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Measures of SES for Electronic Health Record-based Research

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Abstract

Introduction—Although infrequently recorded in electronic health records (EHR), measures of SES are essential to describe health inequalities and account for confounding in epidemiologic research. Medical Assistance (i.e., Medicaid) is often used as a surrogate for SES, but correspondence between conventional SES and Medical Assistance has been insufficiently studied.

Methods—Geisinger Clinic EHR data from 2001 to 2014 and a 2014 questionnaire were used to create six SES measures: EHR-derived Medical Assistance and proportion of time under observation on Medical Assistance; educational attainment, income, and marital status; and area-level poverty. Analyzed in 2016–2017, associations of SES measures with obesity, hypertension, type 2 diabetes, chronic rhinosinusitus, fatigue, and migraine headache were assessed using weighted age- and sex-adjusted logistic regression.

Results—Among 5,550 participants (interquartile range, 39.6–57.5 years, 65.9% female), 83% never used Medical Assistance. All SES measures were correlated (Spearman's $p \leq 0.4$). MA was significantly associated with all six health outcomes in adjusted models. For example, the OR for prevalent type 2 diabetes associated with Medical Assistance was 1.7 (95% CI=1.3, 2.2); the OR for high school versus college graduates was 1.7 (95% CI=1.2, 2.5). Medical Assistance was an

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imperfect proxy for SES: associations between conventional SES measures and health were attenuated <20% after adjustment for Medical Assistance.

Conclusions—Because systematically collected SES measures are rarely available in EHRs and are unlikely to appear soon, researchers can use EHR-based Medical Assistance to describe inequalities. As SES has many domains, researchers who use Medical Assistance to evaluate the association of SES with health should expect substantial unmeasured confounding.

INTRODUCTION

SES is associated with virtually every disease endpoint as well as many risk factors, such health-related behaviors and healthcare utilization and treatment.[1–3] In epidemiologic research, accurate measures of SES are essential to describe and monitor health inequalities and to account for confounding when evaluating risk factors.[2,4] Recently, a confluence of forces—technological advances, financial incentives to healthcare providers, and tightening research funding—has led to increased use of electronic health records (EHRs) for epidemiologic research.[5] Because healthcare systems originally adopted EHRs for administrative purposes and to improve patient care, they do not employ systematic SES data collection.[6,7]

On the other hand, needs-based insurance status, because of its direct link to patient billing, is robustly and accurately recorded.[8] As of 2014, Medicaid (in Pennsylvania, referred to as Medical Assistance [MA]) enrollees totaled more than 66 million Americans.[9] Because MA eligibility is based on state and federal guidelines regarding poverty,[10] researchers in the U.S. have considered MA an indicator of low SES (Appendix Table 1 describes common SES indicators).[11–16] In Europe, Canada, and other countries with universal health care, the application of area-level social deprivation[17,18] as a surrogate for individual SES is common.[19–22] U.S. researchers have also used area-level measures of SES.[23–25] A large literature documents independent associations between several individual and area-level SES measures and health, suggesting that SES is multidimensional.[2,26,27]

SES broadly refers to myriad correlated social and economic factors—education, income, occupation, and household assets or wealth (Appendix Figure 1)—that measure social standing[27,28] and influence standard of living, social interactions, workplace conditions, environmental exposures, access to health care, and health status.[2,3] Because of the pervasive relationship between SES and health, researchers have long understood the importance of controlling for SES in epidemiologic studies.[4] Traditional measures of SES have had little perceived relevance to healthcare provision in the U.S., and thus generally are not recorded in EHR data.

Infrequent documentation of conventional SES measures and possible residual confounding by SES has emerged as a limitation of EHR-based research.[29,30] In response, researchers have used MA as a surrogate, but correspondence between conventional SES measures and MA has been insufficiently studied.[31–33] Such an understanding is essential to guide the use of MA in EHR-based research.

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This study uses a novel dataset that included EHR-derived MA and self-reported measures of SES (i.e., income, educational attainment, and marital status) from Geisinger Clinic primary care patients in Pennsylvania. It aims to describe the relationship between MA and conventional SES and to determine the extent to which they can serve as proxies for one another.

