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The influence of neighborhood socioeconomic position on the transition to type II diabetes in older Mexican Americans: The SALSA Study

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Abstract

Background: Low neighborhood socioeconomic position (NSEP) has been associated with higher prevalence of type II diabetes. The purpose of this study was to examine the influence of NSEP on development of diabetes over time.

Methods: Sacramento Area Latino Study on Aging is a longitudinal study of the health of 1789 older Latinos. The NSEP scale was derived from US Census 2000 data and linked to participants' residential neighborhoods. We used Multi-state Markov regression to model transitions through four possible states over time: 1= normal; 2=pre-diabetic; 3=diabetic; and 4=death without diabetes.

Results: At baseline, nearly 50% were non-diabetic, 17.5% were pre-diabetic, and nearly 33% were diabetic. At the end of follow-up there were a total of 824 people with type 2 diabetes. In a fully adjusted MSM regression model, among nondiabetics, higher NSEP was not associated with a transition to pre-diabetes. Among nondiabetics, higher NSEP was associated with an increased risk of diabetes (HR= 1.66, 95%CI= 1.14, 2.42) and decreased risk of death without diabetes (HR: 0.56, 95% CI = .33, .96). Among pre-diabetics, higher NSEP was significantly associated with a transition to nondiabetic status (HR: 1.22, 95% CI = 0.99, 1.50). Adjusting for BMI, age, education, physical activity, smoking, alcohol consumption, medical insurance and nativity did not affect this relationship.

Conclusion: Our findings show that high NSEP poses higher risk of progression from normal to diabetes compared to a lower risk of death without diabetes. This work presents a possibility that these associations are modified by nativity or culture.

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Strengths and Limitations of the Study

Our study adds to the body of literature on older Latinos, NSEP, and diabetes status. If in the next four decades Latinos become the largest ethnic minority in the US, then understanding the roles that NSEP and cultural change play in the prevention of prediabetes and diabetes and its health related costs and complications is vital.

Data are from a longitudinal cohort study of physical and cognitive impairment and cardiovascular diseases in community-dwelling older Mexican Americans residing in Sacramento Metropolitan Statistical Area.

Three levels of data were used for this data analysis where individuals were nested within neighborhoods over time. We had neighborhood-level and individual-level data. The analysis accounted for both socio-demographic and health/behavioral variables.

Our findings may be due to unmeasured mediators such as behavior and/or differential access to health care. As Latino immigrants become more acculturated they are more likely to have higher levels of education and income but they also may be more likely to consume more alcohol, smoke and adapt unhealthy food choices associated with a more US diet.

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Introduction

Research into the effects of the community context on individual health outcomes reveals that neighborhood socioeconomic position (NSEP) is a risk factor for chronic disease.[1-3] Lower NSEP has been associated with increased risk of diabetes[1,2] and its related complications, including cardiovascular disease,[2] chronic kidney disease,[4] and all-cause mortality.[5] Research shows that these conditions disproportionately affect minorities, including Hispanic adults.[1,6] Neighborhood and individual cultural factors may influence the progression to type 2 diabetes. Some work has suggested that residence in a majority Hispanic neighborhood is protective for diabetes, obesity and other health outcomes.[4,5] This same work has reported that foreign-born Mexican Americans may experience better health outcomes compared to US born, even when accounting for neighborhood cultural and socio-demographic characteristics.

The development and progression of adult onset type 2 diabetes is influenced by an accumulation of behaviors and exposures over a lifetime, including many factors linked to neighborhoods, such as the availability of recreational opportunities, access to fresh fruits and vegetables, and social support networks.[6,7] Successful management of diabetes is influenced by access to medical care and behavioral risk factor modification. Despite recommendations from the American Diabetes Association,[9] many patients with diabetes are initially managed without medication.[10,11] Both individual socioeconomic status and NSEP are associated with access to medical insurance and medical care.[8] In addition, neighborhoods with low SEP tend to have lower density of stores selling fresh produce[6] as well as less space for recreational activities.[7] This may result in higher

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rates of obesity and, subsequently, higher rates of diabetes.[2] Therefore, through access to a healthful environment and access to medical care, NSEP is an important component of both prevention and management of diabetes.

Our objective was to examine the relationship between NSEP and transitions to diabetes status over time in cohort of Latino older adults, while accounting for individual social, health and behavioral characteristics. We hypothesized that Latinos living in higher NSEP neighborhoods would be less likely to transition into worse diabetes states than Latinos in lower NSEP neighborhoods.

Methods

Study Participants

Participants were from the Sacramento Area Latino Study on Aging (SALSA), a longitudinal cohort study of physical and cognitive impairment and cardiovascular diseases in community-dwelling older Mexican Americans residing in Sacramento Metropolitan Statistical Area.[6] Recruitment occurred between 1998-1999 and included 1,789 participants between the ages of 60–101 years at baseline. Every 12 to 15 months, interviews, biological and clinical data were collected on participants during in-home visits, with a maximum of six follow-ups to 2008. The Institutional Review Boards (IRB) at the University of Michigan, University of North Carolina, the University of California, San Francisco, and the University of California, Davis approved the SALSA study and along with the principles of the Helsinki Declaration. All participants provided appropriate informed consent annually.

Participants with missing baseline information (n = 10) or outliers (n = 2) on key study variables were excluded, yielding a final sample size of 1,777 participants.

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Study Variables

Three levels of data were used for this data analysis where individuals were nested within neighborhoods over time.

Individual-level data.

Assessment of type-2 diabetes and pre-diabetes status: We defined diabetes as meeting any of the following criteria in semiannual follow-up interviews or annual laboratory examinations: 1) self-report of a physician's diagnosis of diabetes, 2) fasting blood glucose level of ≥ 126 mg/dL, 3) usage of diabetes medication (insulin or oral hypoglycemic agent), or 4) diabetes listed as a cause of death anywhere on a death certificate, provided the death occurred within the study period.[7] Pre-diabetes was ascertained by a fasting blood glucose level between 100 mg/dL and 125 mg/dL.

Assessment of other clinical and biological data: During the baseline examination, trained interviewers measured study participants' standing height and weight; body mass index (BMI; kg/m^2), was calculated as weight/ $height^2$. Participants reported the number of hours per week they engaged in certain physical activities (e.g. doing yard work, heavy housework, and walking around neighborhood). These were combined into a physical activity summary score and used as a continuous variable to facilitate convergence.

Assessment of socio-demographics: At baseline, demographic characteristics of participants were collected based on self-report, including age, health insurance, has a doctor, any alcohol consumption, any smoking, acculturation[8] and nativity (born in Mexico/other Latin American country or US).

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Assessment of individual-level socioeconomic position (SEP) measures: Several individual-level SEP factors were also measured at baseline. Each participant self-reported years of education completed, gross past-month household income, and major lifetime occupation. We created a variable that grouped gross past-month household income into low (< $1,500) and high (≥ $1,500) categories, and another variable that categorized participant's occupation as manual, non-manual, or other (a category that included housewives, the unemployed).

Neighborhood-level data.

Neighborhood socioeconomic position (NSEP): In line with prior literature, we operationalized neighborhoods as census tracts.[9-11] Participants' baseline addresses were geocoded to the 2000 US Census tracts, and linked participant data to census data. We utilized factor analysis to construct a NSEP score using previously validated procedures.[11] The factor analysis was performed with census tract-level socioeconomic variables using PROC FACTOR in SAS. Neighborhood characteristics that showed a loading greater than 0.4 in either a positive or negative direction were selected, used z-score standardized for scale consistency, reverse coded when necessary, and then summed to create a NSEP score (mean= 22.4 , SD=4.8 and range = 0 – 30.6). Our NSEP variable included 6 variables: the percentage of individuals 25 years of age or older without a high school diploma; the percentage of the population living below the poverty line; the percentage of individuals ≥ 16 years of age who at one time had been in the work force and who were unemployed; the percentage of households that owned their home, percentage of housing units that were vacant; and the median number of rooms in the household. Higher NSEP scores indicated higher neighborhood

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socioeconomic status. Further details on the statistical methods resulting in the NSEP score have been published elsewhere.[12] We also created the Hispanic Isolation Index which is defined as the average percentage of the study population that is Hispanic in a neighborhood.[4] We categorized the Hispanic isolation index (HII) into quartiles.

Statistical Analysis

We compared baseline covariates by presence of absence of diabetes. We used Multi-state Markov models[13] to model each participant's transitions between four possible states over time: 1=normal; 2=pre-diabetic; 3=diabetic; and 4=death without diabetes. Multi-state Markov models describe the associations of covariates with probabilities of state transitions using hazard rates and assumes that the hazard rates are independent of which states were previously occupied and the time spent in the current state. Our models permitted the following transitions: from normal to pre-diabetic, normal to diabetic, normal to death without diabetes, pre-diabetic to normal, pre-diabetic to diabetic, and pre-diabetic to death without diabetes. We assumed that the diabetic and death without diabetes states were absorbing (final state). We fit a series of Multi-state Markov models to the data.

