Published in final edited form as:

AIDS Behav. 2020 July ; 24(7): 2033–2044. doi:10.1007/s10461-019-02757-5.

Neighborhood poverty and control of HIV, hypertension, and diabetes in the Women's Interagency HIV Study

Anna B. Cope[1], **Andrew Edmonds**[2], **Christina Ludema**[1,3], **Stephen R. Cole**[2], **Joseph J. Eron**[1], **Kathryn Anastos**[4], **Jennifer Cocohoba**[5], **Mardge Cohen**[6], **Igho Ofotokun**[7], **Elizabeth T. Golub**[8], **Seble Kassaye**[9], **Deborah Konkle-Parker**[10], **Lisa R. Metsch**[11], **Tracey E. Wilson**[12], **Adaora A. Adimora**[1,2]

[1]Division of Infectious Diseases, School of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, NC

[2]Department of Epidemiology, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC

[3]Department of Epidemiology and Biostatistics, School of Public Health, Indiana University at Bloomington, Bloomington, IN

[4]Departments of Medicine and Epidemiology & Population Health, Albert Einstein College of Medicine and Montefiore Medical Center, Bronx, NY

[5]Department of Clinical Pharmacy, University of California San Francisco School of Pharmacy, San Francisco, CA

[6]Department of Medicine, Cook County Health and Hospital System and Rush University, Chicago, IL

[7]Department of Medicine, Division of Infectious Diseases, Emory University, Atlanta, GA

[8]Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

[9]Division of Infectious Diseases and Travel Medicine, Department of Medicine, Georgetown University, Washington, DC

[10]Division of Infectious Diseases, Department of Medicine, University of Mississippi Medical Center, Jackson, MS

[11]Department of Sociomedical Sciences, Mailman School of Public Health, Columbia University, New York, NY

[12]Department of Community Health Sciences, School of Public Health, State University of New York Downstate Medical Center, Brooklyn, NY

Abstract

Neighborhoods with high poverty rates have limited resources to support residents' health. Using census data, we calculated the proportion of each Women's Interagency HIV Study participant's

Corresponding Author: Anna B. Cope, Division of Infectious Diseases, School of Medicine, University of North Carolina, Bioinformatics, Campus Box 7030, Chapel Hill, NC 27599-7030, USA. acbarry@unc.edu. Telephone: 919-843-3871. Fax: 919-966-6714.

census tract (neighborhood) living below the poverty line. We assessed associations between neighborhood poverty and 1) unsuppressed viral load [VL] in HIV-seropositive women, 2) uncontrolled blood pressure among HIV-seropositive and HIV-seronegative hypertensive women, and 3) uncontrolled diabetes among HIV-seropositive and HIV-seronegative diabetic women using modified Poisson regression models. Neighborhood poverty was associated with unsuppressed VL in HIV-seropositive women (>40% versus ≤20% poverty adjusted prevalence ratio (PR), 1.42; 95% confidence interval (CI), 1.04–1.92). In HIV-seronegative diabetic women, moderate neighborhood poverty was associated with uncontrolled diabetes (20–40% versus ≤20% poverty adjusted PR, 1.75; 95% CI, 1.02–2.98). Neighborhood poverty was associated with neither uncontrolled diabetes among HIV-seropositive diabetic women, nor uncontrolled hypertension in hypertensive women, regardless of HIV status. Women living in areas with concentrated poverty may need additional resources to control health conditions effectively.

Keywords

Contextual poverty; viral suppression; blood pressure; health disparity; census tract

INTRODUCTION

Effective management of HIV and other chronic illnesses such as diabetes and hypertension requires consistent access and adherence to medications and adequate healthcare. Uncontrolled HIV, hypertension, and diabetes escalate healthcare costs and increase morbidity and mortality [1–3]. Unsuppressed HIV infection also increases risk of HIV transmission [4–6]. Approximately 73% of people diagnosed with HIV in the United States (US) received HIV care in 2014, but only 58% had ≥1 undetectable plasma viral load (VL) measurement [7] and 48% achieved sustained viral suppression that year [8]. Viral suppression is lowest in minority populations [7, 8]. In the US, approximately 52% of individuals with hypertension in 2015–2016 and 52% of individuals with diabetes during 2009–2012 had poorly controlled disease [9, 10]. The reasons for poor control of HIV, hypertension, and diabetes likely include both individual- and community-level factors.

Over half of the 15% of Americans living below the poverty line live near one another in concentrated areas of poverty [11, 12]. Since 2000, the number of people living in areas with a poverty rate ≥20% increased by 56%, with approximately a quarter of the US population living in these areas [13, 14]. Resources that support the health and well-being of the population overall, such as access to healthcare, stores selling healthy food, and recreational facilities are often limited in places with high poverty rates [15, 16]. Several studies have documented the associations of neighborhood-level poverty, independent of individual socioeconomic status, with morbidity and mortality due to HIV [17–19] and other diseases including heart disease [15, 20] and diabetes [21]. Compared to white Americans, more minorities live in neighborhoods with high proportions of poor residents, a differential that likely promotes pervasive racial disparities in health [12, 16, 21–24].

Despite evidence that contextual and structural inequities impact disease prevalence [15, 17–21], their effects on critical markers of HIV control (e.g., virologic suppression) and primary

care (e.g., blood pressure or glucose control) have received relatively little attention [15, 25, 26]. In our conceptual model, neighborhood-level poverty worsens people's health and their ability to control disease through deprivation of important resources such as health care, education, economic opportunities, and affordable food and housing [15, 16, 27, 28]. The absence of these resources may increase stress levels and ultimately interfere with a person's ability to adhere to treatment regimens and adequately control their disease [29]. The Women's Interagency HIV Study (WIHS) follows women with or at risk for HIV, many of whom live in poverty [30–32] and experience other comorbid conditions [33–35]. In the WIHS, US Census data are linked to residential addresses of consenting women, providing an opportunity to characterize neighborhood-level poverty in populations with high prevalence of diseases that are manageable with appropriate treatment and care. The primary aims of this analysis were to examine prevalence of controlled HIV, hypertension, and diabetes, and to assess the relationships between neighborhood-level poverty and control of these conditions among a representative group of US women with or at risk for HIV infection.

