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Longitudinal Associations between Neighborhood Factors and HIV Care Outcomes in the WIHS

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Abstract

Identifying structural determinants affecting HIV outcomes is important for informing interventions across heterogeneous geographies. Longitudinal hierarchical generalized mixed-effects models were used to quantify the associations between changes in certain structural-level factors on HIV care engagement, medication adherence, and viral suppression. Among women living with HIV in the WIHS, ten-unit increases in census-tract level proportions of unemployment, poverty, and lack of car ownership were inversely associated with viral suppression and medication adherence, while educational attainment and owner-occupied housing were positively associated with both outcomes. Notably, increased residential stability (aOR 5.68, 95% CI: 2.93, 9.04) was positively associated with HIV care engagement, as were unemployment (aOR: 1.59, 95% CI: 1.57, 1.60), lack of car ownership (aOR 1.14, 95% CI: 1.13, 1.15), and female-headed households (aOR 1.23, 95% CI: 1.22, 1.23).. This underscores the importance of understanding neighborhood context, including factors that may not always be considered influential, in achieving optimal HIV-related outcomes.

RESUMEN

La identificación de los determinantes estructurales que afectan los resultados del VIH es importante para informar las intervenciones en geografías heterogéneas. Se utilizaron modelos longitudinales jerárquicos generalizados de efectos mixtos para cuantificar las asociaciones entre los cambios en ciertos factores de nivel estructural en el compromiso con los cuidados del VIH, la adherencia a la medicación y la supresión viral. Entre las mujeres que viven con el VIH en el WIHS, los aumentos de diez unidades en la proporción de desempleo, pobreza y falta de propiedad del automóvil en el nivel del censo se asociaron inversamente con la supresión viral y la adherencia a la medicación, mientras que el logro educativo y la vivienda ocupada por el propietario se asociaron positivamente con ambos resultados. Notablemente, mayor estabilidad residencial (aOR 5.68, IC 95%: 2.93, 9.04) pero también desempleo (aOR: 1.59, IC 95%: 1.57, 1.60), falta de propiedad del automóvil (aOR 1.14, IC 95%: 1.13, 1.15) y los hogares encabezados por mujeres (aOR 1.23, IC 95%: 1.22, 1.23) se asociaron positivamente con el compromiso con los cuidados del VIH. Esto subraya la importancia de comprender el contexto del vecindario, incluidos los factores que no siempre se pueden considerar influyentes, para lograr resultados óptimos relacionados con el VIH.

Keywords

Neighborhood determinants; HIV; Adherence; Care engagement; WIHS

INTRODUCTION

It is critical to optimize the care of people living with HIV at each step of the HIV care continuum, both for improving health of individuals living with HIV as well as controlling HIV transmission. Prior studies have highlighted several individual-level social determinants associated with suboptimal care engagement and medication adherence, including alcohol and illicit substance use, poverty, housing instability, and relationship status.(1–7) In addition, studies have pointed out the need to identify and address not only individual-level but also structural-level factors contributing to disparities among vulnerable sociodemographic subgroups at each step along the HIV continuum of care.(7, 8) Structural determinants of health are broadly defined as the social, physical, and economic environments that shape everyday circumstances and actions.(9, 10) Identifying structural determinants affecting HIV care is important for informing appropriate prevention and treatment interventions across heterogeneous geographies and communities.(10)

Much of the prior work on structural determinants has focused on their effects on risk behaviors and HIV acquisition, incidence, and prevalence.(8, 10–14) There have been fewer studies examining the associations of structural determinants with antiretroviral therapy (ART) adherence or HIV care engagement/retention.(8) Prior studies have explored several community-level factors that influence ART adherence, including economic disadvantage, neighborhood disorder, racial segregation, and social capital.(8, 15–18) However, findings are not always consistent or in the expected direction. For example, observed associations between neighborhood-level poverty and viral suppression have been inconsistent. Among studies that controlled for individual-level covariates, some showed an association between

poverty and poorer adherence or viral suppression, while others have counterintuitively shown that individuals in higher poverty areas have better outcomes than those in lower poverty areas.(8, 17, 19–21)