Model 1 included just the main predictor of interest, neighborhood SEP score (in units of interquartile range, IQR=7). Model 2 adds adjustment for other individual-level factors, including baseline BMI, baseline age, years of education, physical activity, smoking status, any alcohol consumption, medical insurance and nativity. Hazard ratios for each transition along with their 95% CI were estimated for each each transition adjusted for covariates.

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All analyses were performed using SAS version 9.4 and the msm package in R version 3.1.1.[14]

Results

At baseline, while the majority of participants did not have diabetes (49.6%) the prevalence of diabetes (33%) and pre-diabetes (17.5%) was high (Table 1). At baseline, there were 586 cases of type 2 diabetes and 310 pre-diabetes cases. Follow-up data on diabetes and pre-diabetes were available through June 2008, with a total of 205 incident diabetes cases and 824 incident pre-diabetes cases. Diabetes status was significantly associated with older age, higher BMI, and lower physical activity. Compared to non-diabetics, those with diabetes were more likely to have health insurance, and a regular doctor. Mexican born were less likely to have diabetes than US born. Diabetics were less likely to drink alcohol. Acculturation, years of education, household income, and occupation did not differ by diabetes status.

Association between neighborhood socioeconomic position (NSEP) and diabetes transitions.

Table 2 shows the distribution of the number of participants by quartile of the NSEP. The majority of participants (75.8%) fell into the two lowest quartiles. Also shown is the distribution of the number of transitions by NSEP quartile. Forty percent of the transitions from normal to pre-diabetes, 37% of normal to diabetes transitions, 52.5% of transitions from normal to death, 43% of pre-diabetes to diabetes transitions, 50% of pre-diabetes to death and nearly 36% of pre-diabetes to normal all occurred in the lowest NSEP quartile. Mexican-born nativity was significantly higher in the lowest

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compared to the highest quartile (55.4% vs. 42.3%, p=.0003). Mean acculturation score and years of education were lowest in Quartile 1 compared to Quartile 4 (p<.0001, respectively).

Association between neighborhood socioeconomic position (NSEP) and transitions.

Table 3 shows the results of transition models with no adjustment (Model 1), and (Model 2) with adjustment for BMI, and adjustment for BMI, baseline age, physical activity, health insurance, alcohol consumption, smoking, acculturation and nativity. In Model 2, among participants who were normal at baseline, NSEP was not associated with a transition from normal to pre-diabetes. Higher NSEP was significantly associated with an increased risk for transition from normal to diabetes (HR= 1.66, 95% CI= 1.14, 2.42) and a decreased risk for transition from normal to death without diabetes (HR: 0.56, 95% CI = 0.33, 0.96).

Among pre-diabetics, in Model 2, NSEP was not associated with transition to diabetes or to death without diabetes. Among pre-diabetics, higher NSEP was marginally associated with a transition to normal status for the fully adjusted model (HR: 1.22, 95% CI = 0.99, 1.50). Transitions from pre-diabetes to diabetes or to death without diabetes were not statistically significant. Figure 1 shows the associations between the NSEP measure and the Hispanic isolation index (both in quartiles). NSEP and HII are strongly associated such that higher Hispanic Index is associated with lower NSEP scores (Likelihood Ratio Chi square = 780.36, df=9, p<.0001). Thus, those living in the lower NSEP neighborhoods are also living in communities with greater proportions of Hispanics and are less isolated from a cultural context. From an MSM model stratified

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on nativity, we found that among normal US born, NSEP was associated with significantly higher risk of developing type diabetes (incident diabetes: HR: 1.13, CI: 1.03-1.24) and significantly lower risk of dying without diabetes (dying without diabetes: HR: 0.92, CI: 0.86-0.98). These are modest effects and among Mexican-born these associations were not significant.

Conclusion

We found that higher NSEP was associated with a greater likelihood to transition from normal to diabetes. However, higher NSEP was associated with a lower likelihood of transitioning to death without diabetes. Higher NSEP was associated with a greater likelihood that pre-diabetics would transition to normal status. All other transitions were not influenced by NSEP. We accounted for both socio-demographic and health/behavioral variables in our adjustments. Adjustment for individual socioeconomic factors (education, income, occupation) did not substantially influence the association of Census-level NSEP with the various transitions. The opposite effects of NSEP in normal participants of higher risk of incident diabetes and lower risk of death without diabetes may be explained by the negative influence of low SES and potentially beneficial higher concentrations of cultural protections represented by the HII.

Our findings may be due to unmeasured mediators such as behavior and/or differential access to health care. As Latino immigrants become more acculturated they are more likely to have higher levels of education and income but they also may be more likely to consume more alcohol, smoke and adapt unhealthy food choices associated with a more US diet. In other literature, higher levels of acculturation have

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been associated with higher rates of obesity and diabetes.[12] Work by Kershaw et al[4] about neighborhood ethnic isolation suggested that prevalence of obesity was actually lower in Mexican American study participants living in a predominantly Hispanic neighborhood. In this same study, obesity was lower in the foreign-born but estimates were not made for the influence of nativity on obesity in relation to ethnic isolation.

Consistent with our initial hypothesis and some other work,[15] we did find that the transition from normal to non-diabetes death was associated with lower neighborhood social position (NSEP), while the transition from prediabetes to no diabetes was associated with higher NSEP. Latinos with increased levels of education and income are more likely to have access to and utilize health care. Health care utilization may increase medical screenings and treatment; all important factors in the prevention of death from any disease. For older Latinos, the utilization of health care is key as they are disparately at higher risk of diabetes and prediabetes compared to non-Latino Whites.[16] However, we adjusted for health care access with no effect. Access to care is more likely to affect progression of a condition than incidence, unless an intervention targets a risk factor such as obesity. We did not have measures of diet which is a limitation of the study.

The higher risk of developing diabetes associated with higher NSEP in our study of older Latinos was consistent with the Hispanic Paradox.[15] The protective effect of low NSEP on risk of death in normal participants contradicts the Hispanic Paradox. The Hispanic Paradox postulates that Latinos have better health outcomes despite a lower socioeconomic status than non-Latino whites. Criticisms of this view suggest that migrants are a healthier population than the US born. Work by Espinoza[15] reports that

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the mortality difference in Mexican Americans vs. European Americans is largely explained by adjustment for socioeconomic measures. We have some evidence that less acculturated Latinos are less likely to transition to diabetes. It may be that as Latinos in our study became more acculturated over time, they adopted more unhealthy behaviors. Along with the rest of the nation, Latinos will age and live longer. It is predicated that over the next 40 years Latinos over the age of 65 will double and those over the age of 85 will triple.[16,17] If in the next four decades Latinos become the largest ethnic minority in the USA, then understanding the roles that NSEP and cultural change play in the prevention of prediabetes and diabetes and its health related costs and complications is vital.

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Competing Interests No potential conflicts of interest relevant to this article were reported.

Informed Consent The parent study (SALSA) was conducted with appropriate informed consent and in agreement with established Human Institutional Review Board procedures and consent at the University of Michigan, the University of California, San Francisco, and the University of California, Davis and along with the principles of the Helsinki Declaration.

Contributors LG conceived of the study, drafted the paper, interpreted the data, critically revised, and approved the manuscript. AL, JN performed statistical analysis and interpreted the data, and critically revised and approved the manuscript. AZHA, SM, AA, TE interpreted the data and critically revised and approved the manuscript. MNH obtained the funding; conceived of the study, wrote, critically revised, interpreted the data and approved the manuscript. LG and MNH are the guarantors of this work and, as such, and take responsibility for the integrity of the data and accuracy of the data analysis.

Data Sharing Statement No additional data available.

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Table 1. Baseline Characteristics of SALSA Participants by baseline diabetes status.