METHODS

Study Population

The WIHS is a multicenter prospective cohort study established in 1993 to investigate clinical and epidemiologic aspects of HIV infection among women. Participants were recruited during four waves (1994–5, 2001–2, 2011–2, and 2013–5) from 10 centers. The original sites (Brooklyn, NY; Bronx, NY; Washington, DC; Chicago, IL; Los Angeles, CA; San Francisco, CA) enrolled women during the first three recruitment waves, and the southern sites (Chapel Hill, NC; Atlanta, GA; Miami, FL; Birmingham, AL/Jackson, MS) enrolled participants in the most recent wave. Study visits occur at six-month intervals and consist of standardized interviews, clinical exams, and specimen collection. Detailed descriptions of recruitment, retention, and characteristics of WIHS participants have been previously published [30–32]. Each site used ArcGIS version 10.2 (Environmental Systems Research Institute, Redlands, CA) to geocode the current addresses of participants who consented to this procedure and attended a study visit between 1 April and 30 September 2015 (henceforth the index visit). Federal Information Processing Standard (FIPS) codes for state, county, census tract, and census block group were assigned to each participant based on geocoded coordinates.

We included participants in this analysis if they attended the index visit and were assigned a valid FIPS code for their current address (no participants from the Los Angeles site attended the index visit). Study protocols were approved by Institutional Review Boards (IRBs) at each clinical site, and specifically for this analysis, were reviewed by the University of North Carolina at Chapel Hill IRB. Written informed consent was obtained from all participants.

Contextual Data

The American Community Survey (ACS) is a household survey administered by the US Census Bureau that samples 3 million addresses yearly to obtain timely demographic, economic, and housing information from residents [36]. ACS variables are reported in 1-, 3-

and 5-year estimates, depending on population size (only 5-year estimates are reported for geographic units with small populations) and sensitivity of the particular variable.

In this analysis, we used census tract as a proxy for a person's neighborhood [37]. Five-year ACS poverty estimates (2010–2014) for census tracts [38] were linked to WIHS participant census tracts using FIPS codes. Census tract-level (henceforth neighborhood) poverty was defined as the proportion of each participant's census tract living below the federal poverty line during the past 12 months. Five-year estimates of the percentage of the population living below the poverty line are available at the census tract-level, but not the census block-group level. The US Census defines a poverty area as census tracts where at least 20% of the population lives below the poverty line [14]. We classified neighborhood poverty into three categories: ≤20%, >20–40%, or >40–100% of the total population living below the poverty line. These categorizations have previously been used to classify areas with low, high, and extreme poverty, respectively [14, 39]. We varied the cut-points in sensitivity analyses to assess if changes in the functional form of the exposure impacted the observed associations.

Health Outcomes

We used WIHS interview, physical examination, and laboratory data to classify all health outcomes. For HIV-seropositive women, we classified unsuppressed HIV as >200 copies/mL. We defined a hypertension diagnosis (in both HIV-seropositive and -seronegative women) as self-reported hypertension [40] and/or self-reported use of anti-hypertensive medications [41] at or before the index visit to ensure that hypertensive women were aware of their diagnosis. Although anti-hypertensive medication can be prescribed for conditions unrelated to hypertension, we assumed this to be minimal among participants. For women with a diagnosis of hypertension, we defined uncontrolled hypertension as systolic blood pressure >140 (mm Hg) or diastolic blood pressure >90 at the index visit.

For all women (HIV-seropositive and -seronegative), we defined a diagnosis of diabetes as ever self-reporting anti-diabetic medication or, when non-pregnant, (1) ever having two fasting serum glucose measurements ≥126 mg/dL, or (2) measurements of HgbA1c ≥6.5% and fasting serum glucose ≥126 mg/dL. Among women who were classified as ever having been diagnosed with diabetes, we classified uncontrolled diabetes at the index visit as an HgbA1c measurement >7.0% [9].

Covariates

Self-reported race/ethnicity (African American non-Hispanic, white non-Hispanic, Hispanic, or other), and birthdate were recorded at entry into the WIHS cohort. Annual household income (≤$12,000, $12,001-$30,000, or >$30,000 per year), current insurance status (uninsured or insured [privately, publicly, or unknown type]), receipt of food stamps, including Temporary Assistance to Needy Families program and the Supplemental Nutrition Assistance Program (received or not received), marital status (married, cohabitating, widowed/divorced/separated, never married, or other), education status (<grade 12, grade 12, or >grade 12), body mass index, and self-reported receipt of healthcare from a provider in the preceding six months (received or not received) were collected for all women at the index visit. Self-reported AIDS diagnosis prior to the index visit; and enrollment status in

the AIDS Drug Assistance Program (ADAP) (enrolled or not enrolled), CD4 cell count, HIV VL, and antiretroviral therapy (ART) status (defined as self-reported use of ≥3 antiretroviral medications, one of which is a protease inhibitor, a non-nucleoside reverse transcriptase inhibitor, one of the nucleoside reverse transcriptase inhibitors abacavir or tenofovir, an integrase inhibitor, or an entry inhibitor) at the index visit were also collected for HIV-seropositive women.

Statistical Analysis

We evaluated three outcomes: unsuppressed VL among HIV-seropositive participants, uncontrolled diabetes among diabetic participants, and uncontrolled hypertension among hypertensive participants. HIV viral suppression, diabetes control, and hypertension control were analyzed separately with the latter two stratified by HIV status, for a total of five models. Modified Poisson regression models [42] using generalized estimating equations (GEE) were fit to estimate prevalence ratios (PRs) and robust 95% confidence intervals (CIs) for each outcome. We used GEE with an independent working covariance matrix to account for clustering due to residents living in the same census tract.

