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The Contribution of Socioeconomic Factors to HIV RNA Suppression in Persons with HIV Engaged in Care in the NA-ACCORD

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Abstract

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Conflicts of Interest: JG is an ad hoc member of HIV national advisory boards to Merck, Gilead and ViiV Health. KVCM has received consultation fees from Eli Lilly, Bayer, Gilead Sciences, Merck, and ViiV. PR has received consultation fees from Gilead and Janssen. KNA serves on the scientific advisory board for TrioHealth, Inc. All other authors have no conflicts of interest to report.

Introduction—Socioeconomic status (SES) influences well-being among people living with HIV (PWH); when individual-level SES information is not available, area-level SES indicators may be a suitable alternative. We hypothesized that: a) select ZIP Code-level SES indicators would be associated with viral suppression, and b) accounting for ZIP Code-level SES would attenuate racial disparities in viral suppression among PWH.

Setting—The NA-ACCORD, a collaboration of clinical and interval cohorts of PWH.

Methods—Participants with ≥1 viral load measurement and ≥1 US residential 5-digit ZIP Code(s) between 2010–2018 were included. In this serial cross-sectional analysis, multivariable logistic regression models were used to quantify the annual association of race and ethnicity with viral suppression, in the presence of SES indicators as well as sex, Hepatitis C status, and age.

Results—We observed a dose response relationship between SES factors and viral suppression. Lower income and education were associated with 0.5 to 0.7-fold annual decreases in odds of viral suppression. We observed racial disparities of ~40% decreased odds of viral suppression among non-Hispanic Black compared with non-Hispanic White individuals. The disparity persisted but narrowed by 3–4% when including SES in the models.

Conclusion—ZIP Code-based SES was associated with viral suppression, and accounting for SES narrowed racial disparities in viral suppression among PWH in the NA-ACCORD. Inclusion of ZIP Code-level indicators of SES as surrogates for individual-level SES should be considered to improve our understanding of the impact of social determinants of health and racial disparities on key outcomes among PWH in North America.

Background

Socioeconomic status (SES) is a broad construct that indicates an individual's access to resources, including material items, education/employment opportunities, money/wealth, power/social status, personal and societal stability, healthcare and other desired resources; there is no agreed-upon SES status measurement.[1,2] It is now well-established that an individual's sociodemographic characteristics influence optimal health and well-being; stressors stemming from lower SES have been associated with poor physical and mental health outcomes.[3,4] In the context of HIV, complex relationships between lower SES and adverse health outcomes, including unsuppressed HIV RNA, exist.[5–10]

Recent studies demonstrate that structural racism is a root cause of disparities in HIV incidence and treatment among people with HIV (PWH).[11,12] What is less clear is to what degree community level SES interacts with and/or influences racial differences in health outcomes.[13–16]

Challenges exist to measuring individual-level SES due to it being a complex construct represented by measurable as well as latent indicator variables including income, education, and employment. Individual-level estimation of SES enables direct examinations of the pathways resulting in inequities in health between groups of individuals and identification of subgroups most vulnerable and in need of focused intervention. When individual-level SES information is not available, area-level SES indicators may serve as surrogates.[17] Under the assumption that neighborhoods are often sociodemographically segregated, it

can be reasonable to hypothesize that people's individual-level SES indicators could approximate the medians and/or distributions of those indicators in the area in which they live.[18,19] Previous studies explored the correlation between individual and area-level SES characteristics with mixed results; Soobader *et al.* suggest that in some instances, small area-level measures (*i.e.*, census tract) may capture a more inclusive representation of SES than individual-level measures.[20,21] Some studies have shown moderate agreement between individual-level and area-level SES characteristics, and conclude that such surrogate use may be done albeit with caution.[17,22] Recognizing that the potential appropriateness of using area-level SES indicators as surrogates for individual-level SES indicators differs by health outcome area, study population, geographic location, and other factors, we sought to explore their utility in one large multi-site study population, the NA-ACCORD. The North American AIDS Cohort Collaboration on Research and Design (NA-ACCORD) is a collaboration of clinical and interval cohorts of PWH in care that has provided evidence to support advances in the clinical course and treatment of HIV for decades.[23]

The NA-ACCORD does not systematically or routinely collect SES information from all participants. Therefore, analyses within the NA-ACCORD exploring racial or regional disparities in outcomes or mortality have not controlled for confounding by SES.[24,25] The NA-ACCORD does compile 5-digit residential address ZIP Codes for US-based participants when contributed by the cohort/subsite. Although ZIP Code is not an ideal geographic measure for epidemiologic inquiry due to variations in size and sociodemographic composition within ZIP Codes as well as frequent changes in ZIP Code boundaries, it is possible to obtain ZIP Code-level SES indicators from the US Census.[18]

The objectives of our study were to 1) explore the association between viral suppression and three ZIP Code-level indicators of SES (median household income, proportion employed among those 16 years of age or older and in the labor force, and proportion 25 years or older with a college-level education or above) as surrogates for individual-level SES measurements; and 2) determine if area-level indicators of SES influenced the relationship between race and ethnicity and HIV RNA suppression among PWH in the NA-ACCORD.

