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Allostatic load, unhealthy behaviors, and depressive symptoms in the Hispanic Community Health Study/Study of Latinos

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ABSTRACT

Background: The Environmental Affordances Model (EAM) proposes that the effects of chronic stress on depression are moderated by unhealthy behaviors and race/ethnicity. The unique social structures and contexts of Hispanics/Latinos in the U.S. may influence such relationships. This study evaluated whether unhealthy behaviors weakened the relationship between allostatic load, a measure of chronic stress, and future elevated depressive symptoms among Hispanic Community Health Study/Study of Latinos participants.

Methods: Longitudinal data (2008–2011 and 2014–2017) from 11,623 participants were analyzed. The exposure was allostatic load, an index of twelve established biomarkers categorized using clinically relevant cut points, at Visit 1. Elevated depressive symptoms were operationalized as a score of ≥10 (out of 30) on the CES-D 10 at Visit 2. An index of unhealthy behaviors, with one point each for cigarette smoking, excessive/binge drinking, sedentary behavior, and poor diet quality at Visit 1, was examined as an effect modifier. Multivariable logistic regression, in the overall sample and among Mexicans specifically and adjusted for demographic characteristics and elevated depressive symptoms at Visit 1, was used to model allostatic load, unhealthy behavior index (range: 0–4), and their interaction in relation to elevated depressive symptoms at Visit 2.

Results: Overall, greater allostatic load was associated with higher odds of elevated depressive symptoms after at least 6 years (aOR = 1.06, 95% CI = 1.01, 1.10). Overall, individuals with greater allostatic load and an unhealthy behavior index = 1, compared to those with an unhealthy behavior index = 0, had lower odds of elevated depressive symptoms at follow-up (aβ = −0.065, 95% CI = −0.12, −0.007).

Conclusions: The relationship between chronic stress and depression was partially moderated among Hispanics/Latinos who engaged in unhealthy behavior, which may have reduced their risk of elevated depressive symptoms given more chronic stress.

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1. Introduction

Depression is the main contributor to mental health morbidity in all populations. Among Hispanics/Latinos, the prevalence of depression is highest among Puerto Ricans compared to the prevalence in persons from other Hispanic/Latino heritages (Alegria et al., 2007; González, Tarraf, Whitfield, & Vega, 2010; Perreira et al., 2015; Wassertheil-Smoller et al., 2014). Mexicans and Puerto Ricans are also more likely than Whites to experience chronic major depression (González et al., 2010). The reasons why these heritage groups are more impacted by depression are not well understood. Some have observed that heritage-based differences in mental illness may be related to social contexts experienced by Hispanics/Latinos, such as perceived discrimination or socioeconomic disadvantage (Perreira et al., 2015; Wassertheil-Smoller et al., 2014), linked to chronic stress (Baum, Garofalo, & Yali, 1999; Pascoe & Smart Richman, 2009). Unhealthy behaviors also differ by heritage, with cigarette smoking being more common among Puerto Ricans and Cubans compared to other Hispanics/Latinos (Kaplan et al., 2014). Puerto Ricans and Mexicans are the most likely to have alcohol use disorders (Rios-Bedoya & Freile-Salinas, 2014). Furthermore, obesity is highest among Puerto Ricans and Dominicans while diet quality is lowest among Puerto Ricans and Cubans (Isasi et al., 2015; Mattei et al., 2016). Research has yet to elucidate how factors that differ by heritage, such as unhealthy behaviors, may interact with depression-related factors, such as chronic stress, to further influence depression among Hispanics/Latinos.

A theoretical framework, called the Environmental Affordances Model, has been proposed to explain how unhealthy behaviors may interact with chronic stress from inequalities in social, economic, and environmental opportunities to affect health among racial/ethnic minorities (Fig. 1). Differences by Hispanic/Latino heritage in evaluations of the Environmental Affordances Model would suggest that the differing social structures and contexts of individual heritages may modify the relationships between chronic stress, unhealthy behaviors, and depression. Therefore, the potential for unhealthy behaviors to differentially moderate the effect of chronic stress on depression by heritage would be due to the impact of differences in resources and opportunities by heritage. Given these variable social contexts and behavioral differences, there is a need to test whether the Environmental Affordances Model is relevant across individual Hispanic/Latino heritages.