Based on a review of the literature and construction of causal diagrams [43], viral suppression models were adjusted for race/ethnicity, self-reported AIDS diagnosis prior to the index visit, age at index visit (continuous), income category, combined health insurance/ADAP enrollment status (uninsured/no ADAP; uninsured/ADAP; insured/no ADAP; insured/ADAP), and CD4 cell count (continuous). The models for both diabetes and hypertension control were adjusted for race, age at index visit (continuous), income and either health insurance status (HIV-seronegative women) or combined health insurance/ADAP enrollment status (HIV-seropositive women). The diabetes control model was adjusted for receipt of food stamps; previously, this program has been associated with glucose control because it provides recipients with access to basic foods, enabling participants to purchase healthier and often more expensive items (e.g., medication). [44, 45]. We did not include self-reported AIDS diagnosis prior to the index visit, CD4 cell count, or HIV VL in the final diabetes and hypertension models for HIV-seropositive women because addition of these variables did not alter the effect estimates. We conducted all statistical analyses in SAS version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

In total, 2342 women attended the index visit; 2094 women (89%) provided a residential address that could be geocoded and were included in this analysis. Among excluded women, 169 (68%) refused to provide their address, 29 (12%) did not have a stable address, 24 (10%) provided an address that could not be matched to a location in ArcGIS, and 26 (11%) were missing an address. Most geocoded participants were African American, non-Hispanic (N=1519, 73%) and most were unmarried (N=1680, 80%). Nearly half of women reported an annual household income ≤$12,000 (N=1024, 49%), 32% (N=678) had less than a high school education, 25% (N=517) reported either injection or non-injection drug use in the past 6 months, and 58% received food stamps (N=1218). The median age of participants was 49 years (interquartile range (IQR), 42–55) [Table 1]. Compared to geocoded participants,

non-geocoded participants were less likely to have diabetes and hypertension, and were more likely to have HIV infection and missing income and drug use information [Supplemental Table 1]. The remaining analyses only consider geocoded women.

Most geocoded women were HIV-seropositive (N=1463, 70%), of whom 1271 (87%) were receiving ART. In total, 233 HIV-seropositive women (16%) had a VL >200 copies/mL; 120 of these women reported current receipt of ART. Overall, 1188 women (57%) had a hypertension diagnosis (848 HIV-seropositive, 340 HIV-seronegative); 27 women were classified as hypertensive based solely on report of anti-hypertensive medication. Of 1188 hypertensive women, 803 (68%) had controlled hypertension at the index visit: 601 HIV-seropositive (71%) and 202 HIV-seronegative (59%). A total of 418 women (20%) had been diagnosed with diabetes (280 HIV-seropositive, 138 HIV-seronegative), of whom 231 (55%) had controlled diabetes: 161 HIV-seropositive (58%) and 70 HIV-seronegative (51%) [Table 2]. The proportions of diabetic women with controlled diabetes who were receiving food stamps were approximately equivalent in HIV-seropositive and -seronegative women (68% versus 66%). However, a smaller proportion of HIV-seropositive women with uncontrolled diabetes received food stamps (60%, versus 69% of HIV-seronegative women).

Only 322 (15%) women had not seen a medical provider in the last six months [9% (N=138) of HIV-seropositive women; 12% (N=157) of hypertensive women; 12% (N=52) of diabetic women]. Among women who had not seen a medical provider, 35 (25%) were HIV-seropositive with an unsuppressed VL, 42 (27%) were diagnosed with hypertension and had uncontrolled hypertension, and 12 (23%) were diagnosed with diabetes and had uncontrolled diabetes.

Participants lived in census tracts where the median proportion of the population living below the poverty line was 26% (IQR, 16–37%). The median proportion of a respondent's own race living below the poverty line in their census tract was substantially higher among African American, non-Hispanics (30%; IQR, 19–42%) and participants of other (non-white) races/ethnicities (23%; IQR, 11–39%) than white participants (17%; IQR, 9–27%). The median proportion of people living in poverty in the participant's census tract decreased as the respondent's household income increased (≤$12,000, median, 29%; $12,001-$30,000, median, 26%; >$30,000, median, 18%). The median proportion of the census tract population living below the poverty line was 12% (IQR, 8–17%) for participants residing in the ≤20% neighborhood poverty category, 29% (IQR, 25–34%) for participants residing in the >20–40% neighborhood poverty category, and 47% (IQR, 43–50%) for participants residing in the >40–100% neighborhood poverty category [Table 3].

Viral Suppression

Although most HIV-seropositive women were receiving ART, the proportion decreased as neighborhood poverty increased [≤20% poverty: N=460/514 (89%); >20–40% poverty: N=575/657 (88%); >40–100% poverty: N=236/292 (81%); p=0.002]. Among 192 HIV-seropositive women not receiving ART, most had seen a healthcare provider in the previous 6 months; although similar across poverty levels, the proportion was highest in women living in areas of extreme poverty [≤20% poverty: N=42/54 (78%); >20–40% poverty: N=65/82 (79%); >40–100% poverty: N=50/56 (89%); p=0.2]. The prevalence of

unsuppressed VL was higher among HIV-seropositive women living in neighborhoods of extreme poverty in both unadjusted analyses (>40–100% versus ≤20% PR, 1.79; CI, 1.30–2.48) and analyses adjusted for individual-level markers of HIV disease, socioeconomic status, and demographics (>40–100% versus ≤20% adjusted PR [aPR], 1.42; CI, 1.04–1.92). The relationship between unsuppressed VL and poverty was attenuated and less precise among women living in neighborhoods of moderate poverty in unadjusted (>20–40% versus ≤20% PR, 1.27; CI, 0.94–1.71) and adjusted (>20–40% versus ≤20% aPR, 1.12; CI, 0.85–1.48) analyses [Table 4].

Hypertension

We did not observe a difference in the prevalence of hypertension with increasing neighborhood poverty in either HIV-seropositive or -seronegative women (Supplemental Table 2).

The prevalence of uncontrolled hypertension did not differ with increasing neighborhood poverty among HIV-seropositive women with self-reported hypertension (>20–40% versus ≤20% aPR, 0.94; 95% CI, 0.71–1.26; >40–100% versus ≤20% aPR, 1.08; 95% CI, 0.77–1.52). Among HIV-seronegative hypertensive women, uncontrolled hypertension was similar across all levels of neighborhood poverty (>20–40% versus ≤20% aPR, 1.06; 95% CI, 0.76–1.48; >40–100% versus ≤20% aPR, 1.09; 95% CI, 0.76–1.58) [Table 4].

Diabetes

The prevalence of diabetes was not associated with neighborhood poverty among either HIV-seropositive or HIV-seronegative women (Supplemental Table 2).

We did not observe an association between the prevalence of uncontrolled diabetes and increasing neighborhood poverty among HIV-seropositive women (>20–40% versus ≤20% aPR, 0.85; 95% CI, 0.59–1.22; >40–100% versus ≤20% aPR, 1.08; 95% CI, 0.69–1.69) [Table 4].