METHODS

Study Population

The study population was drawn from the Chronic Rhinosinusitis Integrative Studies Program (CRISP) at the Geisinger Clinic.[34] Geisinger Clinic, an integrated health system, provides comprehensive care from 48 outpatient clinics and eight hospitals to more than 500,000 primary care patients in Pennsylvania, who are representative of the general population of the region.[13] As an open healthcare system, Geisinger serves patients with a variety of health plans, including MA. The study population included participants aged 18 to <65 years who lived in Pennsylvania.

The CRISP questionnaire was mailed to a random sample, stratified by race/ethnicity and probability of chronic rhinosinusitis diagnosis, of Geisinger primary care patients in April 2014.[34] The dataset consisted of these questionnaire responses and patient EHRs from January 1, 2001 to December 31, 2014. The analysis was cross-sectional because self-reported measures from the CRISP questionnaire were collected only once. The study was reviewed and approved by the Geisinger Health System IRB.

Measures

Within the EHR, each outpatient encounter had an associated payor (e.g., MA, Blue Cross Blue Shield). An algorithm was implemented to create a binary indicator that designated participants as users versus not users of MA, beginning with each participant's first healthcare encounter (as early as 2001) until return of the mailed survey in 2014: use at three or more encounters if patient had greater than three encounters; use at two or more encounters if patient had three encounters; use at one or more encounter if patient had two encounters; or use at one encounter if patient had one encounter. The proportion of time spent on MA (proportion MA) was calculated using payor type at each outpatient encounter (code available in Appendix). Proportion MA was skewed to the right, so categories were used in regression analyses (i.e., 0, 0.1 to 33.3%, 33.4% to 66.7%, 66.8 to 99.9%, 100%).

The study included three self-reported SES measures. The questionnaire asked about educational attainment: *What is the highest grade or highest degree you have completed?* Response options: *no schooling*, *a few years*, *finished grammar school*, *some high school*, *high school graduate*, *general equivalency diploma (GED)*, *some college*, *associate degree*, *bachelor's degree*, *master's degree*, or *doctoral degree*. It also asked participants to report their income: *About how much income did you receive last year?* Response options were: *$0–$9,999*, *$10,000–$24,999*, *$25,000–$49,000*, *$50,000–$74,999*, *$75,000–$99,999*, *$100,000–$149,999*, or *≥$150,000*. Although not a direct measure of SES, marital status likely correlates with financial insecurity and financial vulnerability, particularly in older

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women.[35,36] Therefore, participants' marital status (married, separated, divorced, widowed, never married, living with partner) was ascertained from responses to the question: *what is your current marital status?*

Based on previously reported socioeconomic disparities, the study included six health outcomes a priori. BMI was calculated using height and weight in the EHR for the visit closest to the date of questionnaire return and categorized BMI as obese (≥30 kg/m^2) or not (<30 kg/m^2). Hypertension was defined as two or more abnormal blood pressure readings (≥140 mmHg systolic/90 mmHg diastolic) or two or more diagnoses for hypertension (ICD-9 code 401.0–401.9) from encounters, problem list, or medications. Similarly, type 2 diabetes (T2DM) was identified with ICD-9 codes 250.x0 or 250.x2. Using questionnaire data, patients with chronic rhinosinusitus symptoms in the past 3 months, migraine headache symptoms in the past year, and fatigue symptoms in the past week were identified using validated questions as previously described.[37]

Pennsylvania neighborhoods were conceptualized as townships, boroughs, and census tracts in cities[38] because they have distinct political and cultural characteristics. American Community Survey data from 2008 to 2012 was used to estimate the percent of families living in poverty within each neighborhood.[38–40]

Statistical Analysis

Analysis was conducted during 2016–2017 with the goal to summarize six measures of SES, evaluate correlations among them, and to compare their associations with six health outcomes. In particular, analysis sought to evaluate the extent to which conventional measures of SES remained associated with six health outcomes, after controlling for MA. Spearman's rank correlation coefficients, sensitivity, specificity, and kappa coefficients were calculated to compare bivariate associations.

Associations among educational attainment (<high school, high school graduate or GED, some college/Associate's degree, college graduate [reference], >college graduate), income ($0–$9,999, $10,000–$24,999, $25,000–$49,999, $50,000–$74,999 [reference], $75,000–$99,999, ≥$100,000), marital status (in aforementioned categories), area-level poverty (quartiles), and MA were evaluated using weighted, age- and sex-adjusted logistic regression models. Associations between MA and conventional SES measures and the six health outcomes were also examined. Base models were adjusted for age and sex. Next, to assess the residual association of MA and all other SES variables with each health outcome two other models were run, the first controlling for MA alone (MA-adjusted) and the second all other SES variables in the same model (fully adjusted). To account for stratified sampling and differential participation in CRISP, weights (inverse probability of inclusion in study, range, 2.8–32.3)[37] and robust SEs were used. Missing self-reported SES was included with a missing indicator.