1.1. Unhealthy behaviors and relationships with chronic stress

Studies have found potential biological mechanisms to explain why people may adopt unhealthy behaviors to deal with chronic stress. These plausible mechanisms include (a) the influence of stress on glucocorticoids to increase sensitivity of mesencephalic dopaminergic neurons to substances such as nicotine (Piazza & Le Moal, 1998); (b) the stress response of corticotropin-releasing factor, which alters neurological circuits responsible for reinforcement of excessive consumption of ethanol (Koob et al., 1998); and (c) the activation of glucocorticoids and glucocorticoid receptor occupancy by stress, having an effect on a metabolic feedback signal that inhibits stressor-induced direct glucocorticoid drive on the brain, which therefore increases the desire for sugary foods (Dallman et al., 2003).

1.2. Stress mediators and allostatic load

Two of the most commonly studied systems involved in the body's response to stress are the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (McEwen & Wingfield, 2003). The HPA axis responds to external stressors by a cascade of hormones that results in the production of glucocorticoids such as cortisol. The autonomic nervous system is known for stimulating the release of catecholamines in response to stress. In addition to other hormonal mediators, these primary stress mediators are adaptive responses to occasional events experienced by the individual in order to survive (McEwen & Seeman, 1999). However, when stressful events become chronic experiences then these responses can be maladaptive and lead to adverse health effects (McEwen & Stellar, 1993). These maladaptive effects can be assessed using markers of overused physiologic systems (Beckie, 2012). Conceptually, allostatic load is a measurement of the wear and tear on bodily systems due to such experiences and the unabated biological responses to chronic stress (McEwen, 2000).

Allostatic load has been conceptualized as a physiological reflection of self-reported chronic stress and was first constructed using data on ten biomarkers among African Americans and Whites: four primary mediators (serum dehydroandrosterone sulfate, urinary cortisol, urinary epinephrine, and urinary norepinephrine) and six secondary outcomes (systolic and diastolic blood pressure, waist-hip ratio, serum high-density lipoprotein and total cholesterol, and glycosylated hemoglobin) (McEwen, 2000; Seeman, Singer, Rowe, & et al., 1997). Since then, research has led to additional biomarkers such as fasting glucose, fasting triglycerides, body mass index, and heart rate (Beckie, 2012). Among Hispanics/Latinos, additional biomarkers have included homeostatic model assessment of insulin resistance, pulse pressure, and white blood cell count (Salazar et al., 2016). Although the components of an allostatic load measure in any one study are generally determined by available data and more often includes secondary outcomes than primary mediators, allostatic load has been consistently found to be associated with mental and physical well-being as well as all-cause and cause-specific mortality (Robertson, Beveridge, & Bromley, 2017; Schulz, Mentz, Lachance, & et al., 2012).

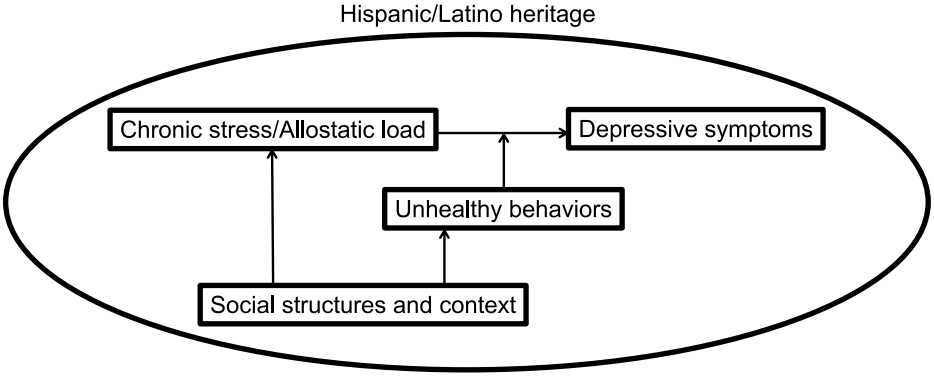

Fig. 1. Causal path between chronic stress or allostatic load, unhealthy behaviors, and depressive symptoms given the social structures and context of Hispanics/Latinos.

