interventions to reach AYMSM. The different patterns of associations we observed by race/ethnicity suggest that there may be different pathways by which area disadvantage and local racial/ethnic spatial concentration affect AYMSM’s uptake of HIV testing. These mixed findings invite future research to further explore how contextual features of AYMSM’s residential environment, such as race- and ethnicity-specific residential segregation patterns, may affect AYMSM’s access to HIV testing and further illuminate the multilevel and multifactorial barriers AYMSM face. Our study also demonstrates how area-level measures can be utilized with HIV behavioral surveillance data to better understand area-level testing patterns among AYMSM to inform HIV testing interventions.

Chapter 5 Conclusions and public health implications

The overarching goal of this dissertation was to utilize a multilevel approach to explore the association between structural place-based factors in the residential environment and HIV prevention among gay, bisexual, and other AYMSM. We examined AYMSM's residential environment regarding urban-rural residence, area-level socioeconomic disadvantage, and racial/ethnic spatial concentration and their relationships with sexual identity disclosure, receipt of free condoms, and HIV testing in a geographically and age diverse sample of AYMSM.

AYMSM are a particularly vulnerable group due to their young age and minority sexual identity, as well as minority racial/ethnic identity for Black, Hispanic/Latinx, and other AYMSM of color (113). Due to this intersectional vulnerability, they face considerable obstacles in accessing and utilizing health care overall and HIV prevention specifically (27,35,74). As such, HIV prevention that is effective in reducing HIV incidence, as well as the racial/ethnic disparities, must address the structural factors that impede their access and discourage their utilization of services. Without addressing the structural drivers that create differential access and utilization of HIV-related services, such as poverty, stigma, and racial residential segregation (34,35), it will not be possible to reach the goal of 90% reduction in new infections and end the HIV epidemic in the U.S. Furthermore, as Nosyk et al. concluded based on their modeling study of HIV incidence in the U.S., implementing biomedical interventions without addressing social determinants of health, such as access to services, may achieve large reduction in absolute numbers of new infections but will not eliminate current racial/ethnic disparities in HIV incidence (128).

As the relationship between place-based factors and HIV prevention among AYMSM has been understudied, this dissertation sought to advance our understanding of the structural barriers that affect AYMSM's access to HIV prevention and testing. Online-based HIV behavioral surveillance, a complementary system to venue- and school-based surveillance that has been strengthened over the past decade, has been successful in recruiting AYMSM less than 18 years of age, who reside in geographically diverse areas, and who represent diverse racial/ethnic identities. Leveraging these strengths, we utilized data from the largest ongoing online-based behavioral study to explore the relationships between structural place-based factors and HIV prevention among AYMSM. The major findings of each dissertation aim, the innovation, public health implications, and future directions are discussed below.

Review of Major Findings

In Aim 1, we explored the relationship between urban-rural residence and sexual identity disclosure overall, and to a HCP specifically, among AYMSM by their perceived neighborhood tolerance of gay and bisexual individuals. Overall, there were similarly high levels of sexual identity disclosure across urban, suburban, small and medium metropolitan, and rural areas. However, reported disclosure to a HCP was low overall, and was lowest among AYMSM residing in rural ZCTAs. Among those who perceived their neighborhood to be tolerant of gay and bisexual identities, there was a consistent pattern of less disclosure to anyone across suburban, SMM, and rural areas, compared to disclosure among AYMSM in urban areas. For disclosure to HCP, this same pattern was observed, with AYMSM in rural areas being least likely to have disclosed compared to AYMSM in urban areas. Greater overall disclosure was associated with residing in SMM areas, compared to urban areas, among AYMSM who were neutral about their neighborhood's tolerance and with residing in suburban areas among AYMSM who perceived their neighborhoods to be intolerant. Taken together, these findings suggest there may be different relationships between the different urban-rural residence categories and sexual identity disclosure, and that these relationships may be modified by sexual identity-related stigma in AYMSM's contextual environment.

In Aim 2, we examined the associations between two structural place-based factors, area disadvantage and local racial/ethnic spatial concentration, and receipt of free condoms by AYMSM's race/ethnicity. Overall, receipt of free condoms was reported by less than half of

AYMSM. Reported receipt was higher in the most disadvantaged ZCTAs than the least disadvantaged ZCTAs and in the highest POC concentration ZCTAs than the highest White concentration ZCTAs, though this difference was minimal. In regression models that adjusted for individual-level demographic, socioeconomic, health-seeking behaviors, sexual risk behaviors, and HIV prevention knowledge characteristics and area-level factors (urban-rural residence and region), receipt of free condoms was associated with residing in the highest disadvantaged ZCTAs compared to the least disadvantaged ZCTAs and in the high POC concentration ZCTAs for White AYMSM. For Hispanic, free condom receipt was associated with residing in ZCTAs with the highest level of disadvantage, and no associations were observed between local racial/ethnic spatial concentration and free condom receipt. Among Black AYMSM, no associations were observed between the two place-based factors and free condom receipt. We found evidence of positive multiplicative interaction but not additive interaction for disadvantage and race/ethnicity. No multiplicative or additive interaction was observed for local racial/ethnic spatial concentration and race/ethnicity.

