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Examining Between-Group Differences in Social Network Density and High-Sensitivity C-Reactive Protein in Older Adults: Implications for the Hispanic Mortality Paradox

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ABSTRACT

Objective: Hispanic/Latino(x) and African American/Black older adults experience disproportionate cardiometabolic disease burdens when compared with their non-Hispanic White counterparts. Sources of resilience such as social networks have been found to mitigate the risk of this disease and its end points like high-sensitivity C-reactive protein (hs-CRP). However, little is known about the social network infrastructure among these groups. Moreover, existing work has largely ignored the degree to which members of one's network are connected to one another (network density), which may be important for navigating structural barriers within interdependent groups. The objective of this study was to understand the association between network density and 5-year hs-CRP (blood spot) and whether this association was moderated by race-ethnicity.

Methods: A subsample of Hispanic/Latino(x), African American/Black, and non-Hispanic White older adults (N = 1431) from the National Social Life Health and Aging Project was used. Multivariable regression was used to estimate the association between network density and its interaction with race-ethnicity, with hs-CRP 5 years later.

Results: Although no main effect of network density on 5-year hs-CRP was found, results revealed a significant network density by race-ethnicity interaction (Wald $\chi^2(2, 1242) = 3.31$, $p = .037$). Simple slopes analyses revealed that Hispanic/Latino(x) older adults with high network density had significantly lower hs-CRP levels when compared with their same-ethnic counterparts with low network density ($b = -0.73$, standard error = 0.31, 95% confidence interval = −1.33 to −0.13, $p = .018$).

Conclusions: Results demonstrate population-level differences in social network structure and differential associations of this infrastructure with health. Implications for the Hispanic Mortality Paradox are discussed.

Key words: network density, high-sensitivity C-reactive protein, Hispanic, African American, older adults, Hispanic Mortality Paradox.

INTRODUCTION

Hispanic/Latino(x) and African American/Black older adults living in the United States experience disproportionately high levels of cardiometabolic disease compared with their non-Hispanic White (NHW) counterparts. These health disparities stem from high stress burdens including lower access to education, income, consistent and quality health care, and exposure to interpersonal prejudice (1,2). As disparities persist, factors associated with resilience to these stressors are most prudent to inform current health equity agendas. Resilience-based health interventions capitalize on the strengths of a community or cultural group and shift the focus from individual deficits to working with strong social infrastructures to optimize feasible structural change (3).

A robust literature demonstrates interpersonal social resources such as network size as being associated with long-term health, citing stress-buffering and behavioral processes as potential mechanisms. Several meta-analyses show strong associations between social network size and lower risk for cardiovascular disease and early death (4,5). These associations have been replicated with cardiometabolic end points such as high-sensitivity C-reactive protein (hs-CRP), an acute-phase protein and indicator of tissue death and systemic inflammation (e.g., tumor necrosis factor α, monocytes, and interleukin 6), and a robust predictor of cardiovascular disease

hs-CRP = high-sensitivity C-reactive protein, **NHW** = non-Hispanic White, **NSHAP** = National Social Life Health and Aging Project

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incidence, and progression (6–8). Although myriad factors influence hs-CRP in an aging population, structural and psychosocial factors such as stress and social networks also influence this end point. Furthermore, the uneven distribution of structural stress burden carried by racial-ethnic minority groups has led past research to investigate the potential for social infrastructure to act as a resilience factor for inflammatory processes including hs-CRP. Such studies have revealed potential modifiable pathways upon which to maximize strengths in social infrastructures to improve health and well-being in these populations (9).

However, one limitation of readily used network scales is their lack of ability to measure density, or the *connections between* network members. Little work has focused on network density and its association with health outcomes and end points. A dense network organization may facilitate an infrastructure where the burden of stressors can be quickly distributed among members and health-relevant information can be shared more easily—rendering an individual less vulnerable to challenges (10). Current work in this area has found that network density is associated with greater self-esteem and efficacy in young adults, as well as less risk for the mistreatment of older adults (11,12). Although little research has assessed how this specific aspect of network infrastructure may contribute to cardiometabolic risk including inflammatory end points such as hs-CRP in adults across the life span (13). The purposes of this study were to understand the association between network density and 5-year hs-CRP, and to understand whether this association varies across racial-ethnic groups in an older sample.

Race and ethnicity are social variables that capture an amalgam of social advantage, disadvantage, and shared culture and language. Although there are few studies examining nuanced differences in social capital across racial-ethnic groups of older adults, past research suggests that racial and ethnic identity as well as social advantage/disadvantage help to shape social infrastructure and sensitivity to social resources differentially (14–16). For example, NHW adults tend to endorse individualism, emphasizing the goals and values of an individual as opposed to a group (17). In addition, this group has greater generational wealth and socioeconomic status when compared with other racial-ethnic groups in the United States. This disparity is a direct consequence of historical slavery and structural racism, which also drives social exclusion and prejudice directed at non-White groups. Given these historical experiences, Hispanic/Latino(x) and non-Hispanic African American/Black older adults may be more inclined to align themselves in networks where emotional and tangible support are commonplace. For example, Hispanic/Latino(x) and non-Hispanic African American/Black adults tend to endorse more interdependent values, emphasizing the goals of a group versus the individual (18–20). Hispanic/Latino(x) adults tend to endorse high values of familism, or the tendency to prioritize time and resources toward family needs (20,21). African American/Black adults value familial older adults as natural mentors, potentially looking to older siblings, aunts or uncles, and grandparents for guidance (22). They also draw from institutional group involvement including church-related and political/activism groups to form their social networks and support (23,24). In addition, African American/Black adults endorse greater levels of familism when compared with their NHW counterparts in a sample of caregivers (25). Taken together, these studies suggest that racial-ethnic differences in social organization and values may influence how these groups offset stress from structural burdens (14).