1.3. Social structures and contexts of Hispanics/Latinos

Resources and opportunities are not equally distributed across all heritages of Hispanics/Latinos. The percentages of Central Americans and Mexicans without a high school diploma are both over 40%, while proportions are about half that among Cubans (21.0%) and Puerto Ricans (22.6%) (Dominguez et al., 2015) compared to 10% among Whites. Poverty and unemployment also differ by heritage, with Dominicans and Puerto Ricans more likely to live below the poverty line (28.3% and 26.2%, respectively) and being unemployed (8.7% and 8.0%, respectively) between 2009 and 2013 (Dominguez et al., 2015). This compares to heritages such as Cubans, with lower prevalence of poverty (20.0%) and unemployment (6.0%), although higher than the U.S. overall (15.8% and 5.3%, respectively) (Dominguez et al., 2015).

Several other structural factors also differ by heritage among Hispanics/Latinos. Central American, Dominican, and Mexican immigrants have higher proportions of employment in service occupations; natural resources, construction, and maintenance occupations; and production, transportation, and material moving occupations compared to other Hispanics/Latinos with higher proportions of employment in management, business, science, and arts occupations (Migration Policy Institute, 2018a, 2018b, 2018c, 2019, 2020). Furthermore, the proportion of Hispanic/Latino immigrants with citizenship is approximately 60% among Cubans and 50% among Dominicans compared to about 30% among both Central Americans and Mexicans (Migration Policy Institute, 2018a, 2019; Pew Research Center, 2019b, 2019c). Puerto Ricans are U.S. citizens by birth.

Differences in health-related structural factors have also been observed. Central Americans and Mexicans have been disproportionately affected by the lack of access to health insurance (range: 20–35%) compared to Cubans (14%), Dominicans (12%), and Puerto Ricans (8%) (Pew Research Center, 2019a). Additionally, Puerto Ricans report some of the highest levels of discrimination while Cubans report lower levels (Arellano-Morales et al., 2015). Taken together, the differential distribution of these resources and opportunities across diverse Hispanics/Latinos provide context to the experiences of specific heritage groups.

1.4. Environmental Affordances Model

Both chronic stress and unhealthy behaviors have been independently linked to an increased risk of depression. A longitudinal relationship between life stressors throughout the lifespan with depression in adulthood has been consistently observed in the literature (Estrada-Martinez, Caldwell, Bauermeister, & Zimmerman, 2012; Hammen, 2005; Mandelli, Petrelli, & Serretti, 2015; Tennant, 2002). Additionally, unhealthy behaviors such as cigarette smoking (Quattrocki, Baird, & Yurgelun-Todd, 2000), at risk alcohol consumption (Sullivan, Fiellin, & O'Connor, 2005), poor diet quality (Li et al., 2017; Molendijk, Molero, Ortuno Sanchez-Pedreno, Van der Does, & Angel Martinez-Gonzalez, 2018), and sedentary behavior (Teychenne, Ball, & Salmon, 2010; Zhai, Zhang, & Zhang, 2015) have been associated with depression or depressive symptoms. The Environmental Affordances Model is a theoretical framework that attempts to understand the relationships between chronic stress, unhealthy behaviors, and depression.

The Model was generated in response to the observation that African Americans have a lower prevalence of major depression and suicide despite also having more socioeconomic disadvantage and more sources for chronic stress, including discrimination. The Model suggests that engaging in more unhealthy behaviors weakens, through moderation, the causal relationship between chronic stress and mental illness (Mezuk et al., 2013). Research by Jackson and colleagues suggested that as African Americans age, they engage in unhealthy behaviors to deal with chronic stress and unknowingly avoid depression (Jackson, Knight, & Rafferty, 2010). However, the use of unhealthy behaviors as a mechanism to deal with chronic stress and prevent depression among African Americans has been debated (Bates, Barnes, & Keyes, 2011; Boardman & Alexander, 2011; Mezuk et al., 2010). Other studies conducted among African Americans and Whites have failed to observe that unhealthy behaviors modified the relationship between chronic stress and depression (Keyes, Barnes, & Bates, 2011; Rodriquez et al., 2016; Walsh, Senn, & Carey, 2013).