In HIV-seronegative women with diabetes, neighborhood poverty was associated with uncontrolled diabetes, with a threshold effect in census tracts with >20% poverty (>20–40% versus ≤20% aPR, 1.75; 95% CI, 1.02–2.98); effects were weaker and less precise among participants living in areas of extreme poverty (>40–100% versus ≤20% aPR, 1.33; 95% CI, 0.72–2.45) [Table 4].

Adjusting neighborhood poverty level cut-points in sensitivity analyses did not substantially change the directions or magnitudes of observed point estimates for control of HIV, hypertension, or diabetes in either HIV-seropositive or HIV-seronegative women (data not shown).

DISCUSSION

In this low-income population of predominantly African American women, over half of study participants resided in neighborhoods where more than 20% of residents lived below the federal poverty line. Increased prevalence of uncontrolled viremia among HIV-

seropositive women was associated with extremely high levels, but not moderately high levels, of neighborhood-level poverty. Among HIV-seropositive women, we observed no associations between neighborhood poverty and uncontrolled hypertension or diabetes. Worse control of diabetes, but not hypertension, was associated with living in high-poverty neighborhoods in HIV-seronegative women, although this relationship was attenuated and imprecise, due to the small number of participants who lived in neighborhoods of extreme poverty.

Previous research revealed associations between HIV infection prevalence and both personal poverty and residence in a high-poverty area [46, 47]. In British Columbia, with universal healthcare, residence in a high-poverty area was associated with increased mortality among people with HIV [18]. In New York City, residents of high poverty neighborhoods were less likely to maintain viral suppression than residents of lower poverty neighborhoods [26]. Our study, unlike this prior analysis, controlled for personal income and other individual-level indicators of socioeconomic status. We confirmed the relationship between viremia and extreme neighborhood level poverty. As expected, this relationship was largely driven by the smaller proportion of women living in areas of extreme poverty receiving ART compared to those who lived in areas with less poverty. In high-poverty areas, low ART receipt may be due to structural factors that inhibit access to adequate HIV care, such as a limited number of HIV providers and pharmacies, or administrative burdens related to providing HIV services at clinics serving low-income clients [48]. Over half of the women with detectable viremia in this study were receiving ART. The stressors of living in areas of extreme poverty (e.g., elevated crime rates, homelessness, food insecurity) may interfere with the ability of residents to adhere adequately to ART and subsequently control HIV.

Although it is possible that the lack of observed associations between neighborhood-level poverty and either hypertension or diabetes control among HIV-seropositive women is real, we believe these results may be due to other reasons. First, study participants generally lived in neighborhoods of concentrated poverty and were themselves overwhelmingly poor, with nearly half of women reporting an annual household income ≤$12,000. Only 13% of women lived in areas with low (<10%) levels of poverty, and one-third of these women were poor themselves. This restricted range of individual income and neighborhood poverty is a testimony to the difficult socioeconomic contexts in which women with HIV live and may have limited our ability to observe associations between neighborhood poverty and hypertension and diabetes control. The results of this analysis reflect a complex interaction between individual- and neighborhood-level factors related to poverty and health. Both individual income and neighborhood poverty likely affect a person’s ability to access health-care and control disease [27, 28]. Furthermore, unadjusted prevalence estimates for diabetes control among HIV-seropositive women living in high poverty areas were approximately equal to estimates among HIV-seronegative women living in low poverty areas, possibly because HIV-seropositive women often receive care for comorbid conditions during HIV care visits and have improved access to free or reduced price treatment to control diabetes and hypertension via the ADAP [49, 50]. Since HIV-seronegative women may not access healthcare as regularly as HIV-seropositive women, they may be more susceptible to adverse effects from living in poor neighborhoods. We did not observe similar results for hypertension control, possibly because hypertension may be more likely to remain

undiagnosed than diabetes. Because our classification of hypertension was mostly based on self-report, if women living in higher poverty neighborhoods were more likely to have undiagnosed hypertension, there may be greater differences across levels of neighborhood poverty than we observed in this analysis, which may have led to underestimates of the associations between neighborhood-level poverty and uncontrolled hypertension.

Women participating in the WIHS may fundamentally differ from non-participants living in similar neighborhoods. HIV-seropositive participants in the WIHS are racially and ethnically representative of women with HIV infection in the US, and HIV-seronegative enrollees are well-matched to HIV-seropositive women with respect to demographic and HIV-risk characteristics [30–32]. However, compared to national estimates in women, a higher proportion of HIV-seropositive WIHS participants had a suppressed VL (55% among women nationally versus 79% among WIHS participants), controlled hypertension (53% among women nationally versus 71% among WIHS participants), and controlled diabetes (54% among women nationally versus 58% among WIHS participants) [7, 9, 10]. It is possible that WIHS women residing in poor neighborhoods may be better able to access medical assistance and treatment for their HIV infection, diabetes, and hypertension than non-participants who live in similar neighborhoods [51]. We were unable to include homeless women in this analysis because these women did not have an address to geocode. If homeless women have worse outcomes and cluster in high poverty neighborhoods, their exclusion could have underestimated our observed associations.

Racial differences in mortality among people with HIV often persist, even when access to care appears equal [52, 53]. Because African Americans are more likely to live in high poverty areas, neighborhood context may at least partially explain this racial disparity in mortality and result from the higher prevalence of people with uncontrolled HIV infection in these neighborhoods.

Defining a person’s neighborhood poses methodologic challenges. In this analysis, we used census tract delineations to define each woman’s neighborhood, which correspond reasonably well to the perceptions of neighborhood boundaries of most Americans living in urban areas [39] and have been previously shown to be valid geographical units of analysis to assess health inequities [37]. Although it is possible for residents of the same census tract to experience different levels of contextual poverty, census tracts typically include populations with similar social characteristics [54] and are the smallest geographic unit with an estimate for the proportion of individuals who live below the poverty level [55]. In this analysis, poverty estimates for WIHS participants may have been misclassified due to a discrepancy in dates; neighborhood poverty estimates were based on a sample of responses in the ACS over a 5-year period ending in 2014, but the index visit and all corresponding health outcomes were obtained in 2015. However, it is unlikely that poverty levels decreased substantially in neighborhoods where most WIHS participants resided during this timeframe [56]. In addition, both the neighborhood poverty indicator and the WIHS individual income variable may not capture wealth or financial support networks accurately. Urban high poverty neighborhoods may differ from suburban and rural high poverty areas in terms of availability of and access to resources, including healthcare services [56]. Although both the original and Southern WIHS sites are located in mostly urban areas, the patient population

that each site draws from extends beyond urban centers into more rural areas. Furthermore, WIHS participants living with HIV mirror the HIV epidemic among US women in terms of race, ethnicity, and socioeconomic status, [51] providing support for the generalizability of our results. Finally, the small number of HIV-seronegative women with uncontrolled diabetes and hypertension also limited this analysis. However, dichotomous comparisons between women living in impoverished neighborhoods (>20–100% poverty) and those living in non-impoverished neighborhoods (≤20% poverty) suggest associations, though modest, between neighborhood-level poverty and both uncontrolled diabetes and uncontrolled hypertension, even when sample size is limited.