A large proportion of literature on social networks and health has focused on network size and/or the specific make up of members within a network (network diversity) (26–28). Results from these studies show mixed results. On the one hand, larger supportive networks are associated with better cardiometabolic health outcomes for both healthy and clinical populations. For example, larger social networks as measured by the Social Network Index are associated with lower stroke incidence and mortality from cardiovascular disease in older adults (29). Family versus friend ties seem to have a greater influence on health in this regard. For instance, in a community sample of adults, a greater number of supportive family members (but not friends) were associated with lower hs-CRP levels; however, this association for older adults has not been explored (30,31). Health benefits from supportive ties also extend to one's spouse, illustrating the interpersonal benefits of a supportive network (32). On the other hand, some social network infrastructures can be detrimental. In a study of older adults, Goldman (31) found that network members holding primary "bridging" positions, or positions connecting kin and non-kin members in their network, had higher hs-CRP than those that do not serve as primary bridges. Authors suggest that this finding may be due to high social strain among these individuals (31). Given that the available literature on the salutary effects of family versus friend ties is focused on both adults and older adults, these effects may vary by age or life stage.

The gestalt of these results suggests that it is important to consider how race and ethnicity may moderate these associations in an older sample. For example, racial-ethnic groups that endorse interdependent social values may be differentially sensitive to a densely interconnected social network. Some research has revealed that race-ethnicity moderates the relationship between similar constructs like social support and hs-CRP. For instance, Uchino et al. (9) found that higher perceived social support was associated with lower hs-CRP levels in African American/Black adults, but not in NHW or Hispanic/Latino(x) adults. The relationship between network density, race-ethnicity, and hs-CRP has not been examined in diverse older adults, but could offer key insight into how a network can collectively manage stress experienced by an individual.

Network density is unique because it ignores specific connections from an individual to others in their network. Instead, network density measures the degree to which personal network members are connected to one another (33). Within a social network, connections are represented by "ties," which may be binary or weighted. Network density is equal to the number of ties between network members (alters) divided by the number of possible ties (33). The density of a weighted network is the average of the tie weights across all possible ties (33). A densely connected network would contain individuals who are in close contact with one another. Conversely, a loosely connected network would contain individuals who do not know one another.

Past literature suggests that the lack of social connectedness can influence health through inflammatory pathways (34,35). Specifically, isolation may lead to upregulated inflammatory processes given a higher probability for wounds (i.e., isolated people are more vulnerable to threats) (34). The vulnerability of an individual may indeed vary by the interconnectedness of one's network. For example, resources travel more quickly among members working as a team versus a set of isolated individuals who happen to be connected to the same individual. Therefore, a dense network organization may be a critical factor in mitigating structural stress burdens, especially in interdependent groups (36).

Given that hs-CRP is associated with high stress burden and is a key biomarker for cardiovascular disease risk, individuals within dense networks may enjoy optimal cardiometabolic health (37). Network density has been examined in the context of older adult mistreatment where Schafer and Koltai (11) found that dense (versus diffuse) personal networks were protective against the mistreatment of older adults. Authors of this study argued that dense networks provide structural protection against potential perpetrators (11). However, to our knowledge, no work has investigated whether dense network structures may influence cardiometabolic health in the three largest racial-ethnic groups in the United States.

This study aimed to understand a) the association between network density and cardiometabolic health as measured by 5-year hs-CRP and b) whether this relationship was moderated by race-ethnicity. We hypothesized that greater network density was associated with lower hs-CRP, 5 years later. Furthermore, given interdependent social values, we expected both non-Hispanic African American/Black and Hispanic/Latino (x) older adults with greater network density to experience a greater negative association between network density and 5-year hs-CRP as compared with NHW older adults with comparable network densities.

METHODS

Data Source and Sample

We examined the association between network density and hs-CRP in older Hispanic/Latino(x), non-Hispanic/African American Black, and NHW older adults from the National Social Life and Aging Project (NSHAP), yielding a total sample of $N = 2921$ respondents. The NSHAP is a nationally representative study examining social relationships and health in older adults living in the United States. The NSHAP used a multistage area probability design described elsewhere (38). Wave 1 data collection commenced in 2005 until 2006, and respondents were resurveyed 5 and 10 years later (wave 2, 2010–2011; wave 3, 2015–2016). Study personnel conducted in-home interviews at each wave with an original wave 1 cohort of 3005 older adults aged 57 to 85 years with a mean age of 69.3 years. Although several studies classify adults who are younger than 65 years "middle-aged," we follow the definition of "older persons" offered by the United Nations as 60 years and older, as well as the NSHAP's reference to their samples as an "older population" (39,40). Eighty-four participants who self-reported their race-ethnicity to be non-Hispanic Asian or Pacific Islander ($n = 35$), non-Hispanic American Indian or Alaskan Native ($n = 22$), and non-Hispanic Other ($n = 13$), or did not know or refused to answer the questions about race-ethnicity ($n = 15$) were excluded from the study. The small number of participants in these groups precluded meaningful analyses. This exclusion was indeed a limitation, and future studies should seek to overrepresent respondents from these often-overlooked subpopulations. Of the sample returning at wave 2 ($N = 2193$), baseline hs-CRP was missing for 762 participants. We found that respondents who reported having "some college" and African American/Black older adults were more likely to have a missing baseline hs-CRP value. There were no other significant differences across substantive variables among those who were missing a baseline hs-CRP measure versus those who were not. Our final sample included $N = 1431$ respondents.