The Environmental Affordances Model considers social structures and context to be fundamental determinants of health (Mezuk et al., 2013). Despite differences in such factors by Hispanic/Latino heritage, little research has been conducted. One study found that heavy alcohol use among Mexicans immigrants strengthened the relationship between chronic stress and depressive symptoms (Lipton, 1997). More recently, analyses showed that the effect of chronic stress on depressive symptoms among mostly Mexicans in Northern California was similarly strengthened through moderation by unhealthy behaviors (Rodriquez et al., 2019). Although there are differences in unhealthy behaviors and depression by heritage (González et al., 2010; Isasi et al., 2015; Kaplan et al., 2014; Mattei et al., 2016; Rios-Bedoya & Freile-Salinas, 2014; Wassertheil-Smoller et al., 2014), the Model has not been explored among Hispanics/Latinos of different heritages.

In this study, our overall goal was to identify modifiable biobehavioral mechanisms between behavioral and biological factors that explain the relationships between chronic stress, behavioral risk factors, and depressive symptoms for individual Hispanic/Latino heritages in the context of social structures. We made use of the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) that includes five heritage populations and based our hypotheses on relationships suggested by the Environmental Affordances Model. We had two main study objectives: (1) to describe the prevalence of depressive symptoms and unhealthy behaviors as well as mean levels of chronic stress and allostatic load among five heritages of Hispanics/Latinos and (2) to assess the relationship between chronic stress or allostatic load, unhealthy behaviors, and depressive symptoms.

For the second study objective, we had a series of hypotheses to assess whether the relationship between chronic stress or allostatic load and depressive symptoms differed by engaging in unhealthy behaviors. More specifically, we assessed whether unhealthy behaviors reduced the harmful effect of chronic stress or allostatic load on depressive symptoms or if they increased such effect because of the additional health consequences they cause. For all hypotheses, we expected that the relationship between chronic stress or allostatic load and depressive symptoms would weaken with engagement in unhealthy behaviors. Thus, the harmful effects of chronic stress on depressive symptoms would be blunted by engaging in unhealthy behaviors.

2. Methods

2.1. The Hispanic Community Health Study/Study of Latinos (HCHS/SOL)

HCHS/SOL is a multisite population-based cohort study of Hispanic/Latino populations in the U.S. that began in 2006 with the main goal of investigating the role of risk factors in the development of cardiovascular disease among Hispanics/Latinos. Sampling followed an area probability design that allowed the representative sampling of households in the communities of Bronx, NY; Chicago, IL; Miami, FL; and San Diego, CA. Approximately 60% of the sample at Visit 1 was over 44 years old and more than 4000 individuals were enrolled in each community. Representation across low and moderate levels of socioeconomic status were captured in the first stage of sampling, which were allocated proportionately across strata (Lavange et al., 2010). Further details on the sample design, cohort selection, and study rationale have been published previously (Lavange et al., 2010; Sorlie et al., 2010).

Participants visited their study-related field center for an examination and assessment administered either in English or Spanish (Hispanic Community Health Study/Study of Latinos Data Book: A Report to the

Communities). Data were collected for Visit 1 between 2008 and 2011 and for Visit 2 between 2014 and 2017. The number of participants that completed Visit 2 was 11,638 adults, 70.8% of the original cohort. This analysis only involved the use of deidentified data, which is considered "not human subjects research" and therefore does not require IRB review or approval per NIH policy and the Code of Federal Regulations, Title 45, Part 46.

2.2. Chronic stress and allostatic load

For this analysis, predictors of interest included self-reported chronic stress and allostatic load. Available only for the full cohort at Visit 2, chronic stress included ever experiencing the following for ≥6 months: (1) a serious ongoing health problem; (2) someone close who had a serious ongoing health problem; (3) ongoing difficulties with job or ability to work; (4) ongoing financial strain; (5) ongoing difficulties in a relationship with someone close; (6) someone close who had an ongoing problem with alcohol or drug use; (7) helping someone close who is sick, limited, or frail; and (8) another ongoing problem or a life-threatening illness. A score (range: 0–8) was created by summarizing 'Yes' responses.