Most of these studies have been cross-sectional; the paucity of longitudinal explorations in this area has been identified as a significant gap in the current knowledge.(22) In addition, few of these studies have focused specifically on women living with HIV (WLWH). In a review of articles exploring gender differences in ART adherence between 2000 and 2011, female gender identity was shown to be predictive of poorer adherence.(23) The Women's Interagency HIV Study (WIHS) is a multi-center cohort study that has observed WLWH and women at risk for HIV since the mid-1990s. This cohort provides a unique opportunity to understand the influence of structural factors on HIV care and treatment in WLWH across the United States (US). Among WIHS women enrolled in Chicago, poor quality built-environment (defined as presence of trash and litter, poor building maintenance, little opportunity for walking, *etc.*) and racial segregation were two community-level factors associated with poor ART adherence after controlling for individual-level covariates.(24) Among WIHS women living in the South, Haley *et al.* showed that neighborhood characteristics were associated with sexual risk behaviors among both WLWH and women at risk for HIV. For example, greater social disorder was associated with less anal intercourse (odds ratio [OR] 0.63, 95% confidence interval [CI]: 0.43, 0.94) regardless of HIV status, perhaps indicating that women living in disordered neighborhoods perceived their partners to be riskier and thus were more reluctant to engage in certain sexual behaviors.(25)

As of 2014, the WIHS began to collect and centrally compile residential address information across the entire cohort. This study takes advantage of a unique opportunity to explore the influence of structural factors on HIV care engagement and medication adherence among WLWH in the US. We aimed to explore the longitudinal associations between core structural-level factors and HIV care engagement and medication adherence indicators among WIHS WLWH, controlling for individual-level covariates.

METHODS

Participant details

This study sample consists of WLWH in the WIHS cohort who were enrolled during the 1994–1995, 2001–2002, 2011–2012, or 2013–2015 enrollment waves at one of 10 sites across the US (San Francisco/Bay Area, CA; Bronx/Manhattan, NY; Brooklyn, NY; Washington, DC; Chicago, IL; Chapel Hill, NC; Atlanta, GA; Miami, FL; Birmingham, AL; Jackson, MS).(26) Study visits for the WIHS occur semi-annually. Eligible women for this analysis were WLWH who attended a WIHS visit at least once between April 2015 and September 2017 (n=1,557, 91% of all WIHS WLWH seen at one or more visits in this time period). WIHS participants provided written informed consent and were compensated for their participation in the study. The WIHS protocol has been approved by the institutional review board at each study site and by the WIHS Executive Committee.

Individual-level exposures

We included the following sociodemographic characteristics as covariates, as they were identified as important in previous literature: time-fixed age at baseline defined continuously, and time-varying employment status, annual household income, housing stability, health insurance status, and depression. We categorized age as <40 years, 40 - <50 years, and ≥50 years. Household income was categorized as <\$24,000 per year, \$24,000 per year, and unknown/not reported. Current employment status was dichotomized. Housing status was categorized as “stable” if the participant reported living in their own house/apartment, parent’s house, or someone else’s house/apartment, and “unstable” if the participant reported living in a shelter, jail, residential treatment center, an “other” place, or on the street. Health insurance status was categorized as whether the woman reported having any vs. no insurance coverage. A participant was considered to have symptoms indicative of depression if her score on the Center for Epidemiological Studies Depression (CES-D) Scale was ≥16, and “not depressed” if her score on the CES-D was <15.(27)

Structural-level exposures

Beginning in 2014, WIHS women were asked to provide written informed consent to allow the central collection of residential address information on an annual basis at one of their semi-annual visits. As of the time of data compilation for this analysis, 91% of WLWH within the WIHS had consented to have their address data collected and compiled centrally. Complete address information was sent to a central location at the University of North Carolina at Chapel Hill, where all addresses were geocoded using ArcGIS; latitude and longitude of addresses were matched to census block groups with each participant assigned a corresponding Federal Information Processing Standard (FIPS) code. By linking FIPS codes at the census tract-level to data from three consecutive versions of the 5-year American Community Survey (ACS), an ongoing general household survey administered by the US Census Bureau, we extracted census tract-level sociodemographic variables for each WIHS participant included in the analysis at each contributed time point. This allowed for the possibility that women could move locations between study visits.(28) Each WIHS visit interval that collected residential address information was linked to the 5-year ACS from the prior year to best represent the time-varying area-level context evident when the visit occurred (*i.e.*, April 2015-September 2015, linked to the 2014 ACS; April 2016-September 2016, linked to the 2015 ACS; and April 2017-September 2017, linked to the 2016 ACS).