Network Density

Social network analysis was used to calculate network density from respondents' ego-nets. Respondents were asked to name the number of confidants (alters) in their network with whom they have regular contact via the following, "Now we are going to ask you some questions about your relationships with other people. We will begin by identifying some of the people you interact with on a regular basis." Next, respondents were asked to estimate to what degree their confidants talk to one another (ties) by the question, "How frequently do [name1] and [name2] talk to each other?" Responses ranged from 0 = "have never spoken to each other" to 4 = "once a month," to 8 = "every day." Network density is equal to the number of ties between alters divided by the number of possible ties. Ties may be binary (0 or 1) or weighted as in this study. Weights ranged from 0 to 1 and were the ratio of the frequency to which each alter speaks to one another divided by the highest possible score a respondent can endorse for this question. The density of a weighted network is the average of the tie weights across all possible ties (33). Detailed information regarding the collection and measurement of NSHAP respondent ego-nets may be found elsewhere (41).

Race-Ethnicity

Race-ethnicity is a sociocultural and political construct. This study included race-ethnicity as a social proxy for myriad interpersonal and systematic advantages and disadvantages. Respondents of the NSHAP self-reported their race-ethnicity characterized by Hispanic or Latino, non-Hispanic African American or Black, and NHW. Hispanic/Latino(x) respondents may come from any race. Race-ethnicity should not be construed as a biological variable.

High-Sensitivity C-Reactive Protein

High-sensitivity CRP (in milligrams per liter) was collected at waves 1 and 2 using dried blood spots retrieved during home visits/interviews for respondents in the NSHAP. A thorough review of the NSHAP blood spot protocol is available elsewhere (42). Note: hs-CRP at wave 3 is not publicly available currently.

Covariate Adjustment

Covariate and control variables were chosen based on prior literature and the use of a directed acyclic graph model. Directed acyclic graph models are epidemiological tools used to identify important confounds, mediators, and moderating factors with respect to investigator's hypotheses or assumptions about health processes (43). Standard epidemiological controls including age, sex, and education were considered and included as inflammatory conditions often increase with age and are sensitive to social and economic opportunities often segregated across both gendered and educational divides (44,45). Marital status at both waves 1 and 2 were included as covariates in adjusted models because couple status may influence the size of one's social network and health outcomes alike (46,47). On the other hand, because marital status is often considered a social network variable on its own, planned sensitivity analyses were conducted with and without marital status (see Statistical Analyses). Health variables were included as potential confounds and variables associated with the missingness at wave 2 (see Statistical Analyses). Smoking, waist circumference, and current cardiometabolic disease were included as potential confounds given their strong association with hs-CRP (48–50). Likewise, because literature demonstrates a strong link between smoking and hs-CRP levels, we also modeled the interaction between wave 1 hs-CRP and smoking behavior (38). Depressive symptoms and alcohol consumption were associated with missingness at wave 2 and were thus included in all models. Light to moderate alcohol consumption is also associated with optimal hs-CRP levels in adults (51).

All covariate and control variables were measured at the initial interview. Demographic variables included age, sex, and marital status. Age was measured continuously in years, sex had two levels including "male" and "female," and marital status had four levels including "married or living as married," "divorced or separated," "never married," and "widowed." Although historically conflated with biological sex assigned at birth, sex is a social construct shaped by myriad sociological and political factors. The NSHAP does not ask about biological sex assigned at birth but simply asks, "I am required to ask you the following: are you male or female?" We acknowledge that, although a binary representation of sex is common, it does not capture the continuum and potential fluidity of sex identity. Self-reported educational attainment was used as a proxy for socioeconomic status including the levels, "less than high school," "high school diploma or equivalent," "some college or vocational school," and a "bachelor's degree or greater."

Health variables included smoking, alcohol consumption, waist circumference, presence of cardiometabolic disease, and depressive symptoms. Both smoking and alcohol consumption were self-reported, and smoking behavior included the following levels: "nonsmoker" and "current smoker." The alcohol consumption variable was a combination of two questions including whether a participant currently drinks alcoholic beverages ("yes," "no") and the number of alcoholic beverages one consumes per week. If participants responded "no" to being a current drinker, they were coded as "0," whereas those participants who reported being a current drinker were given their reported number of alcoholic beverages consumed per week. Waist circumference was measured with a tape measure in inches (40). Depressive symptoms were measured using an 11-item version of the *Center for Epidemiologic Studies Depression Scale, Revised*, which is a scale for depressive symptoms and has been validated in older populations (52). An example item is as follows: "During the past week, I felt that everything I did was an effort." Respondents may endorse a 4-point Likert scale ranging from 1 to 4, with 1 = "rarely or none of the time," 2 = "some or a little of the time," 3 = "occasionally or a moderate amount of time," and 4 = "most of the time." This scale displayed adequate internal consistency in the sample total and across groups (total Cronbach α = .80; Hispanic/Latino(x) α = .84; non-Hispanic African American/Black α = .79; NHW α = .79).