Variable	Overall N=1777	Diabetes N=586 (32.9%)	Pre-diabetes N=310 (17.5%)	No Diabetes N=881 (49.6%)	p-value
Demographics					
Age in years, *mean (SD)*	70.7 (7.1)	70.3 (6.9)	69.8 (6.9)	71.2 (7.3)	0.003
Health/Behavioral risk factors					
Body Mass Index (kg/m^2), mean (SD)	29.7 (5.6)	31.0 (6.3)	31.1 (5.6)	28.3 (5.4)	<.0001
Body Mass Index (kg/m^2), n (%)					<.0001
Normal: <25	310 (19.1)	68 (12.5)	26 (8.4)	216 (28.0)	
Overweight: ≥25 and <30	628 (38.6)	209 (38.4)	114 (36.8)	305 (39.5)	
Obese: ≥30	688 (42.3)	267 (49.1)	170 (54.8)	251 (32.5)	
Physical activity summary score, *mean (SD)*	17.2 (5.5)	16.3 (5.4)	17.6 (5.3)	17.6 (5.5)	<.0001
Any alcohol consumption, n (%)	944 (53.2)	234 (39.9)	191 (61.6)	519 (59.0)	<0.0001
Smoking, n (%)					0.05
Never smoked	818 (46.1)	259 (44.3)	130 (41.9)	429 (48.9)	
Former smoker	754 (42.5)	269 (46.0)	140 (45.2)	345 (39.3)	
Current smoker	201 (11.3)	57 (9.7)	40 (12.9)	104 (11.9)	
Health insurance *(n, % with)*	1609 (90.8)	545 (93.0)	267 (86.7)	797 (90.7)	0.008
Has a regular doctor (n, % with)	1564 (88.3)	537 (91.8)	265 (85.5)	762 (86.9)	0.004
Individual level SEP					
Years of education, *mean (SD)*	7.2 (5.3)	7.1 (5.4)	7.6 (5.4)	7.2 (5.3)	0.41
Household income, n (%)					0.51
Low (<$1,500)	1140 (65.2)	382 (66.4)	192 (62.5)	566 (65.4)	
High (≥$1,500)	608 (34.8)	193 (33.6)	115 (37.5)	300 (34.6)	
Lifetime occupation, n (%)					0.59
Non manual	372 (21.2)	122 (21.0)	71 (23.3)	179 (20.6)	
Manual	1054	346 (59.6)	172 (56.4)	536 (61.6)	

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	(60.0)				
Housewives/unemployed	330 (18.8)	113 (19.5)	62 (20.3)	155 (17.8)	
Acculturation score, *mean (SD)*	21.9 (12.9)	22.1 (12.9)	22.6 (13.2)	21.5 (12.8)	0.42
Nativity (Mexican born), n (%)	906 (51.0)	262 (44.7)	153 (49.4)	491 (55.7)	0.0002

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Table 2. Transitions between states defined by quartiles of neighborhood SEP scores.

Neighborhood SEP score (quartiles) (N tracts=257)	TOTALS	Quartile 1 (10.6 - <19.1) N=64	Quartile 2 (19.1 - <23.2) N=64	Quartile 3 (23.2 - <26.3) N=65	Quartile 4 (26.3 - 30.6) N=64
N (%)		785 (44.3)	559 (31.5)	246 (13.8)	187 (10.5)
		Number of Participants			
No Diabetes ever	190	79	65	28	18
Pre-diabetes always	42	20	14	5	3
Diabetes always from baseline	586	287	180	67	52
		Number of state transitions			
Normal to Pre-diabetes	393	161	116	65	51
Normal to Diabetes	132	49	36	24	23
Normal to death w/o diabetes	120	63	35	17	5
Prediabetes to Diabetes	169	73	58	22	16
Prediabetes to death w/o diabetes	56	28	17	9	2
Prediabetes to normal	321	115	95	67	44

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Table 3. Association between NSEP scores (interquartile range) and transitions within Multi-state Markov regression models

	Model 1	Model 2
Transition states:	HR (95% CI)	HR (95% CI)
Normal (no diabetes) - Pre-diabetes	1.01 (0.85, 1.19)	1.05 (0.88, 1.26)
Normal - Diabetes (no diabetes)	1.53 (1.07, 2.20)*	1.66 (1.14, 2.42)**
Normal - Death without Diabetes	0.61 (0.43, 0.85)**	0.56 (0.33, 0.96)*
Pre-diabetes - Normal (no diabetes)	1.26 (1.04, 1.52)*	1.22 (0.99, 1.50)
Pre-diabetes – Diabetes	0.80 (0.62, 1.05)	0.83 (0.62, 1.10)
Pre-diabetes - Death without Diabetes	0.62 (0.35, 1.10)	0.76 (0.40, 1.44)
Log Likelihood	7421.452	6469.601

Model 1 NSEP (7 units)
Model 2 is Model 1 + adjusted for BMI, age, education in years, physical activity summary score, smoking status (ever/never), any alcohol consumption, medical insurance (yes/no), and nativity (US born/Mexican born);
* p<.05; ** p<.001;

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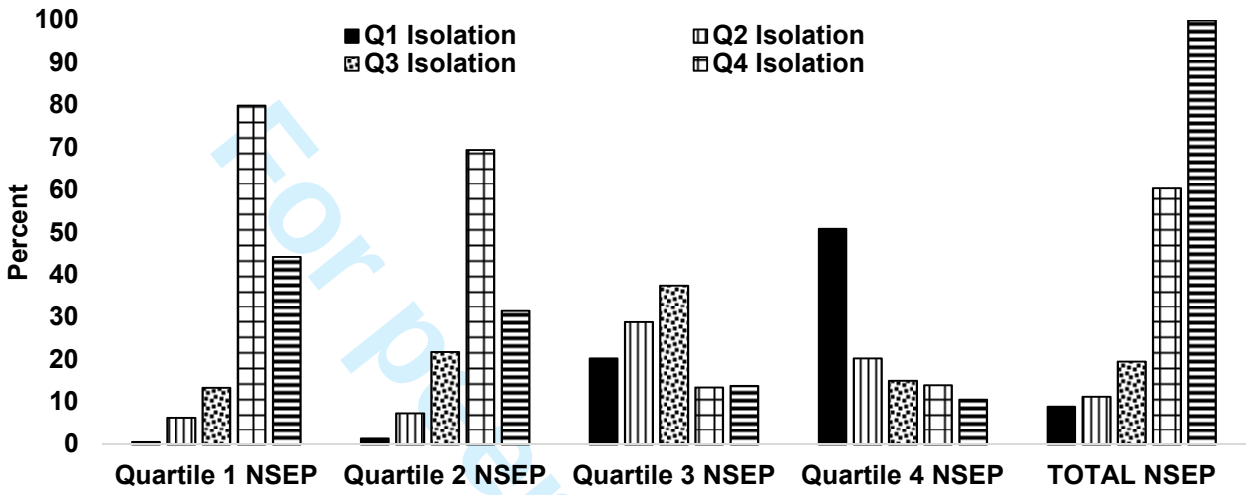
Figure 1 . Association between Neighborhood Socioeconomic Position score and Hispanic Isolation Index



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The influence of neighborhood socioeconomic position on the transition to type II diabetes in older Mexican Americans: The Sacramento Area Longitudinal Study on Aging

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Abstract

Objective: To examine the influence of NSEP on development of diabetes over time.

Design: A longitudinal cohort study.

Setting: The data reported were from the Sacramento Area Latino Study on Aging is a longitudinal study of the health of 1789 older Latinos.

Participants: Community-dwelling older Mexican Americans residing in the Sacramento Metropolitan Statistical Area.

Main Outcome: Multi-state Markov regression were used to model transitions through four possible states over time: 1= normal; 2=pre-diabetic; 3=diabetic; and 4=death without diabetes.

Results: At baseline, nearly 50% were non-diabetic, 17.5% were pre-diabetic, and nearly 33% were diabetic. At the end of follow-up there were a total of 824 people with type 2 diabetes. In a fully adjusted MSM regression model, among nondiabetics, higher NSEP was not associated with a transition to pre-diabetes. Among nondiabetics, higher NSEP was associated with an increased risk of diabetes (HR= 1.66, 95%CI= 1.14, 2.42) and decreased risk of death without diabetes (HR: 0.56, 95% CI = .33, .96). Among pre-diabetics, higher NSEP was significantly associated with a transition to nondiabetic status (HR: 1.22, 95% CI = 0.99, 1.50). Adjusting for BMI, age, education, physical activity, smoking, alcohol consumption, medical insurance and nativity did not affect this relationship.

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Conclusion: Our findings show that high NSEP poses higher risk of progression from normal to diabetes compared to a lower risk of death without diabetes. This work presents a possibility that these associations are modified by nativity or culture.

Strengths and Limitations of the Study

Our study adds to the body of literature on older Latinos, NSEP, and diabetes status. If in the next four decades Latinos become the largest ethnic minority in the US, then understanding the roles that NSEP and cultural change play in the prevention of prediabetes and diabetes and its health related costs and complications is vital.

Data are from a longitudinal cohort study of physical and cognitive impairment and cardiovascular diseases in community-dwelling older Mexican Americans residing in Sacramento Metropolitan Statistical Area.

Three levels of data were used for this data analysis where individuals were nested within neighborhoods over time. We had neighborhood-level and individual-level data. The analysis accounted for both socio-demographic and health/behavioral variables.

Our findings may be due to unmeasured mediators such as behavior and/or differential access to health care. As Latino immigrants become more acculturated they are more likely to have higher levels of education and income but they also may be more likely to consume more alcohol, smoke and adapt unhealthy food choices associated with a more US diet.