The patterns of missingness of self-reported SES were explored. Because sicker individuals may have sought out or had expanded eligibility for MA, relationships between Charlson Index[41] and MA were evaluated. In another sensitivity analysis, final models were adjusted for race/ethnicity. Analyses were conducted using Stata, version 13 and R, version 3.3.2.

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RESULTS

The study included 5,550 primarily non-Hispanic white participants (88.8%). Between 2001 and 2014, 17.0% of participants (n=944) used MA (Table 1). These individuals were younger and more likely to be women and racial/ethnic minorities than non-MA participants (Table 1). Non-MA participants had fewer outpatient clinic visits than MA participants (Appendix Figure 2A, Table 1). MA participants had a median of 56 outpatient encounters, but MA was the payor type at less than half of these visits (median 23 visits, interquartile range, 11–14) (Appendix Figure 2B).

Among MA users, an increased proportion of time on MA was associated with less education and lower income (Appendix Figure 3). There were only moderate correlations and relatively low sensitivity, specificity, and kappa coefficients among the self-reported SES variables and MA (Table 2, Appendix Table 2). The strongest correlations were between MA and annual income (p= −0.39) and annual income and educational attainment (p=0.40). Nearly 32.0% of divorced/separated participants had a history of MA, compared with 10.3% of married/cohabitating participants (Table 1).

In age and sex-adjusted models, lower annual income and educational attainment were associated with higher odds of MA (Figure 1). For example, participants with less than a high school diploma had 10.0 times the odds (95% CI=5.9, 17.1) of using MA (versus college graduates). The 3,814 participants who were married/cohabitating had the lowest odds of MA; 751 divorced/separated participants had the highest odds (OR=4.2, 95% CI=3.2–5.6).

Study participants resided in 647 rural and suburban townships, small town boroughs, and urban census tracts (Appendix Figure 4). MA participants lived in neighborhoods with higher proportions of poverty, 38.0% of MA participants versus 22.3% of non-MA participants lived in communities in the highest quartile of poverty (Table 1). Correlations between area-level poverty and MA were not as strong as those with other individual SES measures (Table 2). Compared with the first, the fourth quartile of poverty was associated with increased odds of MA (OR=3.2, 95% CI=2.3, 4.4; Figure 1).

MA was associated with all six health outcomes in base and fully adjusted models (Figure 2A). As proportion MA increased, associations with adverse health outcomes generally strengthened. Conventional SES and MA were similarly associated with health outcomes. For example, in base models, the odds of hypertension were 1.7 (95% CI=1.3, 2.2) for MA versus non-MA participants, 1.7 (95% CI=1.4, 2.3) for high school versus college graduates, 1.7 (95% CI=1.2, 2.5) for those making $25,000–$49,999 compared with $75,000–$99,999 annually, and 1.4 (95% CI=1.1, 1.9) for never married versus married participants. In fully adjusted models, MA accounted for only a portion of the association between conventional SES measures and health, on average associations with health were attenuated by ≅20% with the addition of MA (Figure 2A and 2B). Area-level poverty was generally not associated with health, except for the fourth quartile of poverty and T2DM (Figure 2B). A higher Charlson score was associated with MA (for Charlson score ≥3 vs 0, OR=8.3, 95%

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CI=5.0, 13.6). In a second sensitivity analysis, adjustment for race/ethnicity did not substantively change inference.

Regarding missing data, 0%, 0.9%, 1.3%, and 8.5% were missing MA, marital status, educational attainment, and income, respectively. No significant differences between participants who reported versus did not report educational attainment were identified. Black and Hispanic participants were slightly less likely to report marital status. By contrast, participants who did not report income (versus reporters) were, on average, older (median age 54 years vs 50 years), less likely to use MA (13.7% vs 17.3%), and healthier (lower prevalence of obesity, chronic rhinosinusitus, fatigue, and migraine).