Based on literature evidence showing associations with HIV care engagement and treatment, we evaluated the following structural measures: census-tract level education, poverty, vacant housing, unemployment, household income, household crowding, female-headed household, lack of car ownership, owner-occupied housing, and residential stability.(8, 16, 17) Education was defined as the percent of adults ≥25 years of age with a high school education/equivalent or greater. Poverty was defined as the percent of households living below the federal poverty line. Vacant housing was defined as the percent of housing units that were vacant in the census tract. Unemployment was defined as the percent of individuals ≥16 years of age that were in the labor force and were unemployed. Household income was defined as the median household income for the census tract. Household crowding was defined as the percent of houses with >1 person per room. Female-headed

household was defined as the percent of households with a female head with at least 1 child. Lack of car ownership was defined as the percent of households without access to a vehicle. Owner-occupied housing was defined as the percent of owner-occupied housing units. Residential stability was defined as the percent of households that had lived in the same housing unit one year prior.

Outcomes

The outcomes in this analysis were engagement in care, self-reported medication adherence, and achievement of HIV viral suppression. Outcomes were analyzed at the semi-annual visits at which address information was collected. Care engagement was defined as whether or not the individual reported having had at least 1 visit with their HIV care provider in the past six months. This definition was chosen as most consistent with what is tracked by the Centers of Disease Control and Prevention's National HIV Surveillance System, although we acknowledge that many HIV care providers recommend different visit frequencies to their patients depending on individual circumstances.(29) Adherence was measured by a self-report question of how often an individual took their ART as prescribed over the past six months; those who reported not being on any HIV medications were excluded from this outcome.(30) Self-reported adherence was previously validated in the WIHS, and is frequently used in WIHS publications.(31) Although 95% adherence is considered optimal for clinical success, we felt that a cut off of 75% adherence was more appropriate for this analysis. Studies have shown that adherence of <75% substantially increases the risk for viral resistance. Given that our study focuses on structural-level effects of exposures on each outcome, we believe that identification of structural-level factors associated with moderate adherence or below would be most amenable to community-level interventions.(32) This approach aligns with other studies that have explored the effects of neighborhood factors on viral transmission risk, for which the cutoff of 1500 copies/mL is used.(33) Viral suppression at the individual level was defined as an HIV RNA not detected or below the lower limit of detection (20 copies/mL), conducted using COBAS TaqMan HIV-1 v2.0 (E. Hoffman-La Roche, Ltd.).

Analytic details

Descriptive statistics were used to show distributions of individual- and census tract-level characteristics for all eligible women. Among women who attended two or more visits at which outcomes were ascertained, a longitudinal hierarchical generalized mixed-effects model with a logit link and a random effect for slope and intercept to allow individual subject-level variation was used to quantify the association between a 10-unit change in each structural-level factor inserted as a fixed effect and each outcome, while controlling for the individual-level covariates outlined above. The models had three levels, with observations (level 1) nested within participants (level 2) that were nested within census tracts (level 3). All analysis was done using R version 3.5.1 with the lme4 and MASS packages.

RESULTS

At the time of entry into this analysis, participants (n=1,557) had a median age of 49 years (interquartile range [IQR]: 42, 55 years) (Table 1). Seventy-two percent (n=1,124) identified

as non-Hispanic Black, 11% (n=166) as non-Hispanic White, and 14% (n=219) as Hispanic. The majority were not employed (n=1,040, 67%) and 74% (n=1,149) had an annual household income of <\$24,000. Based on location of residence at baseline, 38% (n=598) were from the Northeast, 36% (n=558) from the South, and 26% (n=401) from the Midwest or West. The majority (87%, n=1,356) reported having health insurance coverage. Eighty-eight percent (n=1,375) lived in their own or parents' home, and 8% (n=126) lived in someone else's home. Approximately one-quarter (24%, n=380) lived alone, 26% (n=400) lived with children and other adults, and 38% (n=591) lived with other adults only. Weekly, those with children spent approximately 84 hours (IQR: 42, 112 hours) on childcare. Of the 1,464 individuals who answered the question of adherence to ART as prescribed in the past six months at the baseline visit, 1,128 (77%) had 75% adherence, 213 (15%) had <75% adherence, and 123 (8%) were not taking their prescribed medication at all; those 123 were excluded from the adherence outcome analysis. The distributions of these characteristics remained nearly identical when restricting to women who attended two or more visits at which the outcomes were ascertained (Table 1).