Statistical Analyses

All data preparation and statistical analyses were conducted using R Statistical Software version 4.0.3 (53). The primary outcome, wave 2 hs-CRP, was log transformed to facilitate normally distributed model residuals in multiple, general linear regression models with Gaussian links. Wave 2, log-transformed hs-CRP was regressed on the interaction between network density and race-ethnicity, their main effects, and wave 1 hs-CRP. Models were adjusted for the following demographic characteristics: age, sex, marital status at waves 1 and 2, and educational attainment. Smoking behavior, the interaction of smoking behavior by wave 1 hs-CRP, waist circumference, presence of cardiometabolic disease, alcohol consumption, and depressive symptoms were included in all models as potential health confounds. All models were adjusted to account for the probability of selection, with poststratification adjustments for nonresponse. Approximately 8.1% of respondents in this study sample were lost to follow-up at wave 2. A missing mechanisms analysis was conducted to ascertain predictors of missingness. Variables associated with missingness at wave 2 were included in all models, including depressive symptoms and alcohol consumption.

Sensitivity Analysis

Three sensitivity analyses were performed. Because marital status may be associated with both network density and hs-CRP, it was included in all adjusted models as a potential confound. However, because marital status is commonly considered a social network variable on its own, we conducted a sensitivity analysis with marital status excluded from models to assess whether the addition of this variable biased our results. We also assessed whether our results changed when controlling for the potential interaction of marital status and network density on 5-year hs-CRP. In addition, previous research has demonstrated that sex also influences social integration with women having larger social networks than men (54). Thus, we also controlled for the interactive effect of sex by network density to assess whether our results changed.

RESULTS

Adjusted participant demographics across race-ethnicity are presented in Table 1. The sample was 54.4% female sex and reported an average age of 69.2 years. The sample was mostly NHW (66.9%), followed by non-Hispanic Black/African American (22.3%), and lastly Hispanic/Latino(x) (10.8%). Most participants reported being married or coupled (59.4%) and having completed some college (31.8%). Average network density (potential range, 0–1) was significantly higher in Hispanic/Latino(x) older adults (M = 0.62, standard error [SE] = 0.04; b = 0.16, se = 0.04, 95% confidence interval [CI] = 0.11–0.21, p < .001) when compared with NHW older adults (M = 0.45, SE = 0.01) and with non-Hispanic Black/African American older adults (M = 0.53, SE = 0.03; b = 0.11, se = 0.03, 95% CI = 0.05–0.16, p < .001). Likewise, non-Hispanic African American/Black older adults had significantly greater network density when compared with NHW older adults (b = 0.08, se = 0.03, 95% CI = 0.02–0.14, p = .002). The range of network density for all groups was 0 to 1. Network density was greater in male- versus female-identified older adults (b = 0.10, se = 0.02, 95% CI = 0.06–0.13, p < .001), and older adults with less than a high school degree had the highest network density (M = 0.60, SE = 0.03) when compared with all other educational attainment levels (all b values >0.06, all 95% CIs between 0.01 and 0.10). High-sensitivity CRP was significantly greater at baseline in non-Hispanic African American older adults (M = 5.16, SE = 0.91) when compared with both NHW older adults (M = 2.59, SE = 0.29; b = 1.68, se = 0.62, 95% CI = 0.47–2.89; p = .007), and Hispanic/Latino(x) older adults (M = 2.82, SE = 0.41; b = 1.52, se = 0.64, 95% CI = 0.26–2.77, p = .016). Married or coupled older adults (M = 0.60, SE = 0.01) had the highest network density when compared with older adults reporting other marital statuses (all b values >0.06, all 95% CIs between 0.01 and 0.11).

Results detailing hypotheses tests are included in Table 2. There was no main effect of network density on 5-year hs-CRP. Next, the interaction between network density and race-ethnicity was modeled and found to be statistically significant (Wald χ^2(2, 1242) = 3.31, p = .037). Simple slopes analyses revealed that Hispanic/Latino(x) older adults with high network density (+1 standard deviation above mean) had significantly lower hs-CRP