This study suggests that neighborhood-level poverty may interfere with diabetes control as well as access or adherence to ART among women living in the US. The lack of observed associations between neighborhood poverty and control of some diseases, such as hypertension, may be true null associations, or instead due to the fact that WIHS participants receive many services that other women (both HIV-seropositive and HIV-seronegative) living in areas of poverty cannot access. Regardless, the results of this study provide an initial insight into the pathways between socioeconomic context and adverse health outcomes. Future research incorporating duration of residence in high poverty neighborhoods as well as the specific characteristics of high poverty neighborhoods that interfere with the ability of residents to control chronic conditions such as HIV, hypertension, and diabetes is needed to build upon this understanding and develop effective policies at the state and local levels to address these disparities. Interventions that assist women living in poor neighborhoods to navigate the healthcare system could improve their ability to access resources that effectively control existing health conditions and decrease community-wide inequalities.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

FUNDING SOURCE

Data in this manuscript were collected by the Women’s Interagency HIV Study (WIHS). The contents of this publication are solely the responsibility of the authors and do not represent the official views of the National Institutes of Health (NIH). WIHS (Principal Investigators): UAB-MS WIHS (Mirjam-Colette Kempf and Deborah Konkle-Parker), U01-AI-103401; Atlanta WIHS (Ighovwerha Ofotokun, Anandi, Sheth, and Gina Wingood), U01-AI-103408; Bronx WIHS (Kathryn Anastos and Anjali Sharma), U01-AI-035004; Brooklyn WIHS (Deborah Gustafson and Tracey Wilson), U01-AI-031834; Chicago WIHS (Mardge Cohen and Audrey French), U01-AI-034993; Metropolitan Washington WIHS (Seble Kassaye and Daniel Merenstein), U01-AI-034994; Miami WIHS (Maria Alcaide, Margaret Fischl, and Deborah Jones), U01-AI-103397; UNC WIHS (Adaora Adimora), U01-AI-103390; Connie Wofsy Women’s HIV Study, Northern California (Bradley Aouizerat and Phyllis Tien), U01-AI-034989; WIHS Data Management and Analysis Center (Stephen Gange and Elizabeth Golub), U01-AI-042590; Southern California WIHS (Joel Milam), U01-HD-032632 (WIHS I – WIHS IV). The WIHS is funded primarily by the National Institute of Allergy and Infectious Diseases (NIAID), with additional co-funding from the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (NICHD), the National Cancer Institute (NCI), the National Institute on Drug Abuse (NIDA), and the National Institute on Mental Health (NIMH). Targeted supplemental funding for specific projects is also provided by the National Institute of Dental and Craniofacial Research (NIDCR), the National Institute on Alcohol Abuse and Alcoholism (NIAAA), the National Institute on Deafness and other Communication Disorders (NIDCD), and the NIH Office of Research on Women’s Health. WIHS data collection is also supported by UL1-TR000004 (UCSF CTSA), UL1-TR000454 (Atlanta CTSA), P30-AI-050410 (UNC CFAR), and P30-AI-027767 (UAB CFAR).

REFERNCES

1. Levy AR, et al., The direct costs of HIV/AIDS care. Lancet Infect Dis, 2006 6(3): p. 171–7. [PubMed: 16500598]
2. Gillespie CD and Hurvitz KA, Prevalence of hypertension and controlled hypertension - United States, 2007–2010. MMWR Surveill Summ, 2013 62 Suppl 3: p. 144–8.
3. Ali MK, et al., Characteristics associated with poor glycemic control among adults with self-reported diagnosed diabetes--National Health and Nutrition Examination Survey, United States, 2007–2010. MMWR Morb Mortal Wkly Rep, 2012 61 Suppl: p. 32–7.
4. Cohen MS, et al., Prevention of HIV-1 infection with early antiretroviral therapy. N Engl J Med, 2011 365(6): p. 493–505. [PubMed: 21767103]
5. Quinn TC, et al., Viral load and heterosexual transmission of human immunodeficiency virus type 1. Rakai Project Study Group. N Engl J Med, 2000 342(13): p. 921–9. [PubMed: 10738050]
6. Muessig KE and Cohen MS, Advances in HIV prevention for serodiscordant couples. Curr HIV/AIDS Rep, 2014 11(4): p. 434–46. [PubMed: 25145645]
7. Centers for Disease Control and Prevention. Monitoring selected national HIV prevention and care objectives by using HIV surveillance data—United States and 6 dependent areas, 2015. HIV Surveillance Supplemental Report 2017;22(No. 2).
8. Crepaz N, et al., Racial and Ethnic Disparities in Sustained Viral Suppression and Transmission Risk Potential Among Persons Receiving HIV Care - United States, 2014. MMWR Morb Mortal Wkly Rep, 2018 67(4): p. 113–118. [PubMed: 29389918]
9. Office of Disease Prevention and Health Promotion. Healthy People 2020. Diabetes: D-5.2 Proportion of the diabetic population with an A1c value less than 7 percent. Available at https://www.healthypeople.gov/2020/data-search/Search-the-Data#objid=4124. Accessed December 5, 2019.
10. Fryar CD, et al., Hypertension prevalence and control among adults: United States, 2015–2016, National Center for Health Statistics, Hyattsville, MD: 2017.
11. DeNavas-Walt C and BD P, Income and Poverty in the United States: 2013. Washington, DC: U.S. Census Bureau, Current Population Reports, P60–249, 2014.
12. Jargowsky P, Concentration of Poverty in the New Millennium: Changes in Prevalence, Composition, and Location of High Poverty Neighborhoods. The Century Foundation and Rutgers CURE 2013.
13. Jargowsky P. Architecture of Segregation Civil Unrest, the Concentration of Poverty, and Public Policy. In: The Century Foundation; 2015.
14. Bishaw A, Changes in Areas With Concentrated Poverty: 2000 to 2010, in American Community Survey Reports. 2014, U.S. Census Bureau.
15. Buys DR, et al., Association between neighborhood disadvantage and hypertension prevalence, awareness, treatment, and control in older adults: results from the University of Alabama at Birmingham Study of Aging. Am J Public Health, 2015 105(6): p. 1181–8. [PubMed: 25322309]
16. Kirby JB and Kaneda T, Neighborhood socioeconomic disadvantage and access to health care. J Health Soc Behav, 2005 46(1): p. 15–31. [PubMed: 15869118]
17. Zierler S, et al., Economic deprivation and AIDS incidence in Massachusetts. Am J Public Health, 2000 90(7): p. 1064–73. [PubMed: 10897184]
18. Joy R, et al., Impact of neighborhood-level socioeconomic status on HIV disease progression in a universal health care setting. J Acquir Immune Defic Syndr, 2008 47(4): p. 500–5. [PubMed: 18197117]
19. McDavid Harrison K, et al., County-level socioeconomic status and survival after HIV diagnosis, United States. Ann Epidemiol, 2008 18(12): p. 919–27. [PubMed: 19041591]
20. Cubbin C. and Winkleby MA, Protective and harmful effects of neighborhood-level deprivation on individual-level health knowledge, behavior changes, and risk of coronary heart disease. Am J Epidemiol, 2005 162(6): p. 559–68. [PubMed: 16093286]
21. Gaskin DJ, et al., Disparities in diabetes: the nexus of race, poverty, and place. Am J Public Health, 2014 104(11): p. 2147–55. [PubMed: 24228660]