Methods

Study population

The NA-ACCORD compiles and harmonizes information collected from a variety of sources including interviews, exams, and electronic health records (EHR). For this nested study, we included all participants enrolled in the NA-ACCORD that had at least one viral load measurement, residing in the United States and reported one or more 5-digit ZIP Code(s) of residence (Figure 1) between 2010 and 2018. The US Census provides myriad SES indicators at the ZIP Code-level using a census block-to-ZIP Code conversion called the ZIP Code Tabulation Area (ZCTA).[26] ZIP Codes were time-varying, with values collected in 2010 or later being carried forward until a new ZIP Code was reported. We also excluded participants whose cohorts did not share ZIP Code information with the NA-ACCORD, whose ZIP Code did not correspond with a ZCTA, or who reported conflicting ZIP Codes on a single date. In order to fully characterize the subset of the NA-ACCORD population that fulfilled the above-mentioned criteria, we compared this to all NA-ACCORD participants

observed between 2010 and 2018 (regardless of HIV RNA or zip code availability). The NA-ACCORD has approval from the Johns Hopkins School of Medicine institutional review board (IRB), and each participating cohort from their respective IRBs.

Clinical Outcome and Covariates

The primary outcome was HIV RNA suppression (<200 copies/mL). The first objective explored the association between parameterizations of SES and viral suppression. Covariates included age, sex, race and ethnicity, and HCV status, all captured at the individual-level by the NA-ACCORD contributing cohorts. The second objective explored the influence of various parameterizations of SES on the relationship between self-categorized race and ethnicity (non-Hispanic Black, non-Hispanic white, non-Hispanic other, and Hispanic) and viral suppression. Models also included age, sex, and HCV status.

HIV RNA measures were dichotomized as "suppressed" *vs.* "unsuppressed" for each calendar year. "Viral suppression" was defined as a single measured viral load of <200 HIV RNA copies/mL within 24 months of ART initiation, and in each year of interest following; in the instances of more than one viral load measurement in the same year, the first measurement was used. Only individuals with HIV RNA measures for each year in question were included in models for that year.

Age was calculated from year of birth. Race and ethnicity were extracted from electronic health records (EHR). We categorized individuals as non-Hispanic Black, non-Hispanic white, non-Hispanic other, and Hispanic. Sex (at birth) was dichotomized as "male" and "female". Hepatitis C virus (HCV) infection status was dichotomized as ever/never from HCV antibody, HCV RNA, or HCV genotype testing.

SES Indicators

We selected three ZIP Code-level SES indicators measured via the US Census. NA-ACCORD participant residential ZIP Code is contributed annually in the NA-ACCORD from the cohorts that have approval to share this information. We included all participants who provided at least one 5-digit ZIP Code in 2010 or later. The ZIP Code obtained closest to the selected reported viral load for each year was used. If two or more ZIP Codes were provided in the same calendar year, the ZIP Code reported for the largest proportion of the calendar year was selected. If a participant provided two conflicting ZIP Codes on the same day, this participant was excluded from the analysis (n=82). A total of 2,253 ZIP Codes were represented in the final analysis.

ZCTA-level SES indicators were obtained from the US Census using the 2010–2018 American Community Survey 5-year estimates.[26,27] For each year, the 5-year estimate leading up to that year were used; however, no 5-year estimates were available for 2010–2011, so the 2012 estimates were used for 2010–2012. The ZCTA geometry to match ZIP Codes to US census data were developed for the 2010 decennial census and were identical across the years of the study.

Median household income was categorized as $0-<$35,000, $35,000-<$55,000, $55,000-<$75,000, and ≥$75,000. Proportion employed out of the total population aged 16 years

or older in the civilian labor force was categorized as 0–<85%, 85–<90%, 90–<95%, and 95–100%. Proportion with a bachelor's degree or higher out of the total population aged 25 years and above was categorized as 0–<50%, 50–<60%, 60–<70%, 70–<80%, 80–<90%, and 90–100%.

Data Analysis

For the first objective, multivariable logistic regression models (and 95% confidence intervals) were used to quantify the annual association between each as well as combinations of SES indicators and viral suppression, adjusting for the covariates mentioned above. For the second objective, multivariable logistic regression models were used to compare the association between racial categorization (specifically among non-Hispanic white, non-Hispanic Black, and Hispanic individuals) and viral suppression, with and without different parameterization of SES in the models. We calculated standard fit statistics (Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Log Pseudolikelihood, and Pseudo R^2) for each model for each year. All analyses were done using R version 4.0 and a p-value<0.05 guided statistical interpretation.

Results

A total of 29,698 individuals (a subset of the over 78,114 PWH in the NA-ACCORD with data collected during 2010–2018) from 2,253 ZIP Codes and 11 NA-ACCORD sites were included in this analysis (Figure 1). The mean age was 44.7 years (Standard Deviation: 11.9 years), with 82.6% (N=24,520) identifying as male (Table 1). Over one-third (35.7%, N=10,606) self-categorized as non-Hispanic white, 27.6% (N=8,199) as non-Hispanic Black, and 14.1% (N=4,176) as Hispanic. The majority (86.5%, N=25,667) were HCV seronegative. The median household income in participant ZIP Codes was $57,788 (inter-quartile range (IQR): $42,880, $76,787). The median proportion with a college education or above was 64.2% (IQR: 51.3%, 77.1%), and the median proportion employed of the civilian labor force was 91.4% (IQR: 88.1%, 93.7%).

We compared our selected participants (N=29,698) with all those observed between 2010 and 2018 (regardless of HIV RNA or zip code availability, N=78,114). The populations were similar by age, sex, and HCV serostatus; however, the selected participants had a larger proportion with "Other" racial categorization (22.6% vs. 6.5%) and a smaller proportion identifying as non-Hispanic white (35.7% *vs.* 40.9%) and non-Hispanic Black (27.6% *vs.* 40.2%).