DISCUSSION

Geisinger Clinic EHR data from 2001 to 2014 and a 2014 questionnaire were used to assess the correspondence between conventional measures of SES and Medical Assistance and their associations with obesity, hypertension, type 2 diabetes, chronic rhinosinusitus, fatigue, and migraine headache. The six measures of SES, two from EHR data, three from self-reported questionnaire, and one area-level from Census data evidenced differential associations among themselves and differential associations, as well as patterns of confounding, with six common and important health outcomes. The study found strong associations of MA with conventional SES measures—education, income, marital status, and area-level poverty—and among MA recipients, the proportion of time spent on MA exhibited an SES gradient. Health inequalities by MA mirrored those identified using conventional SES measures. MA was associated with all six health outcomes in models adjusted for conventional SES, but MA accounted for only a portion of the association between conventional SES and health.

The results presented in this paper should be understood in the context of the bidirectional relationships between EHR-based MA, SES, and health. In Pennsylvania, individuals enrolled in the Supplemental Security Income Program because of disability are automatically enrolled for MA. Poor health may result in: job loss or diagnosis of disability and subsequent MA enrollment[32]; increased impetus to access MA; or conversely, reduced capacity to enroll in MA.[42] These circumstances may create associations between MA and health unrelated to SES.[43,44] In addition, a healthcare encounter is required to measure MA. Increased diagnoses of T2DM and high cholesterol in states that expanded MA under the Affordable Care Act may indicate sicker MA populations or additional clinical testing among MA participants.[45] Prior studies have also found MA more strongly associated with chronic health conditions like hypertension than conventional individual-level[46,47] or area-level SES.[48–50]

Ideally, the use of MA to account for confounding by SES should eliminate other SES–health associations. In this analysis, estimated associations between conventional SES and health were reduced by 20%, on average, with the addition of MA suggesting that MA does not account for the majority of confounding by conventional SES. A single indicator of SES, whether MA, income, or education, likely fails to capture the range and multiple domains of SES (Appendix Figure 1). MA was an imperfect proxy for conventional SES. The

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substantial health inequalities by MA that mirror other social inequalities in health suggest, however, that MA may be useful to monitor the magnitude of health disparities.[15,34,47,51–53]

Widowed, divorced, and separated participants, those living in poorer communities, and those with lower incomes and less education tended to enroll in MA at higher rates.[31–33,52,54] Each SES measure likely captures a discrete facet of SES with differing advantages and disadvantages and relevance across the life course.[55] In a prior study, household income, but not insurance type, was significantly associated with obesity and overweight in children; in adolescents, the opposite was true.[56] Among older adults who live on assets, income alone may not fully characterize needs and resources.[57] To measure income, assets, and wealth adequately, however, requires time and considerable effort from both researchers and participants. Another large body of research suggests that area-level SES is associated with individual-level health above and beyond individual-level SES[58]; a finding only observed only for T2DM in the present study.

As with other indicators of SES, what MA measures may differ by group and place. Pregnant women, parents of children younger than 18 years, and children qualify for MA at different income thresholds than other individuals.[10] MA may increasingly measure disability, as Americans age. The meaning of MA will also continue to evolve over time. Between 2013 and 2015, when the Affordable Care Act went into effect and some states expanded MA to individuals with income 138% of the poverty limit, the percent of uninsured nonelderly Americans dropped from 16.6% to 10.5%, nearly a 20% reduction. Low income Americans saw even greater changes.[32,45,59]

Limitations

Despite being one of the first to describe relationships among EHR-based MA, SES, and health, this study has several limitations. Data came from a single state with limited racial/ethnic diversity and may not represent broader trends. Self-reported SES was measured at one time point on 5,500 individuals, this sample size resulted in uncertainty in effect estimates. EHR-based MA appeared related to both individual and community-level SES, but limited results related to area-level factors were presented. Future work should assess associations between MA, community socioeconomic deprivation, features of the built environment, and racial and economic segregation.[26,38,60]

Clinically, EHRs were adopted for administrative purposes and to improve patient care through enhanced access to patient histories, cost savings, and streamlined care coordination.[7] However, with the pivot to financial incentives that reward population-based health management, there has been increased attention to the relevance of SES in clinical care, including a call from the National Academy of Medicine to integrate individual measures of SES into EHRs.[29,61] This suite of proposed standardized measures would improve data collection and comparability across health systems. The capture of self-reported SES measures is challenged by the logistics of integrating data collection into clinical care workflows as well as patient reluctance to report personal information, as evidenced by high nonresponse rates to income-related questions (9% of participants in this study) and elsewhere.[62]

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EHR-based measurement of social determinants of health is in its infancy.[63,64] Some have argued that clinicians do not have the resources, expertise, or time to collect additional data.[65] In light of particularly high burnout rates in primary care disciplines, Shanafelt et al.[66] recommended streamlining and reducing documentation. Until social determinants of health data are effectively collected in EHRs, researchers should focus on using available EHR data to measure variables that are critical to research but not necessarily to clinical care. Analysis of text in clinical notes[67] may hold promise for measuring social determinants of health.