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Introduction

Research into the effects of the community context on individual health outcomes reveals that neighborhood socioeconomic position (NSEP) is a risk factor for chronic disease.[1-3] Lower NSEP has been associated with increased risk of diabetes[1,2] and its related complications, including cardiovascular disease,[2] chronic kidney disease,[4] and all-cause mortality.[5] Research shows that these conditions disproportionately affect minorities, including adults.[1,6] Neighborhood and individual cultural factors may influence the progression to type 2 diabetes. Some work has suggested that residence in a majority Hispanic neighborhood is protective for diabetes, obesity and other health outcomes.[7,8] This same work has reported that foreign-born Mexican Americans may experience better health outcomes compared to US born, even when accounting for neighborhood cultural and socio-demographic characteristics.

The development and progression of adult onset type 2 diabetes is influenced by an accumulation of behaviors and exposures over a lifetime, including many factors linked to neighborhoods, such as the availability of recreational opportunities, access to fresh fruits and vegetables, and social support networks.[6,9,10] Successful management of diabetes is influenced by access to medical care and behavioral risk factor modification. Despite recommendations from the American Diabetes Association,[11] many patients with diabetes are initially managed without medication.[12] Both individual socioeconomic status and NSEP are associated with access to medical insurance and medical care.[13] In addition, neighborhoods with low SEP tend to have lower density of stores selling fresh produce[6] as well as less space for recreational activities.[9] This may result in higher rates of obesity and, subsequently, higher rates of diabetes.[2] Therefore,

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through access to a healthful environment and access to medical care, NSEP is an important component of both prevention and management of diabetes.

Our objective was to examine the relationship between NSEP and transitions to diabetes status over time in cohort of Latino older adults, while accounting for individual social, health and behavioral characteristics. We hypothesized that Latinos living in higher NSEP neighborhoods would be less likely to transition into worse diabetes states than Latinos in lower NSEP neighborhoods.

Methods

Study Participants

Participants were from the Sacramento Area Latino Study on Aging (SALSA), a longitudinal cohort study of physical and cognitive impairment and cardiovascular diseases in community-dwelling older Mexican Americans residing in Sacramento Metropolitan Statistical Area.[14] Recruitment occurred between 1998-1999 and included 1,789 participants between the ages of 60–101 years at baseline. Every 12 to 15 months, interviews, biological and clinical data were collected on participants during in-home visits, with a maximum of six follow-ups to 2008. The Institutional Review Boards (IRB) at the University of Michigan, University of North Carolina, the University of California, San Francisco, and the University of California, Davis approved the SALSA study and along with the principles of the Helsinki Declaration. All participants provided appropriate informed consent annually.

We excluded 12 participants with missing baseline diabetes status or who lived in a neighborhood with NSEP score that is an outlier (NSEP score<=10), yielding a final sample size of 1,777 participants.

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Study Variables

Three levels of data were used for this data analysis where individuals were nested within neighborhoods over time.

Individual-level data.

Assessment of type-2 diabetes and pre-diabetes status: We defined diabetes as meeting any of the following criteria in semiannual follow-up interviews or annual laboratory examinations: 1) self-report of a physician's diagnosis of diabetes, 2) fasting blood glucose level of ≥ 126 mg/dL, 3) usage of diabetes medication (insulin or oral hypoglycemic agent), or 4) diabetes listed as a cause of death anywhere on a death certificate, provided the death occurred within the study period.[15] Pre-diabetes was ascertained by a fasting blood glucose level between 100 mg/dL and 125 mg/dL.

Assessment of other clinical and biological data: During the baseline examination, trained interviewers measured study participants' standing height and weight; body mass index (BMI; kg/m^2), was calculated as weight/ $height^2$. Participants reported the number of hours per week they engaged in certain physical activities (e.g. doing yard work, heavy housework, and walking around neighborhood). These were combined into a physical activity summary score and used as a continuous variable to facilitate convergence.

Assessment of socio-demographics: At baseline, demographic characteristics of participants were collected based on self-report, including age, health insurance, has a doctor, any alcohol consumption, any smoking, acculturation[16] and nativity (born in Mexico/other Latin American country or US).

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Assessment of individual-level socioeconomic position (SEP) measures: Several individual-level SEP factors were also measured at baseline. Each participant self-reported years of education completed, gross past-month household income, and major lifetime occupation. We created a variable that grouped gross past-month household income into low (< $1,500) and high (≥ $1,500) categories, and another variable that categorized participant's occupation as manual, non-manual, or other (a category that included housewives, the unemployed).

Neighborhood-level data.

Neighborhood socioeconomic position (NSEP): In line with prior literature, we operationalized neighborhoods as census tracts.[17,18,19] Participants' baseline addresses were geocoded to the 2000 US Census tracts, and linked participant data to census data. We utilized factor analysis to construct a NSEP score using previously validated procedures.[19] The factor analysis was performed with census tract-level socioeconomic variables using PROC FACTOR in SAS. Neighborhood characteristics that showed a loading greater than 0.4 in either a positive or negative direction were selected, used z-score standardized for scale consistency, reverse coded when necessary, and then summed to create a NSEP score (mean= 22.4 , SD=4.8 and range = 0 – 30.6). Our NSEP variable included 6 variables: the percentage of individuals 25 years of age or older without a high school diploma; the percentage of the population living below the poverty line; the percentage of individuals ≥ 16 years of age who at one time had been in the work force and who were unemployed; the percentage of households that owned their home, percentage of housing units that were vacant; and the median number of rooms in the household. Higher NSEP scores indicated higher neighborhood

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socioeconomic status. Further details on the statistical methods resulting in the NSEP score have been published elsewhere.[20] We also created the Hispanic Isolation Index which is defined as the average percentage of the study population that is Hispanic in a neighborhood.[14] We categorized the Hispanic isolation index (HII) into quartiles.

Statistical Analysis

We compared baseline covariates by baseline diabetes status. We used ANOVA to compare the means of continuous variables and chi-square tests to compare the frequencies of categorical variables.

We used Multi-state Markov models[21] to model each participant's transitions between four possible states over time: 1=normal; 2=pre-diabetic; 3=diabetic; and 4=death without diabetes. Multi-state Markov models describe the associations of covariates with probabilities of state transitions using hazard rates and assumes that the hazard rates are independent of which states were previously occupied and the time spent in the current state. Our models permitted the following transitions: from normal to pre-diabetic, normal to diabetic, normal to death without diabetes, pre-diabetic to normal, pre-diabetic to diabetic, and pre-diabetic to death without diabetes. We assumed that the diabetic and death without diabetes states were absorbing (final state). We fit a series of Multi-state Markov models to the data by the method of maximum likelihood.

Model 1 included just the main predictor of interest, neighborhood SEP score (in units of interquartile range, IQR=7). Model 2 adds adjustment for other individual-level factors, including baseline BMI, baseline age, years of education, physical activity, smoking status, any alcohol consumption, medical insurance and nativity. Hazard ratios

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for each transition along with their 95% CI were estimated for each transition adjusted for covariates.

All analyses were performed using SAS version 9.4 and the msm package in R version 3.1.1.[22] All statistical tests were two sided and p<.05 was considered statistically significant.

Results

At baseline, while the majority of participants did not have diabetes (49.6%) the prevalence of diabetes (33%) and pre-diabetes (17.5%) was high (Table 1). At baseline, there were 586 cases of type 2 diabetes and 310 pre-diabetes cases. Follow-up data on diabetes and pre-diabetes were available through June 2008, with a total of 205 incident diabetes cases and 824 incident pre-diabetes cases. Diabetes status was significantly associated with older age, higher BMI, and lower physical activity. Compared to non-diabetics, those with diabetes were more likely to have health insurance, and a regular doctor. Mexican born were less likely to have diabetes than US born. Diabetics were less likely to drink alcohol. Acculturation, years of education, household income, and occupation did not differ by diabetes status.

Association between neighborhood socioeconomic position (NSEP) and diabetes transitions.

Table 2 shows the distribution of the number of participants by quartile of the NSEP. The majority of participants (75.8%) fell into the two lowest quartiles. Also shown is the distribution of the number of transitions by NSEP quartile. Forty percent of the transitions from normal to pre-diabetes, 37% of normal to diabetes transitions, 52.5% of

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transitions from normal to death, 43% of pre-diabetes to diabetes transitions, 50% of pre-diabetes to death and nearly 36% of pre-diabetes to normal all occurred in the lowest NSEP quartile. Mexican-born nativity was significantly higher in the lowest compared to the highest quartile (55.4% vs. 42.3%, p=.0003). Mean acculturation score and years of education were lowest in Quartile 1 compared to Quartile 4 (p<.0001, respectively).

Association between neighborhood socioeconomic position (NSEP) and transitions.