Reduced viral suppression with lower ZIP Code level SES

There was a consistent dose-response relationship between increasing median household income and odds of viral suppression (Table 2). Those living in ZIP Codes with median household income <$35,000 per year had a 0.53 – 0.71-fold decreased odds of viral suppression from 2010 through 2018 compared with the reference group of ≥$75,000 per year. Among those living in areas with lower proportions of individuals aged ≥25-years-old with a Bachelor's degree or above, those living in ZIP Codes with <50% of adults with a college degree or more had a 0.50 to 0.78-fold decreased odds of viral suppression compared

with those living in ZIP Codes with 90–100% of adults with a college degree or higher. Employment showed a similar general trend, with those living in ZIP Codes with <85% of adults in the labor force being employed having a 0.48–0.71-fold decreased odds of viral suppression compared with those living in ZIP Codes with 95–100% employment.

Reduced viral suppression among non-Hispanic Black and Hispanic vs. non-Hispanic White individuals

In the models exploring associations between racial categorization and viral suppression, we found a marked racial disparity in the odds of HIV RNA suppression, with non-Hispanic Black PWH having a 41–49% decreased odds of viral suppression compared with non-Hispanic white (Table 3) that was consistently statistically significant across calendar years. In most years, Hispanic PWH demonstrated an ~10% decreased odds of viral suppression compared with non-Hispanic white PWH.

SES attenuated the racial disparities in viral suppression and was independently significantly associated with viral suppression

The SES indicators were added sequentially into the racial and ethnic categorization and viral suppression model, first as single indicators, then each combination of two, and then all three (Table 3). Notably, the magnitude of these racial disparities in odds of viral suppression among non-Hispanic Black compared with non-Hispanic white was attenuated but still significant when single indicators of SES were included in the model. The magnitudes appeared to be marginally attenuated in certain years when more than one SES indicator was included in the model at the same time. Whether added as a single SES covariate or in combination, median household income (comparing <$35,000 vs. ≥$75,000 annually) remained independently significantly associated with odds of viral suppression. Standard fit statistics also suggested that adding median household income as a single indicator would be the most parsimonious model in this instance (Table 4).

Discussion

ZIP Code-level indicators of SES (education, income and employment) as surrogates for individual-level SES were associated with viral suppression among PWH and attenuated the racial categorization-based inequities in viral suppression in nearly 30,000 participants who provided 5-digit US residential ZIP Codes in the NA-ACCORD. Consistent with previous studies of individual-level SES and its relationships to viral suppression, we observed a dose-response association of increasing Zip Code-level SES with increasing proportion virally suppressed. Additionally, lower odds of viral suppression among non-Hispanic Black individuals compared to non-Hispanic white individuals was still significant but attenuated when including one or more indicators of SES in the model. Persistent differences in viral suppression by race indicates that other important core determinants remain crucial to address, including non-SES factors influenced by structural racism, history of and ongoing oppression of some race-based categories of individuals, and differential access to care.[11,12] Our study contributes to the growing body of literature demonstrating the independence of SES in race-based health disparities and contributes to the ongoing dialogue of conceptual and methodologic frameworks for measuring and addressing race-

based health disparities.[28,29] This disaggregation of influences of SES vs. race and ethnicity is a critical step to achieving the National HIV/AIDS Strategy (NHAS) 2022–2025 goal of reducing HIV-related health disparities and health inequities.[30]

The inclusion of SES in any studies of health disparities should be driven by an evidence-derived conceptual framework.[31,32] In this study, we included SES when quantifying race-based disparities in viral suppression as a demonstration of a proposed approach to utilizing Zip Code-level surrogates for individual-level SES. First, we confirmed that the use of Zip Code-level SES resulted in similar outcomes to other studies of individual-level SES and viral suppression, suggesting that Zip Code-level SES may be a reasonable surrogate for individual-level SES when individual-level SES measurements are not available. Second, we proposed inserting each Zip Code-level SES indicator into the analytic model individually, in combinations of two, then using all three as a strategy to select Zip Code-level SES indicators when there is no clear choice from prior research. This demonstrated that changes in the magnitude of association with the inclusion of SES as well as standard model fit statistics can be used to drive optimal model selection. We recognize that the three measures of SES used in this analysis comprise only a small proportion of the array of indicators that contribute to an individual's socioeconomic status. Future efforts will include incorporating other ZCTA-level social indicators in the NA-ACCORD for investigators to consider for use in their analyses.

The NA-ACCORD pools and harmonizes data gathered in community-based and academic clinics through a variety of data collection mechanisms including electronic health records (EHR).[23] Historically, health systems have not systematically collected indicators of individual-level SES.[33] Studies have recommended that SES information be incorporated into EHR systems; efforts to collect this information in NA-ACCORD contributing cohorts are ongoing, but in some instances would necessitate considerable extra resources.[34] We intend in the future to widen attempts to collect individual-level SES data in the NA-ACCORD, and directly compare area-level SES indicators as possible proxies for individual-level SES. In the interim, using area-level SES data in EHR-based studies is a short-term solution as the individual-level SES data becomes more complete in the EHR over time. The idea of applying area-level SES information as surrogates for individual-level SES indicators in studies using EHR data is not new. Many of these studies retain the area-level characteristic as an area-level measure of SES, and apply it as a secondary-level indicator in a hierarchical (multi-level) model.[35,36] Area-level SES data is certainly important in its own right. Area-level SES factors are important independent determinants of health outcomes even after individual-level SES have been controlled for, and studies quantifying area-level effects pave the way for important community and clinic-level interventions that could serve entire catchment areas.[37,38] However, some studies have specifically inserted the area-level SES measures as an individual-level covariate in HIV-related studies using EHR data. For example, Marcus and colleagues used area-level SES in a study examining risks of invasive pneumococcal disease (IPD) among PWH, and showed a decreased risk of IPD among individuals in higher SES quintiles.[39]