Research (Salazar et al., 2016) using HCHS/SOL Visit 1 data defined allostatic load by grouping twelve biological indicators into four systems. The indicators assessed at both visits were: (a) cardiometabolic risk: body mass index, waist/hip ratio, triglycerides, and fasting high-density lipoprotein (HDL) and low-density lipoprotein (LDL) cholesterol; (b) glucose metabolism: fasting glucose, glycosylated hemoglobin (HbA1c), and homeostatic model assessment of insulin resistance (HOMA-IR); (c) cardiopulmonary functioning: systolic blood pressure, resting pulse pressure, and resting pulse rate; and (d) inflammation: total white blood cell count.

For each indicator, one point was assigned for those with values in the high-risk category, half of a point for moderate-risk values, and zero points for low-risk values (Rodriquez et al., 2019). Clinically relevant cut points were applied to all indicators, except HOMA-IR which was based on tertiles (Table 3). A sensitivity analysis was conducted by comparing allostatic load operationalized using clinically defined cut points to quartile and sex-specific cut points. Allostatic load score was not adjusted for medication use (Seeman et al., 2004). Points were summed across all twelve indicators to define allostatic load score at each visit (range: 0–12) (Beckie, 2012). The change in allostatic load score from Visit 1 to Visit 2 was calculated.

2.3. Unhealthy behaviors

We assessed four unhealthy behaviors at Visit 1: (1) cigarette smoking, (2) excessive or binge drinking, (3) sedentary behavior, and (4) poor diet quality (Jackson et al., 2010). Current smoking was assessed among participants who reported having ever smoked at least 100 cigarettes and now smoke daily or some days. Among participants who presently drink alcoholic beverages, the number of drinks consumed per week was assessed. Established criterion (National Institute on Alcohol Abuse and Alcoholism (NIAAA)) was used to identify excessive drinking: (a) for men <65 years old: >14 drinks per week on average and (b) for all women and men ≥65 years old: >7 drinks per week on average. Binge drinking was determined for women who reported drinking ≥4 drinks and for men who reported drinking ≥5 drinks within a 2-h period at least once a month. Sedentary behavior was identified by the Global Physical Activity Questionnaire as zero minutes per week of moderate or vigorous work-, transportation-, or recreation-related activity but more than zero minutes per day spent sitting or reclining. Poor diet quality was assessed using the Alternative Healthy Eating Index 2010 (AHEI-2010) and determined for participants with AHEI-2010 scores (0 = Worst to 110 = Best) in the lowest quartile (McCullough et al., 2002).

We also assessed cigarette smoking and excessive or binge drinking at Visit 2. For Visit 1, the unhealthy behavior index was constructed by summing 'Yes' responses (range: 0–4). Unhealthy behavior index at Visit 2 was constructed by summing 'Yes' responses for cigarette smoking and excessive or binge drinking at Visit 2 as the other measures were not collected.

2.4. Depressive symptoms

Depressive symptoms were assessed at both visits by the 10-item Center for Epidemiologic Studies Depression (CES-D 10) Scale (Andresen, Malmgren, Carter, & Patrick, 1994; Santor & Coyne, 1997). The items consisted of the following symptoms on a 4-point Likert scale (0 = Rarely or none of the time to 3 = All of the time) during the past week: *I was bothered by things that usually don't bother me*, *I had trouble keeping my mind on what I was doing*, *I felt depressed*, *I felt that everything I did was an effort*, *I felt hopeful about the future*, *I felt fearful*, *my sleep was restless*, *I was happy*, *I felt lonely*, and *I could not get going*. Elevated depressive symptoms were determined for both visits using the established cut point of ≥10 (range 0–30) and has been established to be reliable in HCHS/SOL (Andresen et al., 1994; Gonzalez et al., 2017; Santor & Coyne, 1997).

2.5. Demographic characteristics

Age, gender, educational attainment, country of birth, and heritage (Central American, Cuban, Dominican, Mexican, Puerto Rican, and South American) were assessed at Visit 1. Educational attainment was determined by the highest grade/level of education achieved (less than high school, high school graduate or equivalent, undergraduate certificate/degree, graduate/professional degree). Puerto Ricans born on the island were categorized as not having a birthplace in the 50 U.S. states or D.C. Participants were asked in what country or territory they were born and their self-identified heritage, including Cuban, Dominican, Mexican, Puerto Rican, and the two multinational groups of Central American and South American (heretofore solely referred to by their specific heritage group). Other heritages were excluded.