Table 3 shows the results of transition models with no adjustment (Model 1), and (Model 2) with adjustment for BMI, baseline age, physical activity, health insurance, alcohol consumption, smoking, acculturation and nativity. In Model 2, among participants who were normal at baseline, NSEP was not associated with a transition from normal to pre-diabetes. Higher NSEP was significantly associated with an increased risk for transition from normal to diabetes (HR= 1.66, 95% CI= 1.14, 2.42) and a decreased risk for transition from normal to death without diabetes (HR: 0.56, 95% CI = 0.33, 0.96).

Among pre-diabetics, in Model 2, NSEP was not associated with transition to diabetes or to death without diabetes. Among pre-diabetics, higher NSEP was marginally associated with a transition to normal status for the fully adjusted model (HR: 1.22, 95% CI = 0.99, 1.50). Transitions from pre-diabetes to diabetes or to death without diabetes were not statistically significant. Figure 1 shows the associations between the NSEP measure and the Hispanic isolation index (both in quartiles). NSEP and HII are strongly associated such that higher Hispanic Index is associated with lower NSEP

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scores (Likelihood Ratio Chi square = 780.36, df=9, p<.0001). Thus, those living in the lower NSEP neighborhoods are also living in communities with greater proportions of Hispanics and are less isolated from a cultural context. From an MSM model stratified on nativity, we found that among normal US born, NSEP was associated with significantly higher risk of developing type diabetes (incident diabetes: HR: 1.13, CI: 1.03-1.24) and significantly lower risk of dying without diabetes (dying without diabetes: HR: 0.92, CI: 0.86-0.98). These are modest effects and among Mexican-born these associations were not significant.

Conclusion

We found that higher NSEP was associated with a greater likelihood to transition from normal to diabetes. However, higher NSEP was associated with a lower likelihood of transitioning to death without diabetes. Higher NSEP was associated with a greater likelihood that pre-diabetics would transition to normal status. All other transitions were not influenced by NSEP. We accounted for both socio-demographic and health/behavioral variables in our adjustments. Adjustment for individual socioeconomic factors (education, income, occupation) did not substantially influence the association of Census-level NSEP with the various transitions. The opposite effects of NSEP in normal participants of higher risk of incident diabetes and lower risk of death without diabetes may be explained by the negative influence of low SES and potentially beneficial higher concentrations of cultural protections represented by the HII.

Our findings may be due to unmeasured mediators such as behavior and/or differential access to health care. As Latino immigrants become more acculturated they

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are more likely to have higher levels of education and income but they also may be more likely to consume more alcohol, smoke and adapt unhealthy food choices associated with a more US diet.[23,24] In other literature, higher levels of acculturation have been associated with higher rates of obesity and diabetes.[25] Work by Kershaw et al[7] about neighborhood ethnic isolation suggested that prevalence of obesity was actually lower in Mexican American study participants living in a predominantly Hispanic neighborhood. In this same study, obesity was lower in the foreign-born but estimates were not made for the influence of nativity on obesity in relation to ethnic isolation.

Consistent with our initial hypothesis and some other work,[20] we did find that the transition from normal to non-diabetes death was associated with lower neighborhood social position (NSEP), while the transition from prediabetes to no diabetes was associated with higher NSEP. Latinos with increased levels of education and income are more likely to have access to and utilize health care. Health care utilization may increase medical screenings and treatment; all important factors in the prevention of death from any disease. For older Latinos, the utilization of health care is key as they are disparately at higher risk of diabetes and prediabetes compared to non-Latino Whites.[25] However, we adjusted for health care access with no effect. Access to care is more likely to affect progression of a condition than incidence, unless an intervention targets a risk factor such as obesity. We did not have measures of diet which is a limitation of the study.

The higher risk of developing diabetes associated with higher NSEP in our study of older Latinos was consistent with the Hispanic Paradox.[26] The protective effect of

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low NSEP on risk of death in normal participants may also be consistent with the Hispanic Paradox. The Hispanic Paradox postulates that Latinos have better health outcomes despite a lower socioeconomic status than non-Latino whites. Criticisms of this view suggest that migrants are a healthier population than the US born. Work by Espinoza[26] reports that the mortality difference in Mexican Americans vs. European Americans is largely explained by adjustment for socioeconomic measures. We have some evidence that less acculturated Latinos are less likely to transition to diabetes. It may be that as Latinos in our study became more acculturated over time, they adopted more unhealthy behaviors. Along with the rest of the nation, Latinos will age and live longer. It is predicated that over the next 40 years Latinos over the age of 65 will double and those over the age of 85 will triple.[25,27] If in the next four decades Latinos become the largest ethnic minority in the USA, then understanding the roles that NSEP and cultural change play in the prevention of prediabetes and diabetes and its health related costs and complications is vital.

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Competing Interests No potential conflicts of interest relevant to this article were reported.

Informed Consent The parent study (SALSA) was conducted with appropriate informed consent and in agreement with established Human Institutional Review Board procedures and consent at the University of Michigan, the University of California, San Francisco, and the University of California, Davis and along with the principles of the Helsinki Declaration.

Contributors LG conceived of the study, drafted the paper, interpreted the data, critically revised, and approved the manuscript. AL, JN performed statistical analysis and interpreted the data, and critically revised and approved the manuscript. AZHA, SM, AA, TE interpreted the data and critically revised and approved the manuscript. MNH obtained the funding; conceived of the study, wrote, critically revised, interpreted the data and approved the manuscript. LG and MNH are the guarantors of this work and, as such, and take responsibility for the integrity of the data and accuracy of the data analysis.

Data Sharing Statement No additional data available.

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Table 1. Comparison of Baseline Characteristics of SALSA Participants by baseline diabetes status.

Variable	Diabetes N=586 (32.9%)	Pre-diabetes N=310 (17.5%)	No Diabetes N=881 (49.6%)	p-value*
Demographics				
Age in years, *mean (SD)*	70.3 (6.9)	69.8 (6.9)	71.2 (7.3)	0.003
Health/Behavioral risk factors				
Body Mass Index (kg/m^2), mean (SD)	31.0 (6.3)	31.1 (5.6)	28.3 (5.4)	<.0001
Body Mass Index (kg/m^2), n (%)				<.0001
Normal: <25	68 (12.5)	26 (8.4)	216 (28.0)	
Overweight: ≥25 and <30	209 (38.4)	114 (36.8)	305 (39.5)	
Obese: ≥30	267 (49.1)	170 (54.8)	251 (32.5)	
Physical activity summary score, *mean (SD)*	16.3 (5.4)	17.6 (5.3)	17.6 (5.5)	<.0001
Any alcohol consumption, n (%)	234 (39.9)	191 (61.6)	519 (59.0)	<0.0001
Smoking, n (%)				0.05
Never smoked	259 (44.3)	130 (41.9)	429 (48.9)	
Former smoker	269 (46.0)	140 (45.2)	345 (39.3)	
Current smoker	57 (9.7)	40 (12.9)	104 (11.9)	
Health insurance *(n, % with)*	545 (93.0)	267 (86.7)	797 (90.7)	0.008
Has a regular doctor (n, % with)	537 (91.8)	265 (85.5)	762 (86.9)	0.004
Individual level SEP				
Years of education, *mean (SD)*	7.1 (5.4)	7.6 (5.4)	7.2 (5.3)	0.41
Household income, n (%)				0.51
Low (<$1,500)	382 (66.4)	192 (62.5)	566 (65.4)	
High (≥$1,500)	193 (33.6)	115 (37.5)	300 (34.6)	
Lifetime occupation, n (%)				0.59
Non manual	122 (21.0)	71 (23.3)	179 (20.6)	
Manual	346 (59.6)	172 (56.4)	536 (61.6)	
Housewives/unemployed	113 (19.5)	62 (20.3)	155 (17.8)	

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Acculturation score, *mean (SD)*	22.1 (12.9)	22.6 (13.2)	21.5 (12.8)	0.42
Nativity (Mexican born), n (%)	262 (44.7)	153 (49.4)	491 (55.7)	0.0002

* ANOVA tests for continuous variables and Chi-square tests for categorical variables.

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Table 2. Transitions between states defined by quartiles of neighborhood SEP scores.