22. Gant Z, et al., A census tract-level examination of social determinants of health among black/African American men with diagnosed HIV infection, 2005–2009−−17 US areas. PLoS One, 2014 9(9): p. e107701.
23. Vaughan AS, et al., Connecting race and place: a county-level analysis of White, Black, and Hispanic HIV prevalence, poverty, and level of urbanization. Am J Public Health, 2014 104(7): p. e77–84.
24. Morenoff JD, et al., Understanding social disparities in hypertension prevalence, awareness, treatment, and control: the role of neighborhood context. Soc Sci Med, 2007 65(9): p. 1853–66. [PubMed: 17640788]
25. Laraia BA, et al., Place matters: neighborhood deprivation and cardiometabolic risk factors in the Diabetes Study of Northern California (DISTANCE). Soc Sci Med, 2012 74(7): p. 1082–90. [PubMed: 22373821]
26. Wiewel EW, et al., Neighborhood Characteristics Associated with Achievement and Maintenance of HIV Viral Suppression Among Persons Newly Diagnosed with HIV in New York City. AIDS Behav, 2017 21(12): p. 3557–3566. [PubMed: 28160107]
27. Diez Roux AV, Investigating neighborhood and area effects on health. Am J Public Health, 2001 91(11): p. 1783–9. [PubMed: 11684601]
28. Yen IH and Syme SL, The social environment and health: a discussion of the epidemiologic literature. Annu Rev Public Health, 1999 20: p. 287–308. [PubMed: 10352860]
29. Kwarteng JL, et al., Independent Effects of Neighborhood Poverty and Psychosocial Stress on Obesity Over Time. J Urban Health, 2017 94(6): p. 791–802. [PubMed: 28895036]
30. Barkan SE, et al., The Women's Interagency HIV Study. WIHS Collaborative Study Group. Epidemiology, 1998 9(2): p. 117–25. [PubMed: 9504278]
31. Bacon MC, et al., The Women's Interagency HIV Study: an observational cohort brings clinical sciences to the bench. Clin Diagn Lab Immunol, 2005 12(9): p. 1013–9. [PubMed: 16148165]
32. Hessol NA, et al., Retention and attendance of women enrolled in a large prospective study of HIV-1 in the United States. J Womens Health (Larchmt), 2009 18(10): p. 1627–37. [PubMed: 19788344]
33. Tien PC, et al., Association of HIV infection with incident diabetes mellitus: impact of using hemoglobin A1C as a criterion for diabetes. J Acquir Immune Defic Syndr, 2012 61(3): p. 334–40. [PubMed: 22878421]
34. Khalsa A, et al., Correlates of prevalent hypertension in a large cohort of HIV-infected women: Women's Interagency HIV Study. AIDS, 2007 21(18): p. 2539–41. [PubMed: 18025894]
35. Yi T, et al., The impact of the AIDS Drug Assistance Program (ADAP) on use of highly active antiretroviral and antihypertensive therapy among HIV-infected women. J Acquir Immune Defic Syndr, 2011 56(3): p. 253–62. [PubMed: 21239994]
36. A Compass for Understanding and Using American Community Survey Data: What General Data Users Need to Know. 2008, U.S. Census Bureau: Washington, DC.
37. Krieger N, A century of census tracts: health & the body politic (1906–2006). J Urban Health, 2006 83(3): p. 355–61. [PubMed: 16739037]
38. United States Census Bureau."Table B17020."2010 – 2014 American Community Survey. U.S. Census Bureau's American Community Survey Office, 2015 Web. 1 March 2016 <https://factfinder.census.gov/>.
39. Jargowsky P, Studying Neighborhood Poverty, in Povety and Place: Ghettos, Barrios, and the American City. 1997, Russell Sage Foundation: New York.
40. Okura Y, et al., Agreement between self-report questionnaires and medical record data was substantial for diabetes, hypertension, myocardial infarction and stroke but not for heart failure. J Clin Epidemiol, 2004 57(10): p. 1096–103. [PubMed: 15528061]
41. Boudreau DM, et al., A validation study of patient interview data and pharmacy records for antihypertensive, statin, and antidepressant medication use among older women. Am J Epidemiol, 2004 159(3): p. 308–17. [PubMed: 14742292]
42. Zou G, A modified poisson regression approach to prospective studies with binary data. Am J Epidemiol, 2004 159(7): p. 702–6. [PubMed: 15033648]