CONCLUSIONS

Given the critical role SES plays for health, researchers require indicators of SES to evaluate health inequalities and control for confounding. No single measure can capture all domains of SES. MA offers some advantages—no additional clinical data collection, longer-term measure, universal availability in EHRs, and standardized meaning across health systems—as well as disadvantages owing to its correlation with disability, compared with conventional SES measures. Because systematically collected SES measures are rarely available in EHRs and are unlikely to appear soon, researchers can use EHR-based MA to describe inequalities. As SES has many domains, researchers who use MA to evaluate the association of SES with health should expect substantial unmeasured confounding.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Drs. Casey and Schwartz had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Author contributions were as follows: Casey, Pollak, and Schwartz helped with the concept and design; acquisition, analysis, or interpretation of data was done by Casey, Pollak, Glymour, Mayeda, Hirsch, and Schwartz; Casey drafted the manuscript; critical revision of the manuscript for important intellectual content was done by Pollak, Glymour, Mayeda, Hirsch, and Schwartz; Casey did statistical analysis; Schwartz obtained funding; administrative, technical, or material support was provided by Pollak and Schwartz; and Glymour and Schwartz supervised the study.

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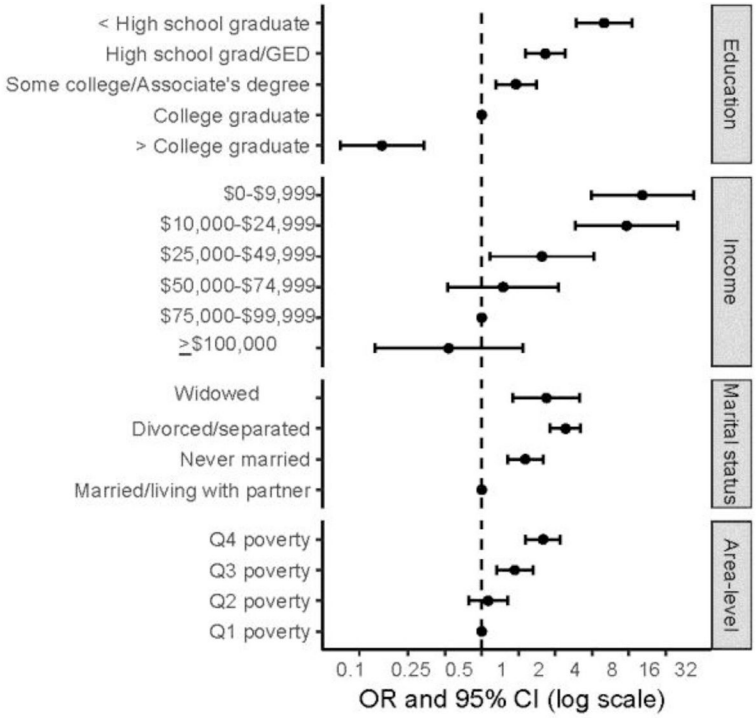

Figure 1.

ORs of MA by self-reported and area-level SES measures.

Notes: ORs and 95% CIs from weighted, age- and sex-adjusted logistic regression models with robust SEs.