The demographic breakdown of our study population was 17% female individuals, 28% non-Hispanic Black individuals, and 14% Hispanic individuals. These numbers are

comparable to but less than the CDC's 2019 surveillance data of PWH, which included 23% female individuals, 42% non-Hispanic Black individuals, and 24% Hispanic individuals.[40] In terms of socioeconomic breakdown, the ZCTAs of our study population had a median household income of $57,788, a rate of 64.2% with a Bachelor's degree or higher, and a 91.4% employment rate. In comparison, the US Census reported in 2018 a national median household income of $63,179, a Bachelor's or higher education rate of 35%, and an employment rate of 62.8%.[41] The NA-ACCORD strives to be reflective of the demographic distributions of PWH across the United States. Our study sub-population slightly under-represents the known sex and self-categorized racial and ethnic distribution and somewhat over-represents the socioeconomic distribution of PWH in the U.S.; it is possible that our results are a conservative estimate of the true inequities, even after accounting for SES.

Our analysis has several important limitations. First, not every cohort participating in the NA-ACCORD has permission to share 5-digit residential ZIP Codes for their patients. Unfortunately, 3-digit ZIP Codes, which can be shared by some participating cohorts, are too geographically large to be mapped accurately to ZCTAs. In addition, in this analysis, we did not incorporate the Canadian NA-ACCORD cohorts. Second, the area of measurement from 5-digit ZIP Codes and ZCTAs may be considered too large to accurately correlate with an individual SES, particularly in rural areas.[42] In our predominantly urban-dwelling population, 5-digit Zip Code-level measurement of SES balanced the various restrictions on sharing identifiable information (*i.e.*, address) across contributing clinical cohorts, correlated with unsuppressed viral load, and attenuated racial disparities (as expected). Third, the NA-ACCORD enrollment criteria require at least two healthcare visits within 12 months, in other words only included individuals that are successfully linked and retained in care.[40] Thus this analysis does not include persons who are disengaged in care, a many of whom experience negative socioeconomic factors.[43] Fourth, our study population had a higher proportion of individuals reporting "Other" race and a lower proportion of individuals reporting "non-Hispanic Black" than all NA-ACCORD participants observed in the same period. It will be important to explore options for sites to provide geographic information (for which plans are underway) in order to fully characterize the use of area-level SES measures as surrogates for individual-level SES in the NA-ACCORD. Finally, we do not have HIV RNA measurements from individuals at times when they were disengaged from care. However, we did include any HIV RNA measurements that were taken in or following 2010, thus re-capturing any unsuppressed viral load information at the time of re-engagement when it occurred within our observation window.

Our analysis underscores the importance of understanding the influence of SES on HIV outcomes, and consideration of SES in efforts to address HIV inequities. We show the value of including indicator(s) of SES as covariates in models to describe and quantify exposure-outcome relationships within the NA-ACCORD. While other studies have concluded that area-level SES are relatively poor surrogates for individual-level indicators, we demonstrate that within the NA-ACCORD, median household income, proportion with college education and above, and proportion employed out of the civilian labor force are all associated with viral suppression, a key HIV-related health outcome. This work demonstrates that SES impacts HIV health outcomes. For the U.S. to truly end the HIV epidemic will likely require strategies and policies that address SES. For NA-ACCORD investigators, we offer

a concrete approach by which the appropriate indicator(s) of SES should be selected when warranted by the research question. We intend to continue studying how these and other SES indicators can be appropriately adapted longitudinally. We demonstrate that specific area-level SES measurements are reasonable surrogates for individual-level SES measurements and encourage investigators to consider incorporating these SES indicators in their analyses in order to improve our understanding of key health-outcomes among people living with HIV in the United States.

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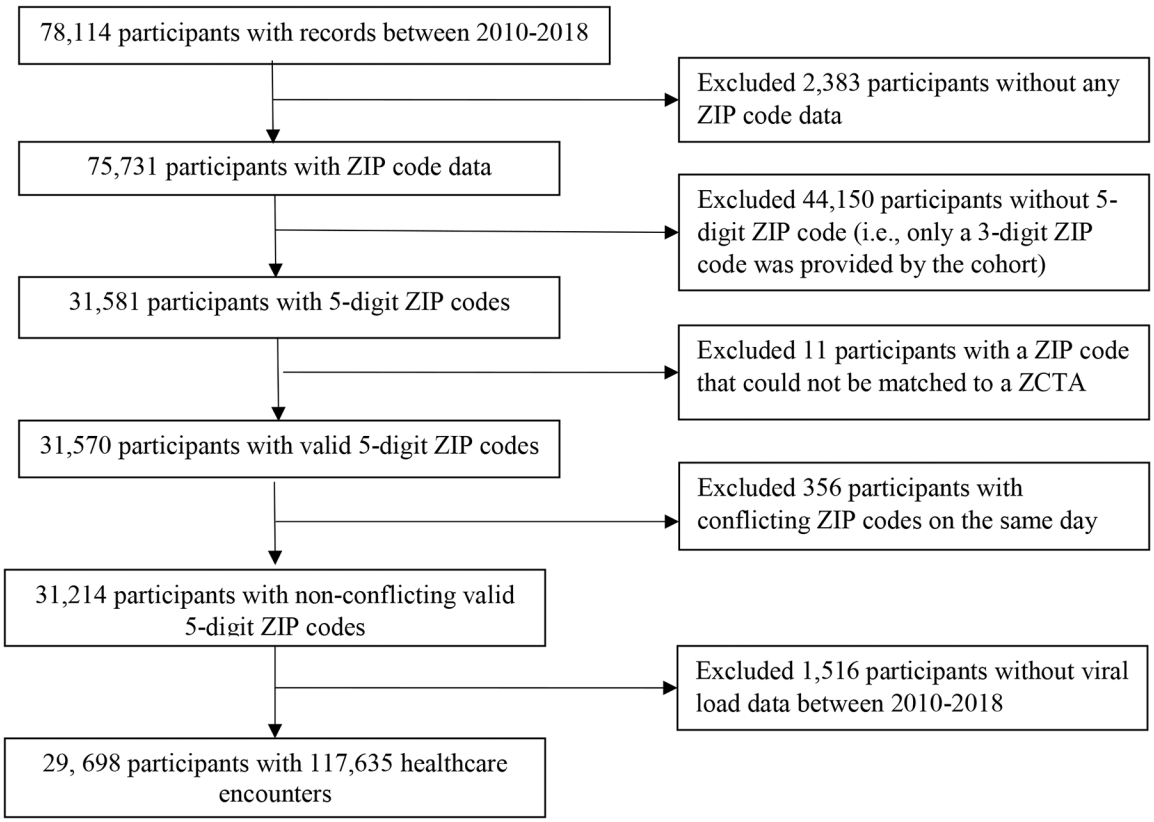