Neighborhood SEP score (quartiles) (N tracts=257)	TOTALS	Quartile 1 (10.6 - <19.1) N=64	Quartile 2 (19.1 - <23.2) N=64	Quartile 3 (23.2 - <26.3) N=65	Quartile 4 (26.3 - 30.6) N=64
N (%)		785 (44.3)	559 (31.5)	246 (13.8)	187 (10.5)
		Number of Participants			
No Diabetes ever	190	79	65	28	18
Pre-diabetes always	42	20	14	5	3
Diabetes always from baseline	586	287	180	67	52
		Number of state transitions			
Normal to Pre-diabetes	393	161	116	65	51
Normal to Diabetes	132	49	36	24	23
Normal to death w/o diabetes	120	63	35	17	5
Prediabetes to Diabetes	169	73	58	22	16
Prediabetes to death w/o diabetes	56	28	17	9	2
Prediabetes to normal	321	115	95	67	44

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Table 3. Association between NSEP scores (interquartile range) and transitions within Multi-state Markov regression models

	Model 1	Model 2
Transition states:	HR (95% CI)	HR (95% CI)
Normal (no diabetes) - Pre-diabetes	1.01 (0.85, 1.19)	1.05 (0.88, 1.26)
Normal (no diabetes)- Diabetes	1.53 (1.07, 2.20)*	1.66 (1.14, 2.42)**
Normal - Death without Diabetes	0.61 (0.43, 0.85)**	0.56 (0.33, 0.96)*
Pre-diabetes - Normal (no diabetes)	1.26 (1.04, 1.52)*	1.22 (0.99, 1.50)
Pre-diabetes – Diabetes	0.80 (0.62, 1.05)	0.83 (0.62, 1.10)
Pre-diabetes - Death without Diabetes	0.62 (0.35, 1.10)	0.76 (0.40, 1.44)
Log Likelihood	7421.452	6469.601

Model 1 NSEP (7 units)
Model 2 is Model 1 + adjusted for BMI, age, education in years, physical activity summary score, smoking status (ever/never), any alcohol consumption, medical insurance (yes/no), and nativity (US born/Mexican born);
* p<.05; ** p<.001;

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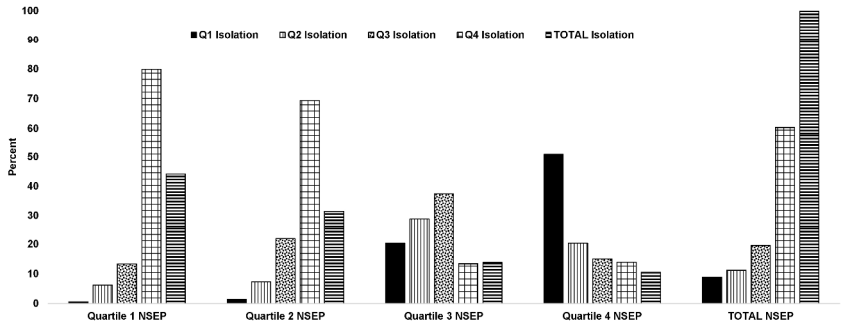
Figure 1. Association between Neighborhood Socioeconomic Position score and Hispanic Isolation Index



Association between Neighborhood Socioeconomic Position score and Hispanic Isolation Index
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The influence of neighborhood socioeconomic position on the transition to type II diabetes in older Mexican Americans: The Sacramento Area Longitudinal Study on Aging

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Abstract

Objective: To examine the influence of neighborhood socioeconomic position (NSEP) on development of diabetes over time.

Design: A longitudinal cohort study.

Setting: The data reported were from the Sacramento Area Latino Study on Aging, a longitudinal study of the health of 1789 older Latinos.

Participants: Community-dwelling older Mexican Americans residing in the Sacramento Metropolitan Statistical Area.

Main Outcome: Multi-state Markov regression were used to model transitions through four possible states over time: 1= normal; 2=pre-diabetic; 3=diabetic; and 4=death without diabetes.

Results: At baseline, nearly 50% were non-diabetic, 17.5% were pre-diabetic, and nearly 33% were diabetic. At the end of follow-up there were a total of 824 people with type 2 diabetes. In a fully adjusted MSM regression model, among nondiabetics, higher NSEP was not associated with a transition to pre-diabetes. Among nondiabetics, higher NSEP was associated with an increased risk of diabetes (HR= 1.66, 95%CI= 1.14, 2.42) and decreased risk of death without diabetes (HR: 0.56, 95% CI = .33, .96). Among pre-diabetics, higher NSEP was significantly associated with a transition to nondiabetic status (HR: 1.22, 95% CI = 0.99, 1.50). Adjusting for BMI, age, education, physical activity, smoking, alcohol consumption, medical insurance and nativity did not affect this relationship.

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Conclusion: Our findings show that high NSEP poses higher risk of progression from normal to diabetes compared to a lower risk of death without diabetes. This work presents a possibility that these associations are modified by nativity or culture.

Strengths and Limitations of the Study

Our study adds to the body of literature on older Latinos, NSEP, and diabetes status. If in the next four decades Latinos become the largest ethnic minority in the US, then understanding the roles that NSEP and cultural change play in the prevention of prediabetes and diabetes and its health related costs and complications is vital.

Data are from a longitudinal cohort study of physical and cognitive impairment and cardiovascular diseases in community-dwelling older Mexican Americans residing in Sacramento Metropolitan Statistical Area.

Three levels of data were used for this data analysis where individuals were nested within neighborhoods over time. We had neighborhood-level and individual-level data. The analysis accounted for both socio-demographic and health/behavioral variables.

Our findings may be due to unmeasured mediators such as behavior and/or differential access to health care. As Latino immigrants become more acculturated they are more likely to have higher levels of education and income but they also may be more likely to consume more alcohol, smoke and adapt unhealthy food choices associated with a more US diet.

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Introduction

Research into the effects of the community context on individual health outcomes reveals that neighborhood socioeconomic position (NSEP) is a risk factor for chronic disease.[1-3] Lower NSEP has been associated with increased risk of diabetes[1,2] and its related complications, including cardiovascular disease,[2] chronic kidney disease,[4] and all-cause mortality.[5] Research shows that these conditions disproportionately affect minorities, including adults.[1,6] Neighborhood and individual cultural factors may influence the progression to type 2 diabetes. Some work has suggested that residence in a majority Hispanic neighborhood is protective for diabetes, obesity and other health outcomes.[7,8] This same work has reported that foreign-born Mexican Americans may experience better health outcomes compared to US born, even when accounting for neighborhood cultural and socio-demographic characteristics.

The development and progression of adult onset type 2 diabetes is influenced by an accumulation of behaviors and exposures over a lifetime, including many factors linked to neighborhoods, such as the availability of recreational opportunities, access to fresh fruits and vegetables, and social support networks.[6,9,10] Successful management of diabetes is influenced by access to medical care and behavioral risk factor modification. Despite recommendations from the American Diabetes Association,[11] many patients with diabetes are initially managed without medication.[12] Both individual socioeconomic status and NSEP are associated with access to medical insurance and medical care.[13] In addition, neighborhoods with low SEP tend to have lower density of stores selling fresh produce[6] as well as less space for recreational activities.[9] This may result in higher rates of obesity and, subsequently, higher rates of diabetes.[2] Therefore,

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through access to a healthful environment and access to medical care, NSEP is an important component of both prevention and management of diabetes.

Our objective was to examine the relationship between NSEP and transitions to diabetes status over time in cohort of Latino older adults, while accounting for individual social, health and behavioral characteristics. We hypothesized that Latinos living in higher NSEP neighborhoods would be less likely to transition into worse diabetes states than Latinos in lower NSEP neighborhoods.

Methods

Study Participants

Participants were from the Sacramento Area Latino Study on Aging (SALSA), a longitudinal cohort study of physical and cognitive impairment and cardiovascular diseases in community-dwelling older Mexican Americans residing in Sacramento Metropolitan Statistical Area.[14] Recruitment occurred between 1998-1999 and included 1,789 participants between the ages of 60–101 years at baseline. Every 12 to 15 months, interviews, biological and clinical data were collected on participants during in-home visits, with a maximum of six follow-ups to 2008. The Institutional Review Boards (IRB) at the University of Michigan, University of North Carolina, the University of California, San Francisco, and the University of California, Davis approved the SALSA study and along with the principles of the Helsinki Declaration. All participants provided appropriate informed consent annually.

We excluded 12 participants with missing baseline diabetes status or who lived in a neighborhood with NSEP score that is an outlier (NSEP score<=10), yielding a final sample size of 1,777 participants.

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Study Variables

Three levels of data were used for this data analysis where individuals were nested within neighborhoods over time.

Individual-level data.

Assessment of type-2 diabetes and pre-diabetes status: We defined diabetes as meeting any of the following criteria in semiannual follow-up interviews or annual laboratory examinations: 1) self-report of a physician's diagnosis of diabetes, 2) fasting blood glucose level of ≥ 126 mg/dL, 3) usage of diabetes medication (insulin or oral hypoglycemic agent), or 4) diabetes listed as a cause of death anywhere on a death certificate, provided the death occurred within the study period.[15] Pre-diabetes was ascertained by a fasting blood glucose level between 100 mg/dL and 125 mg/dL.

Assessment of other clinical and biological data: During the baseline examination, trained interviewers measured study participants' standing height and weight; body mass index (BMI; kg/m^2), was calculated as weight/ $height^2$. Participants reported the number of hours per week they engaged in certain physical activities (e.g. doing yard work, heavy housework, and walking around neighborhood). These were combined into a physical activity summary score and used as a continuous variable to facilitate convergence.