TABLE 1. Descriptions and Summary Statistics for Substantive Variables

	Total (N = 1431)	Hispanic/Latinx (n = 156)	African American/ Black (n = 195)	Non-Hispanic White (n = 1080)
	Mean (SE)[a]	Mean (SE)[a]	Mean (SE)[a]	Mean (SE)[a]
Age, y	69.67 (0.27)	68.45 (0.82)	69.21 (0.84)	70.04 (0.28)
Alcohol consumption (drinks per week)	1.32 (0.07)	0.84 (0.19)	0.45 (0.10)	1.65 (0.09)
Cardiometabolic disease[b], %				
No	63.95	61.68	51.52	67.88
Yes	36.05	39.32	48.48	32.12
Depressive symptoms (*CES-D-11*)	16.13 (0.16)	17.01 (0.51)	16.55 (0.50)	15.83 (0.17)
Education status, %				
Less than high school	20.07	56.29	28.89	10.27
High school diploma/equivalent	24.78	8.98	26.10	27.72
Some college/vocational school	31.80	25.73	28.37	33.94
Bachelor's degree or greater	23.35	9.00	16.65	28.07
Sex, %				
Male	45.61	47.70	32.37	48.61
Female	54.39	52.30	67.63	51.39
High-sensitivity C-reactive protein	3.08 (0.27)	2.82 (0.41)	5.16 (0.91)	2.59 (0.29)
Network density	0.49 (0.01)	0.62 (0.03)	0.50 (0.03)	0.46 (0.01)
Smoking behavior, %				
Current	14.42	11.45	25.01	12.29
Nonsmoker	85.58	88.55	74.99	87.71
Wave 1 marital status, %				
Married or living as married	59.44	61.04	35.29	65.36
Divorced or separated	13.41	12.42	29.50	9.44
Never married	2.92	2.10	6.19	2.25
Widowed	24.14	24.44	29.02	22.95
Wave 2 marital status, %				
Married or living as married	53.45	55.28	33.72	58.22
Divorced or separated	12.73	13.48	26.16	9.07
Never married	2.91	2.66	6.07	2.14
Widowed	30.09	28.57	34.05	30.57

SE = standard error; *CES-D-11 = Center for Epidemiologic Studies Depression Scale, Revised.*

All measures represented were measured at wave 1 (baseline) unless otherwise noted.

[a] Means and standard errors were weighted to adjust for the probability of selection and nonresponse.

[b] Cardiometabolic disease is a binary variable where 1 = a participant reported "yes" to having at least one of the following: myocardial infarction, heart failure, leg angioplasty, stroke, or diabetes, and 0 = reporting "no" to any of the cardiometabolic conditions.

levels when compared with Hispanic/Latino(x) older adults with low (−1 standard deviation below mean) network density (b = −0.73, se = 0.31, 95% CI = −1.33 to −0.13, standardized β = −0.16, p = .018), and this within-group difference was significantly greater than the within-group difference in NHW older adults (b = 0.89, se = 0.36, 95% CI = 0.19–1.59, standardized β = −0.16, p = .013). Network density did not vary within NHW or non-Hispanic African American/Black older adults. See Figure 1.

Results did not meaningfully change in sensitivity analyses. When removing waves 1 and 2 marital status from models, we found no main effect of network density on 5-year hs-CRP (b = −0.06, se = 0.16, 95% CI = −0.37 to 0.25, p = .699). The interaction between network density and race-ethnicity remained significantly associated with 5-year hs-CRP (Wald χ^2(2, 1242) = 3.31, p = .037). In a second sensitivity analysis, we also modeled the potential interaction between wave 1 marital status and network density (controlling for wave 2 marital status). In the network density main effects model, this interaction was associated with 5-year hs-CRP (Wald χ^2(3, 1241) = 3.16, p = .024); however, there was no main effect of network density when controlling for this interaction (b = 0.19, se = 0.22, 95% CI = −0.42 to 0.33, p = .648). In the model assessing the interaction of interest (network density by race-ethnicity), the wave 1 marital status by network density interaction on 5-year hs-CRP was significantly greater than zero (Wald χ^2(3, 1239) = 3.13, p = .025), and the interaction between network density and race-ethnicity