Figure 1:

Selection of the study population from the NA-ACCORD (source population) among those observed in contributing cohorts between 2010 and 2018

Table 1:

Profile of selected participants (study population) and all those observed in the NA-ACCORD during the study period (2010–2018)

Characteristics	Study population	All observed
Individual level	**N=29,698**	**N=78,114**
Age, mean (SD)	44.7 (11.9)	48.9 (12.9)
Sex, n (%)		
Female	5,176 (17.4)	9,384 (12.0)
Male	24,520 (82.6)	68,727 (88.0)
Race & ethnicity, n (%)		
Non-Hispanic white	10,606 (35.7)	26,031 (40.9)
Non-Hispanic black	8,199 (27.6)	25,628 (40.2)
Hispanic	4,176 (14.1)	7,908 (12.4)
Other	6,717 (22.6)	4,116 (6.5)
HCV prevalence, n (%)		
HCV negative	25,667 (86.5)	63,023 (81.7)
HCV positive	4,016 (13.5)	14,155 (18.3)
ZCTA level	**N=2,253**	
Median household income ($), median (IQR)	57,788 (42,880, 76,787)	
Education rate (%), median (IQR)	64.2 (51.3, 77.1)	
Employment rate (%), median (IQR)	91.4 (88.1, 93.7)	

*Education calculated as proportion with college education or above; Employment calculated as proportion employed of the civilian labor force.

Table 2:

Adjusted Associations of Viral Suppression Status with Each Indicator of Socioeconomic Status by Year, NA-ACCORD, 2010–2018 (N=29,698 total individuals observed during the study period)

	2010 (n=8,854)	2011 (n=9,878)	2012 (n=11,091)	2013 (n=11,987)	2014 (n=12,356)	2015 (n=12,919)	2016 (n=16,697)	2017 (n=17,029)	2018 (n=16,824)
Median Household Income									
$75,000 +	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
$55,000 - <$75,000	0.92 (0.78 – 1.08)	0.91 (0.78 – 1.06)	0.96 (0.83 – 1.11)	0.88 (0.72 – 1.07)	0.81 * (0.69 – 0.95)	0.70 * (0.59 – 0.82)	0.85 * (0.73 – 0.99)	0.66 * (0.56 – 0.77)	0.78 * (0.67 – 0.90)
$35,000 - <$55,000	0.79 * (0.67 – 0.92)	0.88 * (0.76 – 1.01)	0.86 * (0.74 – 0.99)	0.80 * (0.66 – 0.95)	0.79 * (0.68 – 0.93)	0.67 * (0.57 – 0.78)	0.79 * (0.68 – 0.93)	0.67 * (0.57 – 0.79)	0.69 * (0.59 – 0.80)
<$35,000	0.59 * (0.50 – 0.70)	0.67 * (0.57 – 0.80)	0.71 * (0.59 – 0.84)	0.69 * (0.57 – 0.85)	0.63 * (0.53 – 0.76)	0.58 * (0.49 – 0.69)	0.68 * (0.58 – 0.79)	0.57 * (0.48 – 0.67)	0.53 * (0.45 – 0.63)
Education (proportion with college education and above)									
90% - 100%	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
80% - <90%	1.16 (0.75 – 1.78)	0.99 (0.71 – 1.39)	0.94 (0.75 – 1.16)	0.82 (0.51 – 1.32)	0.83 (0.58 – 1.18)	0.70 * (0.50 – 0.99)	0.86 (0.56 – 1.31)	0.66 * (0.43 – 1.01)	0.82 (0.58 – 1.16)
70% - <80%	1.12 (0.74 – 1.70)	1.05 (0.76 – 1.44)	1.07 (0.85 – 1.34)	0.83 (0.53 – 1.32)	0.94 (0.68 – 1.31)	0.62 * (0.45 – 0.83)	0.90 (0.61 – 1.34)	0.73 (0.49 – 1.08)	0.84 (0.62 – 1.14)
60% - <70%	0.99 (0.66 – 1.49)	0.93 (0.68 – 1.27)	0.84 (0.68 – 1.04)	0.81 (0.51 – 1.28)	0.76 (0.54 – 1.08)	0.64 * (0.47 – 0.86)	0.80 (0.54 – 1.19)	0.64 * (0.44 – 0.94)	0.77 * (0.58 – 1.03)
50% - <60%	1.01 (0.67 – 1.51)	0.94 (0.69 – 1.28)	0.85 (0.69 – 1.06)	0.67 * (0.43 – 1.04)	0.83 (0.60 – 1.15)	0.57 * (0.43 – 0.77)	0.70 * (0.47 – 1.03)	0.52 * (0.36 – 0.75)	0.63 * (0.47 – 0.84)
<50%	0.77 (0.51 – 1.16)	0.82 (0.61 – 1.12)	0.78 * (0.63 – 0.96)	0.71 (0.45 – 1.11)	0.77 (0.55 – 1.06)	0.50 * (0.37 – 0.67)	0.67 * (0.45 – 0.98)	0.50 * (0.34 – 0.72)	0.54 * (0.41 – 0.72)
Employment (proportion employed of total civilian labor force)									
95% - 100%	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
90% - <95%	0.90 (0.64 – 1.28)	0.76 (0.51 – 1.14)	1.03 (0.69 – 1.56)	0.73 (0.50 – 1.09)	1.01 (0.77 – 1.31)	0.82 * (0.64 – 1.04)	0.93 (0.76 – 1.14)	0.75 * (0.62 – 0.90)	0.72 * (0.63 – 0.82)
85% - <90%	0.88 (0.62 – 1.25)	0.75 (0.50 – 1.13)	0.96 (0.63 – 1.45)	0.72 * (0.49 – 1.06)	0.96 (0.74 – 1.24)	0.68 * (0.53 – 0.87)	0.81 * (0.66 – 1.00)	0.68 * (0.55 – 0.84)	0.54 * (0.46 – 0.64)
<85%	0.66 *	0.59 *	0.83	0.64 *	0.82	0.62 *	0.71 *	0.60 *	0.48 *