In the neighborhoods in which all eligible women lived at the first point of residential address collection, a median of 81% (IQR: 72, 88) of adults had a high school education or more (Table 2). The percent of households living below the poverty line was 21.1% (IQR 11.3, 32.1), and 12% (IQR: 8, 17) of individuals 16 years of age in the labor force were unemployed. Female-headed households comprised 65.5% (IQR: 55.5, 75.0) of households with at least 1 child, 4.7% (IQR: 2.1, 8.9) of houses were considered crowded, and 10.3% (IQR: 6.2, 16.2) of houses were vacant. 35.7% (IQR: 17.9, 57.0) of housing units were occupied by the owner, and 85.9% (IQR: 79.9, 91.1) of households had not moved in the past year. Of note, the means and IQRs of the neighborhood factors were not different when the data were stratified by women who had and had not successfully achieved each of the outcomes at each of the visits (data not shown).

Nearly 80% of women attended all three visits at which the outcomes were assessed (Table 1); longitudinal associations between neighborhood characteristics and HIV care outcomes were assessed among the 1,431 (92%) women who attended two or more visits at which outcomes were ascertained. A total of 120 women (7.7%) moved between census tracts during the study period. There were several neighborhood-level factors significantly associated with measures of HIV care and treatment, even when controlling for important individual-level covariates. As expected, 10-unit increases in proportions of census tract residents with at least a high school level of education (adjusted odds ratio (aOR) 1.37, 95% confidence interval (CI): 1.08, 1.75) and housing units occupied by the owner (aOR 1.17, 95% CI: 1.05, 1.31) were associated with increased odds of achieving viral suppression (Table 3). Increases in households living below the poverty line (aOR 0.72, 95% CI: 0.60, 0.88), unemployment (aOR 0.63, 95% CI: 0.44, 0.89), female-headed households (aOR: 0.84, 95% CI: 0.71, 0.99), and lack of car ownership (aOR 0.86, 95% CI: 0.77, 0.96) were inversely associated with viral suppression. Similarly, neighborhoods with increased education (aOR 4.84, 95% CI: 4.83, 4.84) and owner-occupied housing units (aOR 1.26, 95% CI: 1.01, 1.56) were positively associated with ART adherence. Neighborhoods with increased poverty (aOR 0.52, 95% CI: 0.33, 0.79), unemployment (aOR 0.28, 95% CI: 0.11,

0.71), and lack of car ownership (aOR: 0.85, 95% CI: 0.84, 0.86) were inversely associated with ART adherence.

Most structural-level factors were not significantly associated with engagement in HIV care in our population. Interestingly, however, increased unemployment (aOR 1.59, 95% CI: 1.57, 1.60), female-headed households (aOR 1.23, 95% CI: 1.22, 1.23), and lack of car ownership (aOR: 1.14, 95% CI: 1.13, 1.15) were associated with increased HIV care engagement (Table 3).

DISCUSSION

Our analysis shows a longitudinal association between several structural factors and achievement of optimal HIV care and treatment outcomes among women in the WIHS. As highlighted in several studies, this underscores the importance of considering neighborhood context in assessing and achieving optimal HIV-related outcomes.(8, 10, 20) Viral load is the core biomarker used to monitor infection and assess patient prognosis amongst individuals living with HIV. Suppression of viral load to undetectable levels is important both for long-term health outcomes in the individual and also for limiting HIV transmission in a community. Despite controlling for core individual sociodemographic characteristics, women living in neighborhoods with lower education, car ownership, or owner-occupied housing, as well as increased poverty, unemployment, or female-headed households were less likely to be virally suppressed. Not unexpectedly, achievement of adherence to ART was also influenced by increased education and owner-occupied housing, as well as decreased poverty, unemployment, and lack of car ownership. In order to effectively combat the HIV epidemic, these findings highlight the need to invest in neighborhood-level interventions designed to improve the social context of individuals living with HIV.