TABLE 2. Main Effects, Conditional Effects, on Wave 2 hs-CRP

	Main Effects				Conditional Main Effects With Race/Ethnicity by Density Interaction $\chi^2(2, 1242) = 3.31$; $p = .037$			
	Unstandardized		Standardized		Unstandardized		Standardized	
	b (se)	95% CI	*β*	*p*	*b* (se)	95% CI	*β*	*p*
Network density by race/ethnicity (NHW)	—	—		—	—	—		—
Hispanic/Latino(x)	—	—		—	**−0.89 (0.36)**	**−1.59 to −0.19**	**−0.16**	**.013**
Non-Hispanic Black	—	—		—	0.08 (0.48)	−0.85 to 1.01	0.01	.866
Network density	−0.04 (0.16)	−0.22 to 0.54	−0.01	.796	0.16 (0.19)	−0.22 to 0.54	0.03	.414
Race/Ethnicity (non-Hispanic White)	—	—		—	—	—		—
Hispanic/Latino(x)	−0.02 (0.12)	−0.25 to 0.20	−0.01	.829	0.47 (0.23)	**0.03 to 0.92**	**0.12**	**.038**
Non-Hispanic Black	0.15 (0.13)	−0.09 to 0.40	0.04	.218	0.09 (0.29)	−0.48 to 0.66	0.03	.753
Wave 1 hs-CRP	**0.14 (0.03)**	**0.01 to 0.07**	**0.18**	**<.001**	**0.14 (0.03)**	**0.01 to 0.07**	**0.18**	**<.001**
Age	0.01 (0.01)	−0.01 to 0.02	0.04	.362	0.01 (0.01)	−0.01 to 0.02	0.04	.381
Sex (male)	**−0.32 (0.09)**	**−0.49 to −0.15**	**−0.14**	**<.001**	**−0.31 (0.09)**	**−0.48 to −0.14**	**−0.13**	**<.001**
HS status (completed HS)	—	—		—	—	—		—
Less than HS	0.21 (0.13)	−0.03 to 0.46	0.07	.089	0.24 (0.13)	−0.01 to 0.48	0.08	.058
Some college	0.09 (0.10)	−0.10 to 0.29	−0.02	.353	0.11 (0.10)	−0.08 to 0.30	0.04	.268
Bachelor's+	−0.05 (0.10)	−0.25 to 0.14	0.09	.583	−0.04 (0.10)	−0.23 to 0.16	−0.01	.704
Wave 1 marital status (married)	—	—		—	—	—		—
Divorced/separated	0.07 (0.20)	−0.32 to 0.47	0.02	.715	0.10 (0.20)	−0.29 to 0.50)	0.03	.607
Never married	−0.19 (0.22)	−0.63 to 0.25	−0.03	.390	−0.25 (0.24)	−0.72 to 0.22	−0.03	.305
Widowed	−0.01 (0.14)	−0.30 to 0.27	−0.01	.917	−0.01 (0.14)	−0.28 to 0.27	−0.00	.969
Wave 2 marital status (married)	—	—		—	—	—		—
Divorced/Separated	−0.03 (0.21)	−0.44 to 0.38	−0.01	.872	−0.04 (0.21)	−0.45 to 0.38	−0.01	.862
Never married	0.44 (0.23)	−0.01 to 0.88	0.06	.055	0.50 (0.24)	0.02 to 0.98	0.07	.040
Widowed	−0.04 (0.14)	−0.31 to 0.24	−0.01	.791	−0.04 (0.14)	−0.31 to 0.23	−0.01	.774
Cardiometabolic disease[a] (yes)	−0.05 (0.09)	−0.23 to 0.12	−0.02	.535	−0.06 (0.09)	−0.23 to 0.11	−0.02	.506
Smoking behavior (smoking)	0.16 (0.11)	−0.06 to 0.39	0.05	.151	0.17 (0.11)	−0.05 to 0.39	0.05	.137
Waist circumference (inches)	**0.05 (0.01)**	**0.03 to 0.06**	**0.23**	**<.001**	**0.04 (0.01)**	**0.03 to 0.06**	**0.22**	**<.001**
Alcohol consumption per week	0.00 (0.02)	−0.03 to 0.03	0.00	.932	0.00 (0.02)	−0.03 to 0.03	0.00	.917
Depressive symptoms	0.01 (0.01)	−0.01 to 0.02	0.03	.357	0.01 (0.01)	−0.01 to 0.02	0.03	.314
Wave 1 hs-CRP by smoking behavior[b]	**0.11 (0.04)**	**0.03 to 0.18**	**0.15**	**.004**	**0.10 (0.04)**	**0.03 to 0.18**	**0.15**	**.005**

hs-CRP = high-sensitivity C-reactive protein; se = standard error; CI = confidence interval; NHW = non-Hispanic White; HS = high school.

Estimates in this table were derived by multiple, general linear regression models with Gaussian links weighted to adjust for the probability of selection and nonresponse. The interaction effect was estimated using a Wald χ^2 test.

Bolded estimates indicate effects significantly greater than zero.

[a] Cardiometabolic disease is a binary variable where 1 = a participant reported "yes" to having at least one of the following: myocardial infarction, heart failure, leg angioplasty, stroke, or diabetes, and 0 = reporting "no" to any of the cardiometabolic conditions.

[b] Instead of stratifying by smoker status or removing smokers from the analysis altogether, we modeled the interaction of smoking behavior and baseline hs-CRP to remove its unique contribution to the effect of interest. When interpreting the interaction, we found that smokers who had "high" (third quartile) hs-CRP at baseline also had significantly greater 5-year hs-CRP when compared with smokers who had "low" hs-CRP (first quartile) at baseline ($b = 0.04$, se = 0.02, $p = .019$; 95% CI = 0.07–0.21).

remained significant (Wald $\chi^2(2, 1242) = 3.31$, $p = .037$; in the same direction). When deconstructing the wave 1 marital status by network density interaction, we found that greater network density was protective for never married respondents such that never married respondents with dense networks had significantly lower hs-CRP 5 years after baseline when compared with their never married counterparts reporting diffuse networks ($b = −1.31$, se = 0.59, 95% CI = −2.47 to −0.15, standardized $\beta = −0.28$, $p = .026$). This effect was not present for any other marital status group.

In our third sensitivity analysis, we included a sex by network density interaction in both main effect (network density) and interaction (network density by race-ethnicity) models. In the main effect model, we found no main effect of network density on 5-year hs-CRP ($b = −0.11$, se = 0.26, 95% CI = −0.62 to 0.24, $p = .67$), and the sex by network density interaction effect was not greater than zero (Wald $\chi^2(1, 1243) = 0.17$; $p = .678$). In the model estimating the network density by race-ethnicity interaction effect, we found that the network density by sex interaction effect was not significantly greater than zero (Wald $\chi^2(1, 1244) = 0.36$;