43. Greenland S, Pearl J, and Robins JM, Causal diagrams for epidemiologic research. Epidemiology, 1999 10(1): p. 37–48. [PubMed: 9888278]
44. Mayer VL, et al., Food insecurity, coping strategies and glucose control in low-income patients with diabetes. Public Health Nutr, 2016; 19(6): 1103–1111. [PubMed: 26328922]
45. Aggarwal A, Monsivais P, and Drewnowski A, Nutrient intakes linked to better health outcomes are associated with higher diet costs in the US. PLoS One, 2012 7(5): p. e37533.
46. Adimora AA, et al., Heterosexually transmitted HIV infection among African Americans in North Carolina. J Acquir Immune Defic Syndr, 2006 41(5): p. 616–23. [PubMed: 16652036]
47. Denning P and DiNenno. E. Communities in Crisis: Is There a Generalized HIV Epidemicin Impoverished Urban Areas of the United States? Presented at: XVIII International AIDS Conference; July 16–19, 2010; Vienna, Austria.
48. Kahana SY, et al., Structural Determinants of Antiretroviral Therapy Use, HIV Care Attendance, and Viral Suppression among Adolescents and Young Adults Living with HIV. PLoS One, 2016 11(4): p. e0151106.
49. Adimora AA, et al., Policies and politics that promote HIV infection in the Southern United States. AIDS, 2014 28(10): p. 1393–7. [PubMed: 24556871]
50. National Alliance of State and Territorial AIDS Directors. National ADAP Monitoring Project Annual Report. Available at https://www.nastad.org/sites/default/files/NASTAD-ADAP-Monitoring-Project-Annual-Report-May-2015.pdf. Accessed 3 January 2016.
51. Adimora AA, et al., Cohort Profile: The Women's Interagency HIV Study (WIHS). Int J Epidemiol, 2018 47(2): p. 393–394i. [PubMed: 29688497]
52. Meditz AL, et al., Sex, race, and geographic region influence clinical outcomes following primary HIV-1 infection. J Infect Dis, 2011 203(4): p. 442–51. [PubMed: 21245157]
53. Lesko CR, et al., Ten-year Survival by Race/Ethnicity and Sex Among Treated, HIV-infected Adults in the United States. Clin Infect Dis, 2015 60(11): p. 1700–7. [PubMed: 25767258]
54. Fowler CS, et al., Who are the People in my Neighborhood?: The "Contextual Fallacy" of Measuring Individual Context with Census Geographies. Geographical Analysis, 2019. [Epub ahead of print].
55. US Census Bureau. 2010 geographic terms and concepts—census tract. Last Revised September 16, 2019. Available at: https://www.census.gov/programs-surveys/geography/about/glossary.html#par_textimage_13. Accessed October 7, 2019.
56. Kneebone E, The Growth and Spread of Concentrated Poverty, 2000 to 2008–2012. Brookings Institute; 2014 Available at https://www.brookings.edu/interactives/the-growth-and-spread-of-concentrated-poverty-2000-to-2008-2012/. Accessed 3 December 2018.

Table I.

Demographic Characteristics of 2094 Participants with Geocoded Addresses, Women's Interagency HIV Study, 2015

	Median	IQR[1]
Age	49.3	(41.9–55.4)
Body Mass Index	30.8	(25.8–37.2)
	N	%
Race/Ethnicity		
African American, Non-Hispanic	1519	73
White, Non-Hispanic	191	9
Hispanic	312	15
Other Race, Non-Hispanic	72	3
Marital Status		
Married	404	19
Cohabitating	181	9
Widowed/Divorced/Separated	548	26
Never Married	657	31
Other	213	10
Missing	91	4
Education		
<Grade 12	678	32
Grade 12	641	31
>Grade 12	723	35
Missing	52	3
Residence Type		
Own House/Apartment	1701	81
Parent's House	74	4
Someone Else's House/Apartment	207	10
Rooming/Board/Halfway House	29	1
Shelter/Welfare Hotel	17	1
Other Place	12	1
Missing	54	3
Site		
Original	1363	65
Bronx, NY	307	15
Brooklyn, NY	298	14
Washington, DC	220	11
Chicago, IL	262	13
San Francisco, CA	276	13
Southern	731	35
Chapel Hill, NC	191	9
Atlanta, GA	234	11

	Median	IQR[1]
Miami, FL	96	5
Birmingham, AL	98	5
Jackson, MS	112	5
Drug use in the past 6 months		
Both Injection & Non-Injection Drug Use	13	1
Injection Drug Use Only	2	0
Non-Injection Drug Use Only	502	24
No Reported Drug Use	1516	72
Missing	61	3
HIV Status		
Seropositive	1463	70
Seronegative	631	30
Health Insurance		
Yes	1718	82
No	285	14
Missing	91	4
Health Insurance Type		
Uninsured	285	14
Privately Insured	397	19
Publicly Insured	1318	63
Insured, Unknown Type	3	0
Missing	91	4
If HIV-seropositive, ADAP[2] Status		
Yes	379	26
No	1038	71
Missing	46	3
If HIV-seropositive, Receiving ART[3]		
Yes	1271	87
No	192	13
Annual Household Income		
≤$12,000	1024	49
$12,001-$30,000	580	28
>$30,000	361	17
Missing	129	6
Receiving Food Stamps		
Yes	1218	58
No	851	41
Missing	25	1
Proportion of Census Tract Population Below Federal Poverty Line[4]		
≤20%	735	35
20–40%	929	44

	Median	IQR[1]
>40%−100%	430	21

1. IQR=Interquartile Range

2. ADAP=AIDS Drug Assistance Program

3. ART=Antiretroviral Therapy

4. Census tract-level data were obtained from the American Community Survey (2010–2014) [38]

Table II.