GED, general equivalency diploma; MA, Medical Assistance

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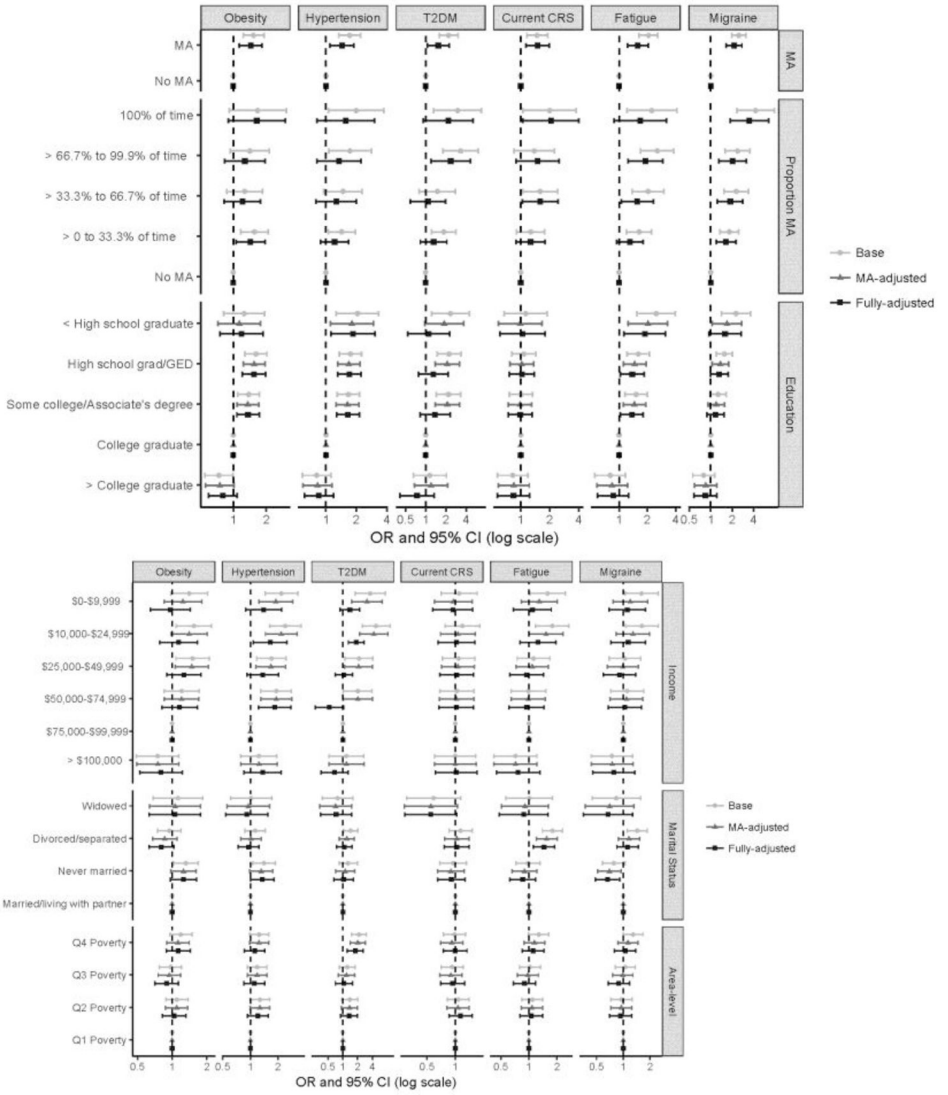

Figure 2.

ORs of six health outcomes by individual and area-level SES measures.

Notes: ORs and 95% CIs from three weighted logistic regression models with robust SEs: base model, adjusted for age and sex; MA-adjusted model, adjusted age, sex, and MA; and fully-adjusted model, adjusted for age, sex, MA, educational attainment, income, marital status, and area-level poverty. (A) MA, proportion of time under observation on MA, and educational attainment; (B) income, marital status, and area-level poverty quartile.

CRS, chronic rhinosinusitus; GED, general equivalency diploma; MA, Medical Assistance; T2DM, type 2 diabetes