Assessment of socio-demographics: At baseline, demographic characteristics of participants were collected based on self-report, including age, health insurance, has a doctor, any alcohol consumption, any smoking, acculturation[16] and nativity (born in Mexico/other Latin American country or US).

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Assessment of individual-level socioeconomic position (SEP) measures: Several individual-level SEP factors were also measured at baseline. Each participant self-reported years of education completed, gross past-month household income, and major lifetime occupation. We created a variable that grouped gross past-month household income into low (< $1,500) and high (≥ $1,500) categories, and another variable that categorized participant's occupation as manual, non-manual, or other (a category that included housewives, the unemployed).

Neighborhood-level data.

Neighborhood socioeconomic position (NSEP): In line with prior literature, we operationalized neighborhoods as census tracts.[17,18,19] Participants' baseline addresses were geocoded to the 2000 US Census tracts, and linked participant data to census data. We utilized factor analysis to construct a NSEP score using previously validated procedures.[19] The factor analysis was performed with census tract-level socioeconomic variables using PROC FACTOR in SAS. Neighborhood characteristics that showed a loading greater than 0.4 in either a positive or negative direction were selected, used z-score standardized for scale consistency, reverse coded when necessary, and then summed to create a NSEP score (mean= 22.4 , SD=4.8 and range = 0 – 30.6). Our NSEP variable included 6 variables: the percentage of individuals 25 years of age or older without a high school diploma; the percentage of the population living below the poverty line; the percentage of individuals ≥ 16 years of age who at one time had been in the work force and who were unemployed; the percentage of households that owned their home, percentage of housing units that were vacant; and the median number of rooms in the household. Higher NSEP scores indicated higher neighborhood

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socioeconomic status. Further details on the statistical methods resulting in the NSEP score have been published elsewhere.[20] We also created the Hispanic Isolation Index which is defined as the average percentage of the study population that is Hispanic in a neighborhood.[14] We categorized the Hispanic isolation index (HII) into quartiles.

Statistical Analysis

We compared baseline covariates by baseline diabetes status. We used ANOVA to compare the means of continuous variables and chi-square tests to compare the frequencies of categorical variables.

We used Multi-state Markov models[21] to model each participant's transitions between four possible states over time: 1=normal; 2=pre-diabetic; 3=diabetic; and 4=death without diabetes. Multi-state Markov models describe the associations of covariates with probabilities of state transitions using hazard rates and assumes that the hazard rates are independent of which states were previously occupied and the time spent in the current state. Our models permitted the following transitions: from normal to pre-diabetic, normal to diabetic, normal to death without diabetes, pre-diabetic to normal, pre-diabetic to diabetic, and pre-diabetic to death without diabetes. We assumed that the diabetic and death without diabetes states were absorbing (final state). We fit a series of Multi-state Markov models to the data by the method of maximum likelihood.

Model 1 included just the main predictor of interest, neighborhood SEP score (in units of interquartile range, IQR=7). Model 2 adds adjustment for other individual-level factors, including baseline BMI, baseline age, years of education, physical activity, smoking status, any alcohol consumption, medical insurance and nativity. Hazard ratios

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for each transition along with their 95% CI were estimated for each transition adjusted for covariates.

All analyses were performed using SAS version 9.4 and the msm package in R version 3.1.1.[22] All statistical tests were two sided and p<.05 was considered statistically significant.

Results

At baseline, while the majority of participants did not have diabetes (49.6%) the prevalence of diabetes (33%) and pre-diabetes (17.5%) was high (Table 1). At baseline, there were 586 cases of type 2 diabetes and 310 pre-diabetes cases. Follow-up data on diabetes and pre-diabetes were available through June 2008, with a total of 205 incident diabetes cases and 824 incident pre-diabetes cases. Diabetes status was significantly associated with older age, higher BMI, and lower physical activity. Compared to non-diabetics, those with diabetes were more likely to have health insurance, and a regular doctor. Mexican born were less likely to have diabetes than US born. Diabetics were less likely to drink alcohol. Acculturation, years of education, household income, and occupation did not differ by diabetes status.

Association between neighborhood socioeconomic position (NSEP) and diabetes transitions.

Table 2 shows the distribution of the number of participants by quartile of the NSEP. The majority of participants (75.8%) fell into the two lowest quartiles. Also shown is the distribution of the number of transitions by NSEP quartile. Forty percent of the transitions from normal to pre-diabetes, 37% of normal to diabetes transitions, 52.5% of

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transitions from normal to death, 43% of pre-diabetes to diabetes transitions, 50% of pre-diabetes to death and nearly 36% of pre-diabetes to normal all occurred in the lowest NSEP quartile. Mexican-born nativity was significantly higher in the lowest compared to the highest quartile (55.4% vs. 42.3%, p=.0003). Mean acculturation score and years of education were lowest in Quartile 1 compared to Quartile 4 (p<.0001, respectively).

Association between neighborhood socioeconomic position (NSEP) and transitions.

Table 3 shows the results of transition models with no adjustment (Model 1), and (Model 2) with adjustment for BMI, baseline age, physical activity, health insurance, alcohol consumption, smoking, acculturation and nativity. In Model 2, among participants who were normal at baseline, NSEP was not associated with a transition from normal to pre-diabetes. Higher NSEP was significantly associated with an increased risk for transition from normal to diabetes (HR= 1.66, 95% CI= 1.14, 2.42) and a decreased risk for transition from normal to death without diabetes (HR: 0.56, 95% CI = 0.33, 0.96).

Among pre-diabetics, in Model 2, NSEP was not associated with transition to diabetes or to death without diabetes. Among pre-diabetics, higher NSEP was marginally associated with a transition to normal status for the fully adjusted model (HR: 1.22, 95% CI = 0.99, 1.50). Transitions from pre-diabetes to diabetes or to death without diabetes were not statistically significant. Figure 1 shows the associations between the NSEP measure and the Hispanic isolation index (both in quartiles). NSEP and HII are strongly associated such that higher Hispanic Index is associated with lower NSEP

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scores (Likelihood Ratio Chi square = 780.36, df=9, p<.0001). Thus, those living in the lower NSEP neighborhoods are also living in communities with greater proportions of Hispanics and are less isolated from a cultural context. From an MSM model stratified on nativity, we found that among normal US born, NSEP was associated with significantly higher risk of developing type diabetes (incident diabetes: HR: 1.13, CI: 1.03-1.24) and significantly lower risk of dying without diabetes (dying without diabetes: HR: 0.92, CI: 0.86-0.98). These are modest effects and among Mexican-born these associations were not significant.

Conclusion

We found that higher NSEP was associated with a greater likelihood to transition from normal to diabetes. However, higher NSEP was associated with a lower likelihood of transitioning to death without diabetes. Higher NSEP was associated with a greater likelihood that pre-diabetics would transition to normal status. All other transitions were not influenced by NSEP. We accounted for both socio-demographic and health/behavioral variables in our adjustments. Adjustment for individual socioeconomic factors (education, income, occupation) did not substantially influence the association of Census-level NSEP with the various transitions. The opposite effects of NSEP in normal participants of higher risk of incident diabetes and lower risk of death without diabetes may be explained by the negative influence of low SES and potentially beneficial higher concentrations of cultural protections represented by the HII.

Our findings may be due to unmeasured mediators such as behavior and/or differential access to health care. As Latino immigrants become more acculturated they

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are more likely to have higher levels of education and income but they also may be more likely to consume more alcohol, smoke and adapt unhealthy food choices associated with a more US diet.[23,24] In other literature, higher levels of acculturation have been associated with higher rates of obesity and diabetes.[25] Work by Kershaw et al[7] about neighborhood ethnic isolation suggested that prevalence of obesity was actually lower in Mexican American study participants living in a predominantly Hispanic neighborhood. In this same study, obesity was lower in the foreign-born but estimates were not made for the influence of nativity on obesity in relation to ethnic isolation.

Consistent with our initial hypothesis and some other work,[20] we did find that the transition from normal to non-diabetes death was associated with lower neighborhood social position (NSEP), while the transition from prediabetes to no diabetes was associated with higher NSEP. Latinos with increased levels of education and income are more likely to have access to and utilize health care. Health care utilization may increase medical screenings and treatment; all important factors in the prevention of death from any disease. For older Latinos, the utilization of health care is key as they are disparately at higher risk of diabetes and prediabetes compared to non-Latino Whites.[25] However, we adjusted for health care access with no effect. Access to care is more likely to affect progression of a condition than incidence, unless an intervention targets a risk factor such as obesity. We did not have measures of diet which is a limitation of the study.