Control of HIV Infection, Diabetes, and Hypertension among Women Whose Addresses were Geocoded, Women's Interagency HIV Study, 2015

	HIV-Seropositive (N=1463)								HIV-Seronegative (N=631)			
	All HIV-seropositive		HIV-seropositive on ART		Hypertension		Diabetes		Hypertension		Diabetes	
	N	%	N	%	N	%	N	%	N	%	N	%
Total	**1463**		**1271**		**848**		**280**		**340**		**138**	
Controlled at index visit[1]	1160	79	1092	86	601	71	161	58	202	59	70	51
Uncontrolled at index visit	233	16	120	9	201	24	103	37	124	37	55	40
Missing outcome data at index visit[2]	*70*	*5*	*59*	*5*	*46*	*5*	*16*	*6*	*14*	*4*	*13*	*9*

1. Control for HIV=viral load ≤200 copies/mL; Control for diabetes=HgbA1c ≤7.0%; Control for hypertension=systolic blood pressure ≤140 and diastolic blood pressure ≤90

2. Outcome for HIV control is HIV viral load; outcome for hypertension control is blood pressure; outcome for diabetes control is HgbA1c

Table III.

Median Proportion of People Living Below the Poverty Line in Census Tracts and Counties Where Participants Reside, Women's Interagency HIV Study, 2015

	Census Tract[1]			County[1]		
	Median	**IQR[2]**	**Range**	**Median**	**IQR[2]**	**Range**
Proportion <Poverty Line	26	16–37	1–73	18	15–23	4–48
Proportion <Poverty Line by Neighborhood Poverty Category						
≤20%	12	8–17	1–20	17	13–18	4–20
>20–40%	29	25–34	20–40	23	23–31	20–38
>40%−100%	47	43–50	40–73	48	48–48	48–48
Proportion of Respondent's Own Race <Poverty Line						
All Respondents	27	41–49	26–73	24	15–23	4–48
If Respondent African American	30	19–42	0–91	27	23–30	8–54
If Respondent White	17	9–27	0–100	11	10–18	3–24
If Respondent Other Race	23	11–39	0–100	21	14–29	8–37
Proportion <Poverty Line by Reported Annual Household Income						
≤$12,000	29	20–40	2–73	18	17–23	6–48
$12,001-$30,000	26	16–37	1–71	18	15–23	5–37
>$30,000	18	10–29	1–63	17	13–23	4–31

1. Census tract- and county-level data were obtained from the American Community Survey (2010–2014) [38]

2. IQR=Interquartile Range

Table IV.

Prevalence of Uncontrolled HIV, Hypertension, and Diabetes Among HIV-seropositive and HIV-seronegative Women, by Census Tract[1] Poverty Level, Women's Interagency HIV Study, 2015

		HIV-seropositive							HIV-seronegative						
					Unadjusted		Adjusted[7]					Unadjusted		Adjusted[7]	
		Uncontrolled[2] Participants	Controlled[3] Participants	Prevalence[4]	PR[5]	95% CI[6]	PR	95% CI[6]	Uncontrolled[2] Participants	Controlled[3] Participants	Prevalence[4]	PR[5]	95% CI[6]	PR	95% CI[6]
Women with HIV+	**Viral Load >200 Copies/mL**														
	Poverty Level														
	≤20%	64	425	13.09	1.00		1.00								
	>20–40%	105	526	16.64	1.27	0.94–1.71	1.12	0.85–1.48							
	>40%−100%	64	209	23.44	1.79	1.30–2.48	1.42	1.04–1.92							
Women with Hypertension	**Blood Pressure >140/90**														
	Poverty Level														
	≤20%	59	201	22.69	1.00		1.00		34	60	36.17	1.00		1.00	
	>20–40%	96	281	25.46	1.12	0.85–1.49	0.94	0.71–1.26	60	98	37.97	1.05	0.75–1.46	1.06	0.76–1.48
	>40%−100%	46	119	27.88	1.23	0.88–1.71	1.08	0.77–1.52	30	44	40.54	1.12	0.77–1.62	1.09	0.76–1.58
Women with Diabetes	**HgbA1c >7.0%**														
	Poverty Level														
	≤20%	37	47	44.05	1.00		1.00		14	27	34.15	1.00		1.00	

	HIV-seropositive							HIV-seronegative						
				Unadjusted		Adjusted[7]					Unadjusted		Adjusted[7]	
	Uncontrolled[2] Participants	Controlled[3] Participants	Prevalence[4]	PR[5]	95% CI[6]	PR	95% CI[6]	Uncontrolled[2] Participants	Controlled[3] Participants	Prevalence[4]	PR[5]	95% CI[6]	PR	95% CI[6]
>20–40%	46	82	35.94	0.82	0.58–1.14	0.85	0.59–1.22	30	28	51.72	1.51	0.92–2.49	1.75	1.02–2.98
>40% −100%	20	32	38.46	0.87	0.58–1.32	1.08	0.69–1.69	11	15	42.31	1.24	0.68–2.27	1.33	0.72–2.45

1. Census tract-level data were obtained from the American Community Survey (2010–2014) [38]

2. Uncontrolled HIV=viral load >200 copies/mL; Uncontrolled hypertension=diastolic blood pressure >90 or systolic blood pressure >140; Uncontrolled diabetes=HgbA1c >7.0%

3. Controlled HIV=viral load ≤200 copies/mL; Controlled hypertension= diastolic blood pressure ≤90 and systolic blood pressure ≤140; Controlled diabetes=HgbA1c ≤7.0%

4. Prevalence of uncontrolled disease [per 100 (unadjusted)] estimated using generalized estimating equations with an independent working covariance matrix.

5. PR=prevalence ratio estimated using generalized estimating equations with an independent working covariance matrix. All participants with missing data for the particular outcome of interest (i.e viral load, hypertension control or diabetes control) were excluded when calculating unadjusted and adjusted prevalence ratios.

6. CI=confidence interval estimated using generalized estimating equations with an independent correlation matrix

7. Viral Suppression Adjustment Set: age (continuous), race/ethnicity, annual household income (categorical), health insurance (No insurance/No ADAP; No insurance/ADAP; insurance/No ADAP; insurance/ADAP), CD4 (continuous), prior AIDS diagnosis (Y/N)

Hypertension Adjustment Set: age (continuous), race/ethnicity, household income (categorical), health insurance (HIV-seropositive: No insurance/No ADAP; No insurance/ADAP; insurance/No ADAP; insurance/ADAP; HIV-seronegative: insured/Not insured)

Diabetes Adjustment Set: age (continuous), race/ethnicity, household income (categorical), health insurance (HIV-seropositive: No insurance/No ADAP; No insurance/ADAP; insurance/No ADAP; insurance/ADAP; HIV-seronegative: insured/Not insured); on food stamps (Y/N)