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Table 1

Demographic Characteristics of Study Subjects by Receipt of Medical Assistance

Characteristic	Used MA	
Demographics	**Yes**	**No**
	N=944 (17.0)	**N=4,606 (83.0)**
Male, N (%)	230 (24.4)	714 (75.6)
Female, N (%)	714 (75.6)	2943 (63.9)
Age, years, median (IQR)	42.6 (30.8, 52.5)	51.5 (41.8, 58.1)
Race/ethnicity, N (%)		
Black	115 (12.2)	170 (3.7)
Hispanic	104 (11.0)	198 (4.3)
White	719 (76.2)	4,210 (91.4)
Other	6 (0.6)	22 (0.5)
Missing	0	6 (0.1)
Number of outpatient encounters prior to survey, median (IQR)	56 (33, 90)	41 (23, 68)
Proportion of time on MA during follow-up, median (IQR)	0.47 (0.22, 0.77)	0 (0, 0)
Education, N (%)		
Less than high school	100 (10.6)	117 (2.5)
High school graduate or GED	399 (42.3)	1,374 (29.8)
Some college/Associate's degree	328 (34.8)	1,494 (32.4)
College graduate	83 (8.8)	912 (19.8)
More than college graduate	21 (2.2)	652 (14.2)
Missing	13 (1.4)	57 (1.2)
Income, N (%)		
$0–$9,999	366 (38.8)	408 (8.9)
$10,000–$24,999	312 (33.1)	673 (14.6)
$25,000–$49,999	133 (14.1)	1,377 (29.9)
$50,000–$74,999	47 (5.0)	947 (20.6)
$75,000–$99,999	11 (1.2)	403 (8.8)
≥$100,000	10 (1.1)	390 (8.5)
Missing	65 (6.9)	408 (8.9)
Marital status, N (%)		
Married/living with partner	392 (41.5)	3,422 (74.3)
Never married	268 (28.4)	528 (11.5)
Divorced/separated	240 (25.4)	511 (11.1)
Widowed	31 (3.3)	106 (2.3)
Missing	13 (1.4)	39 (0.9)
Health outcomes		
BMI[a] (kg/m^2), median (IQR)	30.3 (24.9, 36.3)	29.2 (25.2, 34.4)
Hypertension,[b] N (%)		
Yes	449 (47.6)	2,175 (47.2)
No	495 (52.4)	2,431 (52.8)

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Characteristic	Used MA	
Demographics	**Yes**	**No**
	N=944 (17.0)	**N=4,606 (83.0)**
Type 2 diabetes, N (%)		
Yes	143 (15.2)	524 (11.4)
No	801 (84.9)	4,082 (88.6)
CRS symptoms at baseline, N (%)		
Yes	318 (33.7)	1,147 (24.9)
No	626 (66.3)	3,459 (75.1)
Migraine headache,[c] N (%)		
Yes	460 (48.7)	1,151 (25.0)
No	484 (51.3)	3,455 (75.0)
Fatigue, severe symptoms,[c] N (%)		
Yes	417 (44.2)	1,135 (24.6)
No	527 (55.8)	3,471 (75.4)
Charlson Index, median (IQR)	2 (1, 3)	2 (1, 3)
Area-level variables[d]		
Poverty (%)		
Quartile 1 (<7.2%)	143 (15.2)	1,250 (27.1)
Quartile 2 (7.2 to <10.5%)	182 (19.3)	1,204 (26.1)
Quartile 3 (10.5 to <15.9%)	260 (27.5)	1,126 (24.5)
Quartile 4 (≥15.9%)	359 (38.0)	1,026 (22.3)

[a] BMI from the healthcare visit closest to the survey return date (mean=123 days).

[b] Hypertension defined as ever a diagnosis of hypertension from ICD-9 codes or ≥2 visits with systolic blood pressure >140mmHg or diastolic blood pressure >90mmHg.

[c] Migraine and fatigue reported in the 12 months prior to survey date.

[d] Communities were defined with a mixed definition of place: minor civil division townships and boroughs and census tracts in cities using 2010 U.S. Census boundaries.

GED, general equivalency diploma; IQR, interquartile range; MA, Medical Assistance

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Table 2

Spearman Correlation Coefficients Between Medical Assistance, Income, Education, and Marital Status

Variables	1	2	3	4	5	6
1. MA[a]	1					
2. Proportion MA[a]	0.93	1				
3. Income[b]	−0.39	−0.42	1			
4. Educational level[c]	−0.22	−0.24	0.40	1		
5. Marital status[d]	0.25	0.27	−0.29	−0.10	1	
6. Area-level poverty[e]	0.17	0.17	−0.15	−0.05	0.11	1

[a]MA, a binary indicator of MA; proportion MA, the amount of time under observation spent using MA; both MA and proportion MA are defined in text.

[b]Annual income before taxes and deductions ($0–$9,999; $10,000–$24,999; $25,000–$49,999; $50,000–$74,999; $75,000–$99,999; ≥$100,000).

[c]Completed levels of education (<9 years to some high school; high school graduate/General Equivalency Diploma; some college or Associate's degree; college graduate; >college graduate).

[d]Marital status included four categories (married or living with partner; never married; divorced/separated; widowed).

[e]Assigned at the township, borough, or census tract level based on 2008–2012 American Community Survey data; quartile 4 ≥15.9% residents living below poverty line.

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