In Aim 3, we examined the associations between the same two structural place-based factors and having ever tested for HIV by AYMSM's race/ethnicity. Overall, around half of AYMSM have ever tested for HIV. Having ever tested for HIV was higher among AYMSM residing in the most disadvantaged ZCTAs than AYMSM in the least disadvantaged ZCTAs and among AYMSM residing in the ZCTAs with the highest POC concentration compared to those in the ZCTAs with the highest White concentration. Increased HIV testing was associated with residing in the most disadvantaged ZCTAs and with residing in ZCTAs with the highest concentration of POC for White AYMSM. For Hispanic AYMSM, having ever tested was associated with residing in the most disadvantaged ZCTAs. However, we observed a different pattern of association for local racial/ethnic spatial concentration; residing in ZCTAs with the highest concentration of POC was associated with less HIV testing than residing in the highest White concentration ZCTAs. Among Black AYMSM, no meaningful associations were observed between either exposure and having ever tested for HIV. Multiplicative interaction was observed only between local racial/ethnic spatial concentration and race/ethnicity. There was positive additive interaction between residing in the most disadvantaged ZCTAs and Hispanic ethnicity and negative additive interaction for local racial/ethnic spatial concentration, suggesting potentially different pathways by which these place-based factors affect HIV testing.

Innovations

There were several innovations in this dissertation. A multilevel understanding of the place-based factors that affect AYMSM's access and utilization of HIV prevention and testing is limited, with few previous studies explicitly examining the relationships between place-based factors and HIV prevention-related outcomes among this vulnerable population (35). These three studies add to our understanding by exploring the role of three different place-based factors: urbanicity and rurality; area-level socioeconomic disadvantage, and local racial/ethnic spatial concentration and adds to the literature of how contextual factors may influence not just HIV risk but HIV prevention as well.

For area disadvantage and local racial/ethnic spatial concentration, we used novel measures that more fully captured area-level socioeconomic status and local racial/ethnic spatial concentration within a local area. Previous neighborhood and HIV studies have predominantly utilized single measures, percent below poverty and percent of Black residents, as indicators of socioeconomic disadvantage and demographic composition. Using a composite index allowed us to better capture the multifactorial nature of socioeconomic disadvantage by including multiple domains, such as education and unemployment. For local racial/ethnic spatial concentration, the advantages of ICE were its ability to reflect both extremes simultaneously, provide directional tendency as it represents a spectrum, and be utilized locally. Furthermore, using these indices avoided issues of multicollinearity that frequently arise in examining variables related to race, class, and neighborhood studies which preclude them from being examined together in statistical regression analyses.

This dissertation also represents a novel use of online-based HIV behavioral surveillance data. Online-based surveillance has increased substantially in the past decade and its ability to recruit AYMSM less than 18 years of age and a geographically diverse, for region and urban-rural residence, population is a major benefit to HIV behavioral surveillance. Leveraging these strengths, we were able to examine three place-based factors and their multilevel relationships with HIV prevention across younger and older AYMSM. Examining levels of urban-rural, SES disadvantage, and local racial/ethnic spatial concentration in AYMSM's residential environment has not previously been feasible since previous epidemiological studies, surveillance and analytic, have focused, and understandably so, on AYMSM in urban environments. Understanding associations from online-based surveillance data with its geographic and age diverse study population is useful for generating hypotheses for future research that explores multilevel relationships in HIV prevention among AYMSM and implementation research on where interventions should be targeted.

Relevance and Public Health Impact

The findings from this dissertation have direct relevance to the prevention of HIV among adolescent and young gay, bisexual, and other men who have sex with men in the U.S. The findings show associations between structural place-based factors and HIV prevention and testing among AYMSM, and importantly, that different patterns may exist by sexual identity-related stigma and race/ethnicity when assessing these multilevel relationships.

The public health impact of these findings is not direct. These findings add to the empirical foundation for why contextual factors should be examined in HIV prevention and can inform future research that may establish the causal mechanisms by which these contextual factors affect HIV prevention, and ultimately HIV incidence, among AYMSM. Addressing the disparate concentration of physical, material, social, and political resources that produce spatial concentrations of socioeconomic disadvantage and racial/ethnic minority populations that characterize areas of HIV incidence would ultimately improve access and uptake of HIV prevention among AYMSM. In the short term, however, incorporating contextual factors into our understanding of their access and uptake of HIV prevention enables us to understand where and among whom prevention efforts should be focused (39). This understanding can refine programmatic priorities to create more tailored interventions while considering the allocation of resources.

Future Directions

Based on this dissertation's findings, there are several research questions which should be explored in future research. First, the association between these place-based factors and HIV prevention among AYMSM should be further explored in longitudinal studies that would address this dissertation's limitations with temporality and causality due to the cross-sectional nature of the data. The disadvantage and local racial/ethnic spatial concentration measures can be calculated various local levels, and these multilevel relationships can be assessed within studies that examine the effectiveness of HIV prevention interventions, both in-person and online-based, among AYMSM. Second, it is important for future studies to examine these multilevel relationships between place and HIV prevention among populations that have not been included due to insufficient sample size, including in this dissertation. AYMSM who have Asian, Pacific Islander, Native American, or multiracial identities remain understudied, and future research should intentionally recruit from these populations to ensure representation in HIV prevention research. A third area is to examine Black-White and Hispanic/Latinx-White local spatial concentrations separately in its relationships with HIV prevention. The historical processes by which these populations have been concentrated spatially in the U.S., racial segregation and immigration, are very different. Examining them separately would better enable us to identity the causal pathways by which local spatial concentration may influence their access and uptake of HIV prevention. Fourth, future research should explore how best to capture AYMSM's contextual environment. ZIP Code is the most frequently used method of assigning place to AYMSM. Although this is the most convenient measure to use, evaluating other methods of capturing place and space would help us to better understand the contextual determinants of HIV prevention among AYMSM. Lastly, future HIV behavioral surveillance should consider including contextual-level factors, beyond urban-rural residence and region, in their routine monitoring of HIV-related behaviors among MSM and other high-risk populations. Identifying place-based correlates of HIV prevention among AYMSM and monitoring them over time can advance our understanding of where AYMSM are benefiting, or not, from services and which AYMSM are reached withing a given environment, and thereby assess the impact of HIV prevention initiatives in the U.S.

Chapter 6 References

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