	2010 (n=8,854)	2011 (n=9,878)	2012 (n=11,091)	2013 (n=11,987)	2014 (n=12,356)	2015 (n=12,919)	2016 (n=16,697)	2017 (n=17,029)	2018 (n=16,824)
	(0.46 – 0.95)	(0.39 – 0.88)	(0.54 – 1.28)	(0.44 – 0.95)	(0.63 – 1.06)	(0.48 – 0.81)	(0.57 – 0.88)	(0.48 – 0.75)	(0.38 – 0.60)

* Indicates significance at $p<0.05$

All models are adjusted for sex, race & ethnicity, HCV, and age, and ZCTA as a cluster variable.

Table 3:

Adjusted Associations of Race & Ethnicity with Viral Suppression, With and Without Zip Code-Level Socioeconomic Status Indicators in the Model, NA-ACCORD, 2010–2018 (N=29,698 total individuals observed during the study period)

		2010 (N=8,854)	2011 (N=9,878)	2012 (N=11,091)	2013 (N=11,987)	2014 (N=12,356)	2015 (N=12,919)	2016 (N=16,697)	2017 (N=17,029)	2018 (N=16,824)
No SES indicator	Non-Hispanic white	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Non-Hispanic black	0.59* (0.52 – 0.67)	0.58* (0.51 – 0.65)	0.57* (0.51 – 0.64)	0.54* (0.47 – 0.61)	0.55* (0.48 – 0.62)	0.51* (0.44 – 0.60)	0.52* (0.45 – 0.60)	0.55* (0.48 – 0.62)	0.53* (0.46 – 0.60)
	Hispanic	1.03 (0.87 – 1.22)	0.94 (0.79 – 1.12)	0.90 (0.76 – 1.06)	0.89 (0.75 – 1.06)	0.91 (0.76 – 1.09)	0.86* (0.72 – 1.04)	0.86* (0.74 – 0.99)	0.87* (0.75 – 1.01)	0.92 (0.78 – 1.08)
One SES indicator	**Income**									
	Non-Hispanic white	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Non-Hispanic black	0.66* (0.58 – 0.75)	0.63* (0.55 – 0.71)	0.61* (0.55 – 0.69)	0.58* (0.51 – 0.66)	0.61* (0.53 – 0.69)	0.58* (0.49 – 0.67)	0.56* (0.49 – 0.64)	0.61* (0.54 – 0.69)	0.60* (0.53 – 0.69)
	Hispanic	1.02 (0.86 – 1.20)	0.94 (0.79 – 1.11)	0.89 (0.75 – 1.05)	0.88 (0.74 – 1.05)	0.90 (0.75 – 1.08)	0.86 (0.72 – 1.03)	0.86* (0.74 – 0.99)	0.88* (0.75 – 1.02)	0.93 (0.79 – 1.09)
	Income (<35K vs >75K)	1.70* (1.43 – 2.01)	1.48* (1.25 – 1.76)	1.42* (1.19 – 1.69)	1.44* (1.18 – 1.76)	1.58* (1.31 – 1.90)	1.72* (1.45 – 2.03)	1.48* (1.27 – 1.72)	1.77* (1.50 – 2.09)	1.89* (1.59 – 2.24)
	Education									
	Non-Hispanic white	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Non-Hispanic black	0.64* (0.56 – 0.72)	0.61* (0.54 – 0.68)	0.60* (0.53 – 0.68)	0.57* (0.51 – 0.65)	0.57* (0.50 – 0.65)	0.56* (0.49 – 0.65)	0.56* (0.49 – 0.64)	0.61* (0.54 – 0.69)	0.59* (0.52 – 0.67)
	Hispanic	1.04 (0.88 – 1.23)	0.95 (0.80 – 1.13)	0.91 (0.77 – 1.08)	0.91 (0.76 – 1.09)	0.92 (0.77 – 1.10)	0.89 (0.74 – 1.07)	0.89 (0.77 – 1.02)	0.92 (0.79 – 1.07)	0.97 (0.83 – 1.14)
	Education (90–100% vs. <50%)	1.30 (0.86 – 1.95)	1.21 (0.89 – 1.65)	1.28* (1.04 – 1.59)	1.41 (0.90 – 2.21)	1.31 (0.94 – 1.80)	2.00* (1.49 – 2.68)	1.50* (1.02 – 2.20)	2.02* (1.39 – 2.93)	1.84* (1.39 – 2.45)
	Employment									
	Non-Hispanic white	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Non-Hispanic black	0.63* (0.56 – 0.72)	0.61* (0.54 – 0.70)	0.60* (0.53 – 0.68)	0.55* (0.49 – 0.63)	0.58* (0.51 – 0.66)	0.56* (0.48 – 0.65)	0.56* (0.49 – 0.64)	0.60* (0.53 – 0.68)	0.62* (0.54 – 0.71)
	Hispanic	1.05	0.96	0.91	0.90	0.92	0.89	0.88	0.91	0.96