Interestingly, women had increased odds of being engaged in HIV care if they lived in neighborhoods with increased residential stability and higher proportions of female-headed households. This could be due to augmented social support networks existing for WLWH in those communities; increased perceived social support has been shown to be associated with increased ART adherence among women in the WIHS.(34) Unexpectedly, women living in neighborhoods with increased unemployment and lack of car ownership also had increased odds of HIV care engagement. This is in contrast to what might be expected given the extensive literature associating unemployment with poor health outcomes.(35) However, it is important to acknowledge that these women are by definition engaged with the healthcare system through being a part of this long-term cohort, and therefore represent a unique subsection of the general population of WLWH. In contrast, increased proportion of female-headed households was associated with decreased odds of viral suppression, as was increased unemployment and other indicators of neighborhood disadvantage. This may reflect an increased level of challenge faced by women in these communities to maintain their health needs along with the needs of their households. These nuances need to be explored further in order to understand how these complex social contexts affect HIV health outcomes. As interventions are developed to combat structural barriers preventing optimal care among people living with HIV, structural factors that traditionally may not have been identified as influential should be identified and leveraged.

It is critical to consider possible mechanisms by which neighborhood-level factors affect HIV health when exploring effective place-based interventions to improve health and well-being among WLWH. Several conceptual models have been put forth to explain how neighborhood factors affect health and health equity, as well as the interplay between how the physical and social structures of a neighborhood both influence and are influenced by the individuals living there.(36, 37) Most of these models consider both physical environments (including exposures, access to resources, and aesthetics) as well as social environments (including violence/crime, cohesion/connections, and norms).(36) Prior work has suggested the influence of several of these factors, such as violent crime rates, as proximal drivers of other neighborhood structural conditions or as mediators or modifiers in the pathway between the structural conditions and HIV care outcomes.(10, 38) In applying these models specifically to the long-term needs of WLWH, it will be important to think about the development of multi-level interventions that address not only the needs of individual women but also promote the quality of the physical and social context in which these individuals live.(25)

This study has several limitations. First, our longitudinal analysis was limited to annual measures collected at semi-annual visits over a 3-year period due to limitations in available residential address information. Future studies looking at HIV-related outcomes in the WIHS may benefit from incorporating contextual information over a longer period of time, exploring regional differences, and investigating facility or clinic level differences across sites in different regions. Second, our measures of HIV care engagement and medication adherence were based on self-report. We used viral suppression as the only objective outcome measure, as objective measures of other steps in the HIV care cascade were not available. Third, there are additional important structural level factors that should be considered, such as rates of violent crime or social capital, that influence the effects of the above-mentioned structural factors on HIV care outcomes. Although including these measures was beyond the scope of this analysis, we acknowledge the importance of considering them in future work.

Individual-level interventions to optimize care for WLWH have been shown to be effective, but only to a certain extent. Identification of structural or neighborhood factors that affect HIV outcomes is a first and essential step in optimizing HIV care. Further work to continue to elucidate important structural factors, as well as to design and implement interventions targeting those factors, is essential to achieving HIV care engagement and treatment goals.

Conflicts of Interest and Sources of Funding

The authors have no conflicts of interest to report.

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Table 1:

Baseline characteristics of participating women living with HIV in the WIHS

	All Eligible Women (N=1,557)	Women with 2+ Outcome Visits (N=1,431)
Characteristic	Number (%/IQR)	Number (%/IQR)
Age in years (median, interquartile range [IQR])	49 (42, 55)	49 (42, 55)
Race/Ethnicity		
Black, non-Hispanic	1,124 (72)	1,039 (73)
Hispanic	219 (14)	200 (14)
White, non-Hispanic	166 (11)	151 (11)
Other, non-Hispanic	48 (3)	41 (3)
Region of WIHS Site		
Northeast	598 (38)	555 (39)
Midwest/West	401 (26)	351 (25)
South	558 (36)	525 (37)
Employed		
Yes	515 (33)	463 (33)
No	1,040 (67)	943 (67)
Annual income		
\$12,000	788 (51)	721 (53)
\$12,001–\$24,000	361 (23)	337 (25)
\$24,001–\$36,000	162 (10)	149 (11)
>\$36,000	190 (12)	156 (11)
Health Insurance Coverage		
Yes	1,356 (87)	1,243 (87)
No	201 (13)	188 (13)
Residence		
Own/Parents' home	1,375 (88)	1,252 (89)
Someone else's home	126 (8)	108 (8)
Other	53 (3)	45 (3)
Household composition		
Lives alone	380 (24)	342 (25)
Lives with adults only	591 (38)	536 (39)
Lives with adults and children	400 (26)	370 (27)
Lives with children only	119 (8)	113 (8)
Hours devoted weekly to childcare among those with children (median, IQR)	84 (42, 112)	84 (42, 112)
Number of Outcome Ascertainment Visits		
1	126 (8)	-
2	289 (19)	-
3	1,142 (73)	-
Medication adherence, previous six months		

	All Eligible Women (N=1,557)	Women with 2+ Outcome Visits (N=1,431)
Characteristic	Number (%/IQR)	Number (%/IQR)
Took medications as prescribed ≥75% of time	1,128 (77)	1,108 (77)
Took medications as prescribed <75% of time	213 (15)	203 (14)
Not currently prescribed medications/Unknown	123 (8)	120 (8)

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Table 2:

Census tract-level characteristics of residence at baseline* of participating women living with HIV in the WIHS (n=1,557)

	Definition	Median	Inter-quartile Range [IQR]
Education	% adults >25 years of age with high school diploma or equivalent	81.2	72.8, 88.2
Poverty	Percent of households below poverty line	21.1	11.3, 32.1
Vacant housing	% vacant housing	10.3	6.2, 16.2
Unemployment	% 16 years of age that are in the labor force that are unemployed	12.3	8.3, 17.6
Household crowding	% houses with >1 person per room	4.7	2.1, 8.9
Female-headed household	% Female-headed households with at least 1 child	65.5	55.5, 75.0
Lack of car ownership	% households without access to a vehicle	11.7	3.6, 38.4
Owner-occupied housing	% Owner-occupied housing units	35.7	17.9, 57.0
Residential stability	% Lived in same house 1 year ago	85.9	79.9, 91.1

*Represents neighborhood characteristics of where women were living at the first point of residential address collection.

Table 3:

Changes in the odds of HIV care engagement, antiretroviral adherence, and achievement of viral suppression associated with 10-unit changes in census tract-level social factors, while controlling for key individual-level determinants, among WLWH who attended two or more outcome ascertainment visits in the WIHS (N=1,431)

Structural-level factors**	HIV Care Engagement	Adherence (75%)	Viral suppression
	aOR* (CI)	aOR* (CI)	aOR* (CI)
Education	2.40 (0.94, 6.11)	4.84 (4.83, 4.84)	1.37 (1.08, 1.75)
Poverty	1.25 (0.92, 1.68)	0.52 (0.33, 0.79)	0.72 (0.60, 0.88)
Vacant housing	1.01 (0.67, 1.52)	0.99 (0.51, 1.91)	0.75 (0.54, 1.04)
Unemployment	1.59 (1.57, 1.60)	0.28 (0.11, 0.71)	0.63 (0.44, 0.89)
Household crowding	1.41 (0.49, 4.10)	0.94 (0.32, 2.74)	0.70 (0.45, 1.08)
Female-headed household	1.23 (1.22, 1.23)	0.90 (0.65, 1.24)	0.84 (0.71, 0.99)
Lack of car ownership	1.14 (1.13, 1.15)	0.85 (0.84, 0.86)	0.86 (0.77, 0.96)
Owner-occupied housing	1.15 (0.90, 1.46)	1.26 (1.01, 1.56)	1.17 (1.05, 1.31)
Residential stability	5.68 (2.93, 9.04)	0.96 (0.54, 1.73)	0.93 (0.70, 1.24)

* Adjusted for individual-level age, annual household income, employment, health insurance, employment, depression, and residential stability

** Structural-level factors inserted into models individually as fixed effects