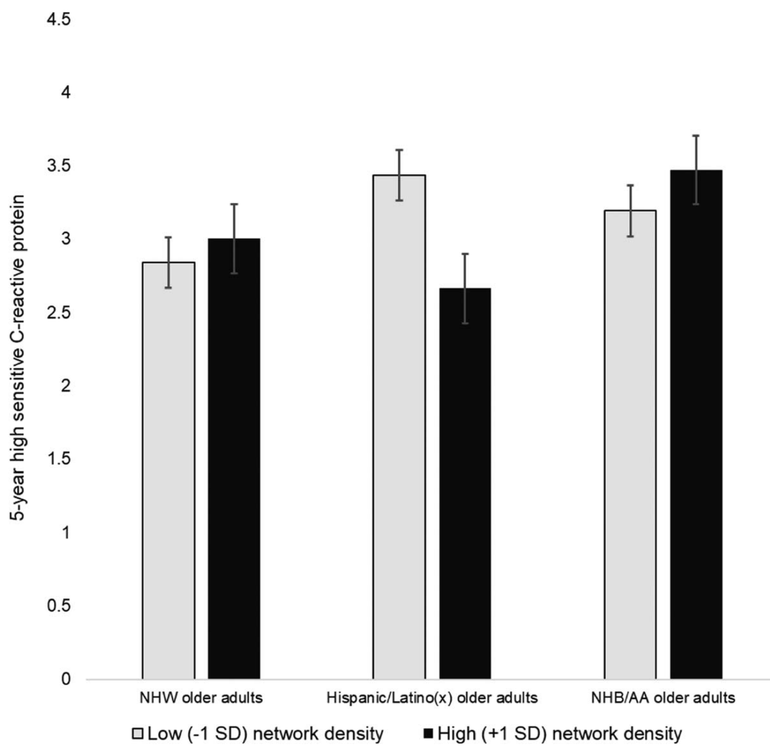

FIGURE 1. Race-ethnicity moderates the association between network density and 5-year high-sensitivity hs-CRP ($\chi^2(2, 1242) = 3.31$; $p = .037$). Hispanic/Latino(x) older adults with high network density (+1 SD above sample mean; SD = 0.27) had significantly lower hs-CRP levels when compared with Hispanic/Latino(x) older adults with low (−1 SD below sample mean) network density ($b = -0.73$, se = 0.31, 95% CI = −1.33 to −0.13; standardized $\beta = -0.16$, $p = .018$). This within-group difference was significantly greater than the within-group difference in NHW older adults ($b = 0.89$, se = 0.36, 95% CI = 0.19 to 1.59; standardized $\beta = -0.16$, $p = .013$). Network density did not vary within NHW or non-Hispanic African American/Black older adults. Estimates are adjusted for baseline hs-CRP, age, sex, education, marital status at waves 1 and 2, depressive symptoms, smoking status, the interaction of smoking status by baseline hs-CRP, alcohol consumption, and cardiometabolic disease. Error bars represent the SE. CI = confidence interval; hs-CRP = high-sensitivity C-reactive protein; NHW = non-Hispanic White; NHB/AA = non-Hispanic Black/African American; SD = standard deviation; se = standard error.

$p = .548$); however, the network density by race-ethnicity interaction effect remained significantly greater than zero (Wald $\chi^2(2, 1245) = 3.18$; $p = .042$). All simple slope effects and interpretations remained the same.

DISCUSSION

This study assessed the association between network density and 5-year hs-CRP in older adults and whether this association was moderated by race-ethnicity. Contrary to our hypothesis, there was no direct association between network density and hs-CRP. However, in partial support of our hypothesis, we did find an interaction between network density and race-ethnicity, indicating that Hispanic/Latino(x) older adults with high levels of network density (versus low) had significantly lower levels of hs-CRP 5 years after baseline. Indeed, for Hispanic/Latino(x) older adults, moving from low network density to high network density resulted in a move from a "moderate or average" cardiovascular risk level to "high" cardiovascular risk (55). No other group displayed this association. We also found that this within-group difference (slope) in Hispanic/Latino(x) older adults was significantly greater when compared with the within-group difference in NHW older adults. This finding provided partial support for our hypothesis that Hispanic/Latino(x) older adults would show a greater protective effect of high network density on hs-CRP when compared with NHW older adults. As expected, both Hispanic/Latino(x) and non-Hispanic African American/Black older adults had greater network density when compared with their NHW counterparts. Interestingly, however, Hispanic/Latino(x) older adults had the highest level of network density across groups. Despite the substantially larger NHW sample relative to others, these differences were relatively large, especially when comparing the Hispanic/Latino(x) and NHW groups.

Although only partially supporting our hypothesis, our study findings may shed light on a potential mechanism underlying the Hispanic Mortality Paradox, an epidemiological phenomenon (56). Despite their worse socioeconomic status and high rates of cardiometabolic disorder (e.g., type 2 diabetes), Hispanic/Latino(x) adults in the United States display lower mortality when compared with their age-matched, NHW counterparts (57,58). Recent literature implies that this phenomenon is driven by social networks and support shaped by cultural values that are focused on family commitment and interpersonal warmth (36,59). However, little empirical evidence supports this hypothesis. Most studies show that social support is a moderator of health outcomes in Hispanic/Latino(x) populations; yet, these studies only replicate, and are not distinguishable from, the broader literature on social support and health and likewise do not always make racial-ethnic comparisons (60,61). The present study suggests that Hispanic/Latino(x) older adults have especially dense social networks compared with other racial-ethnic groups, and health in this group is *differentially* affected by this social network characteristic. Results also suggest that Hispanic/Latino(x) older adults with diffuse networks experience detrimental effects on hs-CRP, suggesting that health in this group is sensitive to network density, whereas other groups are not. This finding is similar to the findings of Barger and Uchino (62), who found that Hispanic older adults had a moderately lower mortality risk for all levels of social integration above the lowest, as opposed to both their NHW and African American/Black counterparts who only showed a moderate to small effect in the highest levels of social integration.