		2010 (N=8,854)	2011 (N=9,878)	2012 (N=11,091)	2013 (N=11,987)	2014 (N=12,356)	2015 (N=12,919)	2016 (N=16,697)	2017 (N=17,029)	2018 (N=16,824)
		(0.88 – 1.24)	(0.81 – 1.14)	(0.76 – 1.08)	(0.76 – 1.07)	(0.76 – 1.10)	(0.74 – 1.07)	(0.76 – 1.01)	(0.78 – 1.06)	(0.82 – 1.14)
	Employment (95–100% vs. <85%)	1.52 * (1.06 – 2.18)	1.71 * (1.14 – 2.56)	1.20 0.78 – 1.84)	1.56 * (1.05 – 2.30)	1.23 (0.94 – 1.60)	1.61 * (1.24 – 2.08)	1.41 * (1.14 – 1.75)	1.66 * (1.33 – 2.09)	2.10 * 1.68 – 2.63)
Two SES indicators	**Income & Education**									
	Non-Hispanic white	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Non-Hispanic black	0.66 * (0.59 – 0.75)	0.63 * (0.55 – 0.71)	0.62 * (0.55 – 0.70)	0.59 * (0.52 – 0.67)	0.60 * (0.52 – 0.68)	0.58 * (0.50 – 0.68)	0.58 * (0.50 – 0.66)	0.63 * (0.55 – 0.71)	0.61 * (0.54 – 0.70)
	Hispanic	1.02 (0.86 – 1.20)	0.94 (0.79 – 1.11)	0.90 (0.76 – 1.06)	0.89 (0.75 – 1.07)	0.89 (0.75 – 1.07)	0.87 (0.73 – 1.05)	0.87 (0.76 – 1.00)	0.90 (0.77 – 1.05)	0.95 (0.81 – 1.12)
	Income (<35K vs >75K)	1.62 * (1.33 – 1.97)	1.47 * 1.18 – 1.83)	1.35 * (1.10 – 1.67)	1.39 * (1.08 – 1.78)	1.70 * (1.35 – 2.13)	1.60 * (1.30 – 1.97)	1.32 * (1.11 – 1.57)	1.55 * (1.27 – 1.89)	1.60 * (1.27 – 2.00)
	Education (90–100% vs. <50%)	0.97 (0.65 – 1.43)	0.99 (0.73 – 1.36)	1.08 (0.84 – 1.39)	1.16 (0.72 – 1.86)	0.92 (0.65 – 1.29)	1.37 (0.99 – 1.91)	1.26 (0.84 – 1.88)	1.45 (0.98 – 2.16)	1.38 (0.99 – 1.91)
	Income & Employment									
	Non-Hispanic white	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Non-Hispanic black	0.66 * (0.59 – 0.75)	0.63 * (0.56 – 0.72)	0.62 * (0.55 – 0.70)	0.58 * (0.51 – 0.66)	0.60 * (0.53 – 0.69)	0.59 * (0.50 – 0.68)	0.57 * (0.50 – 0.65)	0.62 * (0.55 – 0.70)	0.63 * (0.55 – 0.72)
	Hispanic	1.02 (0.86 – 1.20)	0.95 (0.80 – 1.12)	0.89 (0.75 – 1.05)	0.88 (0.74 – 1.05)	0.90 (0.75 – 1.08)	0.88 (0.73 – 1.05)	0.87 (0.75 – 1.00)	0.89 (0.76 – 1.04)	0.96 (0.81 – 1.13)
	Income (<35K vs >75K)	1.66 * (1.38 – 2.01)	1.38 * (1.10 – 1.74)	1.39 * (1.13 – 1.70)	1.48 * (1.16 – 1.89)	1.60 * (1.26 – 2.04)	1.55 * (1.26 – 1.92)	1.36 * (1.15 – 1.62)	1.61 * (1.30 – 1.99)	1.38 * (1.12 – 1.70)
	Employment (95–100% vs. <85%)	1.09 (0.75 – 1.59)	1.40 (0.91 – 2.15)	0.95 (0.62 – 1.47)	1.20 (0.79 – 1.83)	0.92 (0.67 – 1.25)	1.27 (0.95 – 1.70)	1.15 (0.91 – 1.45)	1.21 (0.92 – 1.59)	1.71 * (1.34 – 2.19)
	Education & Employment									
	Non-Hispanic white	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Non-Hispanic black	0.64 * (0.57 – 0.73)	0.62 * (0.54 – 0.70)	0.61 * (0.54 – 0.69)	0.57 * (0.51 – 0.65)	0.58 * (0.51 – 0.66)	0.58 * (0.50 – 0.67)	0.57 * (0.50 – 0.65)	0.62 * (0.54 – 0.70)	0.62 * (0.54 – 0.71)
	Hispanic	1.05 (0.89 – 1.24)	0.96 (0.81 – 1.14)	0.91 (0.77 – 1.09)	0.91 (0.76 – 1.09)	0.92 (0.77 – 1.11)	0.90 (0.74 – 1.08)	0.89 (0.77 – 1.02)	0.93 (0.80 – 1.08)	0.97 (0.83 – 1.15)