The higher risk of developing diabetes associated with higher NSEP in our study of older Latinos was consistent with the Hispanic Paradox.[26] The protective effect of

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low NSEP on risk of death without diabetes in normal participants, specifically the decreased risk for transition from normal to death without diabetes, may also be consistent with the Hispanic Paradox. The Hispanic Paradox postulates that Latinos have better health outcomes despite a lower socioeconomic status than non-Latino whites. Criticisms of this view suggest that migrants are a healthier population than the US born. Work by Espinoza[26] reports that the mortality difference in Mexican Americans vs. European Americans is largely explained by adjustment for socioeconomic measures. We have some evidence that less acculturated Latinos are less likely to transition to diabetes. It may be that as Latinos in our study became more acculturated over time, they adopted more unhealthy behaviors. Along with the rest of the nation, Latinos will age and live longer. It is predicated that over the next 40 years Latinos over the age of 65 will double and those over the age of 85 will triple.[25,27] If in the next four decades Latinos become the largest ethnic minority in the USA, then understanding the roles that NSEP and cultural change play in the prevention of prediabetes and diabetes and its health related costs and complications is vital.

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Competing Interests No potential conflicts of interest relevant to this article were reported.

Informed Consent The parent study (SALSA) was conducted with appropriate informed consent and in agreement with established Human Institutional Review Board procedures and consent at the University of Michigan, the University of California, San Francisco, and the University of California, Davis and along with the principles of the Helsinki Declaration.

Contributors LG conceived of the study, drafted the paper, interpreted the data, critically revised, and approved the manuscript. AL, JN performed statistical analysis and interpreted the data, and critically revised and approved the manuscript. AZHA, SM, AA, TE interpreted the data and critically revised and approved the manuscript. MNH obtained the funding; conceived of the study, wrote, critically revised, interpreted the data and approved the manuscript. LG and MNH are the guarantors of this work and, as such, and take responsibility for the integrity of the data and accuracy of the data analysis.

Data Sharing Statement No additional data available.

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Table 1. Comparison of Baseline Characteristics of SALSA Participants by baseline diabetes status.

Variable	Diabetes N=586 (32.9%)	Pre-diabetes N=310 (17.5%)	No Diabetes N=881 (49.6%)	p-value*
Demographics				
Age in years, *mean (SD)*	70.3 (6.9)	69.8 (6.9)	71.2 (7.3)	0.003
Health/Behavioral risk factors				
Body Mass Index (kg/m^2), mean (SD)	31.0 (6.3)	31.1 (5.6)	28.3 (5.4)	<.0001
Body Mass Index (kg/m^2), n (%)				<.0001
Normal: <25	68 (12.5)	26 (8.4)	216 (28.0)	
Overweight: ≥25 and <30	209 (38.4)	114 (36.8)	305 (39.5)	
Obese: ≥30	267 (49.1)	170 (54.8)	251 (32.5)	
Physical activity summary score, *mean (SD)*	16.3 (5.4)	17.6 (5.3)	17.6 (5.5)	<.0001
Any alcohol consumption, n (%)	234 (39.9)	191 (61.6)	519 (59.0)	<0.0001
Smoking, n (%)				0.05
Never smoked	259 (44.3)	130 (41.9)	429 (48.9)	
Former smoker	269 (46.0)	140 (45.2)	345 (39.3)	
Current smoker	57 (9.7)	40 (12.9)	104 (11.9)	
Health insurance *(n, % with)*	545 (93.0)	267 (86.7)	797 (90.7)	0.008
Has a regular doctor (n, % with)	537 (91.8)	265 (85.5)	762 (86.9)	0.004
Individual level SEP				
Years of education, *mean (SD)*	7.1 (5.4)	7.6 (5.4)	7.2 (5.3)	0.41
Household income, n (%)				0.51
Low (<$1,500)	382 (66.4)	192 (62.5)	566 (65.4)	
High (≥$1,500)	193 (33.6)	115 (37.5)	300 (34.6)	
Lifetime occupation, n (%)				0.59
Non manual	122 (21.0)	71 (23.3)	179 (20.6)	
Manual	346 (59.6)	172 (56.4)	536 (61.6)	
Housewives/unemployed	113 (19.5)	62 (20.3)	155 (17.8)	

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Acculturation score, *mean (SD)*	22.1 (12.9)	22.6 (13.2)	21.5 (12.8)	0.42
Nativity (Mexican born), n (%)	262 (44.7)	153 (49.4)	491 (55.7)	0.0002

* ANOVA tests for continuous variables and Chi-square tests for categorical variables.

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Table 2. Transitions between states defined by quartiles of neighborhood SEP scores.

Neighborhood SEP score (quartiles) (N tracts=257)	TOTALS	Quartile 1 (10.6 - <19.1) N=64	Quartile 2 (19.1 - <23.2) N=64	Quartile 3 (23.2 - <26.3) N=65	Quartile 4 (26.3 - 30.6) N=64
N (%)		785 (44.3)	559 (31.5)	246 (13.8)	187 (10.5)
		Number of Participants			
No Diabetes ever	190	79	65	28	18
Pre-diabetes always	42	20	14	5	3
Diabetes always from baseline	586	287	180	67	52
		Number of state transitions			
Normal to Pre-diabetes	393	161	116	65	51
Normal to Diabetes	132	49	36	24	23
Normal to death w/o diabetes	120	63	35	17	5
Prediabetes to Diabetes	169	73	58	22	16
Prediabetes to death w/o diabetes	56	28	17	9	2
Prediabetes to normal	321	115	95	67	44

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Table 3. Association between NSEP scores (interquartile range) and transitions within Multi-state Markov regression models

	Model 1	Model 2
Transition states:	HR (95% CI)	HR (95% CI)
Normal (no diabetes) - Pre-diabetes	1.01 (0.85, 1.19)	1.05 (0.88, 1.26)
Normal (no diabetes)- Diabetes	1.53 (1.07, 2.20)*	1.66 (1.14, 2.42)**
Normal - Death without Diabetes	0.61 (0.43, 0.85)**	0.56 (0.33, 0.96)*
Pre-diabetes - Normal (no diabetes)	1.26 (1.04, 1.52)*	1.22 (0.99, 1.50)
Pre-diabetes – Diabetes	0.80 (0.62, 1.05)	0.83 (0.62, 1.10)
Pre-diabetes - Death without Diabetes	0.62 (0.35, 1.10)	0.76 (0.40, 1.44)
Log Likelihood	7421.452	6469.601

Model 1 NSEP (7 units)
Model 2 is Model 1 + adjusted for BMI, age, education in years, physical activity summary score, smoking status (ever/never), any alcohol consumption, medical insurance (yes/no), and nativity (US born/Mexican born);
* p<.05; ** p<.001;

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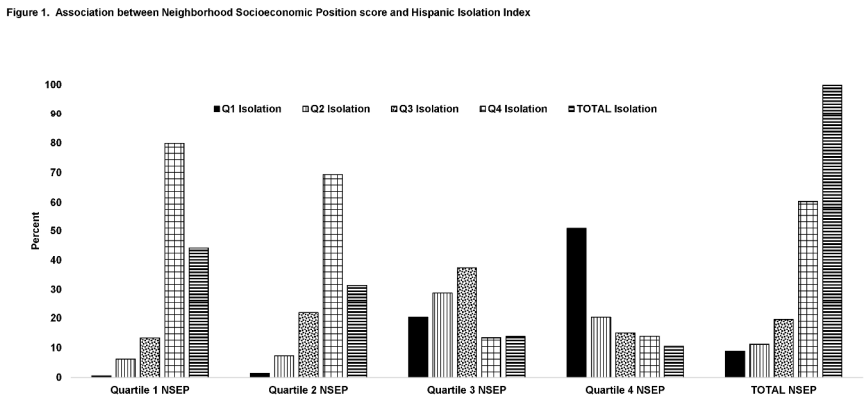

Association between Neighborhood Socioeconomic Position score and Hispanic Isolation Index
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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract ***PAGES 1- 2***	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale ***PAGES 3-4***	2	Explain the scientific background and rationale for the investigation being reported
Objectives ***PAGE 4***	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design ***PAGE 4***	4	Present key elements of study design early in the paper
Setting ***PAGE 4***	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants ***PAGES 4***	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables ***PAGES 5-7***	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement ***PAGES 5-7***	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias ***PAGES 7-8***	9	Describe any efforts to address potential sources of bias
Study size ***PAGES 4***	10	Explain how the study size was arrived at
Quantitative variables ***PAGES 7-8***	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods ***PAGES 7-8***	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy

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(*e*) Describe any sensitivity analyses

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Results		
Participants ***PAGE 8***	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data ***PAGE 8***	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data ***PAGES 8-10***	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results ***PAGES 8-10***	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results ***PAGES 10-12***	18	Summarise key results with reference to study objectives
Limitations ***PAGES 10-12***	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation ***PAGES 10-12***	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding ***PAGE 14***	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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