Although we expected to find similar results with respect to African American/Black older adults, there was no difference across social network density in hs-CRP levels within this group, nor was there a difference in simple slopes when compared with NHW older adults. Our results were dissimilar from findings reported by Uchino et al. (8) where the authors found that non-Hispanic Black adults with high support showed slightly lower levels of hs-CRP when compared with their NHW counterparts. We also did not observe a main effect or general protective effect of high network density on hs-CRP. Because little research exists vis-à-vis cultural/racial-ethnic differences in social network structure as it relates to broader health effects, we explored several post hoc directions in an attempt to understand our findings.

We were curious about whether modeling physical mobility/disability would shift our results to reveal an association between network density and 5-year hs-CRP that may be clouded by racial-ethnic differences on this measure (63). In a post hoc exploratory analysis, we found that disability, as measured by the Difficulty with Activities of Daily Living Scale (32), was significantly associated with lower network density ($p < .0001$) and both higher baseline and 5-year hs-CRP (both p values <0.0001). Subsequently, we included this variable in both the main effects and interaction models. However, no results changed. In fact, the interaction between network density and race-ethnicity on 5-year hs-CRP was qualitatively larger. This result was interesting because network density was negatively correlated with both educational attainment and disability/physical mobility, suggesting that network density may be deleterious versus salubrious as we hypothesized.

We found that older adults with lower educational attainment have denser networks, indicating that most individuals in the networks of these older adults know and speak to one another. This finding may point to a process by which lower educational attainment may inhibit geographic mobility (i.e., moving to different spaces throughout life), which may have stymied the development of a diffuse network. Although why the lack of diffusivity was not detrimental, but in fact protective for Hispanic/Latino(x) and not for others, may be due to a difference in the *make-up* of social networks across groups (family versus friend ties, etc.) such that Hispanic/Latino(x) networks may consist of mostly family members given their strong family-oriented culture (20). We explored this potential in the following paragraph.

Some literature suggests that family ties, but not friend ties, are more salubrious (17,18). Thus, we investigated some network characteristics of the three racial-ethnic groups in our study (Supplemental Digital Content, Table S1, http://links.lww.com/PSYMED/A885). We found that Hispanic/Latino(x) older adults have significantly smaller networks when compared with both NHW and African American/Black groups (Supplemental Digital Content, Table S1, http://links.lww.com/PSYMED/A885). Although they report having similar numbers of family ties as other groups, both NHW and African American/Black groups have significantly greater friend ties when compared with Hispanic/Latino(x) older adults. Interestingly, both non-Hispanic groups have similarly sized networks with similar numbers of role types (family, friend, etc.). However, social network size was not associated with either density or hs-CRP, nor did it interact with density. Perhaps these network differences indicate nuanced differences in cultural values that we did not consider when forming our primary hypotheses. Although we predicted that non-Hispanic African American Black and Hispanic/Latino(x) older adults would show a greater protective effect of network density on inflammation, as both are interdependent groups, perhaps they are interdependent in *different* ways with *different* downstream health effects. Along these lines, a study examining south Asian adults living in the United States found no association between network density and hs-CRP despite South Asians endorsing a largely interdependent culture (13). Given that Hispanic/Latino(x)s are family focused and have social networks made up of primarily family members, it is possible that they are more likely to benefit from network density than other groups. Another explanation may be that both non-Hispanic groups having both family and friend ties may experience more social strain within the dynamics of these groups as Goldman (31) suggested in his study of older adults who hold "bridging" positions between family and friend ties. Indeed, as shown in this study, there may be key differences in how network density may be protective to different racial-ethnic groups, highlighting the need to define and characterize social capital and its associated salubrious effects within different cultural groups.

Future Directions and Limitations

Our findings are not without limitations. We believe that between-group heterogeneity in cultural interdependence exists, and these differences result in different downstream health effects across groups. We assume that cultural differences across racial-ethnic groups drive the observed differences shown in network density. However, because the NSHAP did not directly measure culture, we could not test this hypothesis directly. Furthermore, race-ethnicity was used as a static variable that did not capture the dynamic nature of culture or potential within-group variability of collectivistic or individualistic practices. For example, acculturation nor any of its commonly used proxies (e.g., foreign-born status, years in the United States, Spanish preference) were not captured by the NSHAP for Hispanic/Latino(x) older adults at baseline—a variable with the potential to further explain the meaning of our results. Another limitation through which our results should be interpreted was that the likelihood of being missing at baseline for the hs-CRP measure was higher for African American/Black respondents. Because race-ethnicity was a variable of interest in our study, replication is needed to assess to what extent this missingness may have biased our results. Lastly, there is always a possibility that other variables explain our findings. Future research should include more focused investigations that measure specific cultural processes across groups to understand if and how these values shape social network infrastructure and health. In addition, future studies should attempt to disentangle the pathways from Hispanic/Latino(x) ethnicity to network density, including how stress and structural burden may play a role. Our findings are only generalizable to older adults, and again, replication is needed in a more representative age sample and across longer periods. Overall, our findings demonstrate population-level differences in social network structure and differential associations of this infrastructure with health.

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