		2010 (N=8,854)	2011 (N=9,878)	2012 (N=11,091)	2013 (N=11,987)	2014 (N=12,356)	2015 (N=12,919)	2016 (N=16,697)	2017 (N=17,029)	2018 (N=16,824)
	Education (90–100% vs. <50%)	1.27 (0.82 – 1.96)	1.09 (0.77 – 1.53)	1.21 (0.95 – 1.55)	1.45 (0.89 – 2.35)	1.17 (0.81 – 1.69)	1.70* (1.20 – 2.40)	1.42 (0.95 – 2.11)	1.64* (1.10 – 2.45)	1.25 (0.92 – 1.70)
	Employment (95–100% vs. <85%)	1.21 (0.82 – 1.78)	1.59* (1.02 – 2.46)	1.06 (0.68 – 1.63)	1.30 (0.86 – 1.97)	1.15 (0.84 – 1.59)	1.28 (0.95 – 1.74)	1.15 (0.92 – 1.45)	1.35* (1.03 – 1.76)	1.86* (1.41 – 2.45)
	Income + Education + Employment									
	Non-Hispanic white	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Three SES Indicators	Non-Hispanic black	0.66* (0.58 – 0.75)	0.63* (0.56 – 0.72)	0.62* (0.55 – 0.70)	0.59* (0.52 – 0.67)	0.60* (0.52 – 0.68)	0.59* (0.50 – 0.68)	0.58* (0.50 – 0.66)	0.63* (0.55 – 0.71)	0.62* (0.55 – 0.71)
	Hispanic	1.02 (0.86 – 1.20)	0.95 (0.80 – 1.12)	0.90 (0.75 – 1.06)	0.89 (0.75 – 1.06)	0.89 (0.75 – 1.07)	0.88 (0.73 – 1.06)	0.87 (0.76 – 1.00)	0.90 (0.78 – 1.06)	0.96 (0.82 – 1.14)
	Income (<35K vs >75K)	1.61* (1.31 – 1.96)	1.40* (1.10 – 1.77)	1.35* (1.09 – 1.67)	1.42* (1.09 – 1.84)	1.66* (1.30 – 2.12)	1.56* (1.23 – 1.98)	1.28* (1.07 – 1.54)	1.52* (1.23 – 1.88)	1.34* (1.07 – 1.69)
	Education (90–100% vs. <50%)	1.01 (0.67 – 1.52)	0.96 (0.69 – 1.33)	1.08 (0.82 – 1.42)	1.26 (0.77 – 2.05)	0.91 (0.63 – 1.32)	1.20 (0.82 – 1.76)	1.27 (0.84 – 1.90)	1.32 (0.67 – 1.99)	1.11 (0.80 – 1.54)
	Employment (95–100% vs. <85%)	1.01 (0.69 – 1.49)	1.39 (0.89 – 2.17)	0.92 (0.60 – 1.42)	1.13 (0.74 – 1.73)	0.99 (0.71 – 1.37)	1.23 (0.87 – 1.74)	1.04 (0.81 – 1.33)	1.14 (0.85 – 1.54)	1.66* (1.27 – 2.17)

*Indicates significance at p<0.05

Income compared as median household income of <$35,000 vs. >$75,000 per year; Employment compared as proportion with college education or above of <85% vs. 95–100%; Education compared as proportion employed of the civilian labor force of <50% vs. 90–100%.

All models were adjusted for sex, race & ethnicity, HCV, and age, and ZCTA as a cluster variable. Each model was then adjusted for the indicated Zip Code-level SES variable.

Table 4:

Comparison of Fit Statistics for each Adjusted Associations of Race & Ethnicity with Viral Suppression, With and Without Zip Code-Level Socioeconomic Status Indicators in the Model, NA-ACCORD, 2010

		Akaike Information Criterion (AIC)	Bayesian Information Criterion (BIC)	Log Pseudolikelihood	Pseudo R^2
No SES Indicator		10125.92	10175.54	−5055.962	0.0579
One SES Indicator	Income	10080.11	10151.00	−5030.056	0.0627
	Education	10102.32	10187.38	−5039.161	0.0610
	Employment	10109.65	10180.54	−5044.825	0.0600
Two SES Indicators	Income & Education	10081.42	10187.75	−5025.709	0.0636
	Income & Employment	10082.11	10174.26	−5028.057	0.0631
	Education & Employment	10101.80	10208.13	−5035.900	0.0617
Three SES Indicators	Income, Education & Employment	10083.99	10211.58	−5023.994	0.0639