2.6. Statistical analyses

Means and standard errors were calculated for chronic stress score, allostatic load score, and unhealthy behavior index while frequencies were calculated for all other variables. Chi-square and *t* tests were used to evaluate differences in sample characteristics by Hispanic/Latino heritage. To test our hypotheses, we constructed three two-way interaction terms between chronic stress or allostatic load and unhealthy behavior index and one three-way interaction term between chronic stress or allostatic load, unhealthy behavior index, and heritage. Interaction terms were coded to estimate their effect on elevated depressive symptoms at Visit 2 at each level of unhealthy behaviors (1, 2, and 3 compared to 0). Based on the Environmental Affordances Model, we assessed the statistical significance of each interaction term, specifically the two-way interaction terms.

Bivariate regression models were conducted prior to the construction of multivariable models. A Box Cox transformation was used for variables in linear regression models between chronic stress and allostatic load, both at Visit 2. Multivariable logistic regression was used to conduct analyses to test all hypotheses. To organize the testing of our hypotheses, three sets of models were conducted. In the first set, cross-sectional models included chronic stress and unhealthy behaviors at Visit 2 (Model 1A), tested their interaction among Hispanics/Latinos overall and Mexicans specifically (Model 1B), and tested their three-way interaction with heritage (Model 1C) and their association with elevated depressive symptoms at Visit 2. In similar fashion, models were conducted for the second and third sets using allostatic load at Visit 2 (cross-sectional models) and Visit 1 (longitudinal models), respectively, in replace of chronic stress.

Covariates included demographic characteristics. Elevated depressive symptoms at Visit 1 was also included as a covariate in order to

reduce the chance of reverse causality with respect to our outcome of interest. Additional covariates that were assessed and subsequently removed from the final models, due to a lack of statistical significance, included years in the U.S. and race. Means and percentages were age-standardized and survey data analysis procedures were used to account for the complex sampling and weighting design. Analyses included participants with non-missing values for all variables and were conducted using SAS, Version 9.4 (SAS Institute, Inc., Cary, North Carolina).

3. Results

3.1. Demographic characteristics and elevated depressive symptoms

Out of 11,623 adults with complete data at Visit 2, 41.3% of the weighted sample was of Mexican heritage, 15.5% Puerto Rican, 14.2% Cuban, 10.4% Central American, 8.8% Dominican, and 6.5% South American (Table 1). Cubans (46.6 years), Puerto Ricans (42.9 years), and South Americans (42.4 years) tended to be older in mean age compared to Mexicans (38.6 years), Dominicans (39.3 years), and Central Americans (39.8 years) ($p = 0.001$). Most groups had greater proportions of women than men, with the exceptions of Cubans (52.4% men) and Puerto Ricans (50.3% men) ($p = 0.001$). Having less than a high school level of education was significantly more common among Central Americans (40.5%) and Dominicans (40.2%) while greater than a high school degree or equivalent was more common among Cubans (48.2%) and South Americans (50.3%) ($p = 0.001$). Most of the weighted sample (78.7%) was born outside of the 50 U.S. states or D.C., while Puerto Ricans had the largest proportion born within the 50 U.S. states or D.C. (47.5%). The prevalence of elevated depressive symptoms

Table 1
Age-standardized demographic characteristics, elevated depressive symptoms, and unhealthy behaviors by Hispanic/Latino heritage: 11,623 participants in the Hispanic Community Health Study/Study of Latinos, 2008–2011 (Visit 1) and 2014–2017 (Visit 2).

Characteristics	Total $n = 11,623$ %[a]	Central American $n = 1207$ (10.4%) %[a]	Cuban $n = 1645$ (14.2%) %[a]	Dominican $n = 1021$ (8.8%) %[a]	Mexican $n = 4806$ (41.3%) %[a]	Puerto Rican $n = 1801$ (15.5%) %[a]	p
Age, mean (SE)	41.1 (0.25)	39.8 (0.49)	46.6 (0.53)	39.3 (0.67)	38.6 (0.37)	42.9 (0.50)	<.0001
Age, categorical							<.0001
18–29 years	27.2	29.0	17.1	32.9	30.8	24.4	
30–39 years	21.0	24.3	15.8	18.7	25.0	17.2	
40–49 years	21.8	20.7	24.2	21.4	21.0	22.4	
50–59 years	16.1	15.6	18.9	16.0	13.6	19.4	
≥60 years	13.8	10.4	23.9	11.1	9.5	16.6	
Gender							<.0001
Men	47.5	45.8	52.4	39.4	46.0	50.3	
Women	52.5	54.2	47.6	60.6	54.0	49.7	
Education							<.0001
Less than high school	33.6	40.5	21.0	40.2	39.6	37.0	
High school graduate or equivalent	27.2	24.7	30.9	22.3	26.9	27.7	
Trade/vocational/associate's/ bachelor's degree	35.9	32.1	43.9	34.3	30.5	32.9	
Master's/professional/doctorate degree	3.3	2.7	4.3	3.2	3.0	2.4	
Birthplace							<.0001
Not born in 50 U.S. states or D.C.	78.7	93.4	90.9	86.8	79.3	52.5	
Born in 50 U.S. states or D.C.	21.3	6.6	9.1	13.2	20.7	47.5	
Elevated depressive symptoms at Visit 1[b]	27.8	25.7	27.3	28.4	22.7	38.2	<.0001
Elevated depressive symptoms at Visit 2[b]	24.2	23.0	23.9	26.7	18.3	39.0	<.0001
Unhealthy behaviors at Visit 1							
Current smoking[c]	21.1	14.2	26.8	11.4	16.6	33.6	<.0001
Alcohol drinking: Excessive[d]	6.4	5.6	7.1	5.8	6.0	7.3	0.0002
Alcohol drinking: Binge[e]	38.2	39.7	32.1	39.6	38.7	44.0	<.0001
Sedentary behavior[f]	21.6	17.2	31.9	19.2	19.5	18.5	<.0001
Poor diet quality[g]	23.5	18.7	41.9	13.9	5.2	56.3	<.0001
Unhealthy behavior index[h]							<.0001
1	38.7	35.0	41.5	37.9	36.5	40.3	
2	17.7	13.4	26.7	12.3	11.2	28.5	
3	4.0	1.9	6.5	1.6	1.6	10.0	
4	0.3	<0.1	0.8	0.2	<0.1	1.1	
Unhealthy behaviors at Visit 2							
Current smoking[c]	16.3	10.7	20.6	8.9	12.6	29.0	<.0001
Alcohol drinking: Excessive[d]	8.3	6.4	7.1	8.4	9.3	10.7	0.0017
Alcohol drinking: Binge[e]	24.0	22.9	23.6	20.2	24.9	21.9	0.0950
Unhealthy behavior index[h]							<.0001
1	23.7	15.0	26.9	21.8	21.4	31.9	
2	5.0	4.7	6.0	1.9	4.5	6.8	

Note. SE = standard error.

[a] Percentages based on non-missing values.

[b] Based on a score of ≥10 on the 10-item Center for Epidemiologic Studies Depression (CES-D) Scale (range: 0–30).

[c] Based on smoking daily or somedays at the time of assessment.

[d] For men <65 years old: >14 drinks per week on average; For women and men ≥65 years old: >7 drinks per week on average.

[e] Based on drinking ≥5 drinks per day for men or ≥4 drinks per day for women within a 2-h period at least once a month.

[f] Based on 0 min per week of moderate or vigorous physical activity but >0 min per day spent sitting or reclining as assessed by the Global Physical Activity Questionnaire.

[g] Based on the lowest quartiles as assessed by the Alternative Healthy Eating Index 2010.

[h] Respondents were assigned 1 point for each unhealthy behavior (excessive/binge drinking was 1 unhealthy behavior). Range at Visit 1: 0–4, range at Visit 2: 0-2.

was higher at Visit 1 (27.8%) than at Visit 2 (24.2%) except for Puerto Ricans, of which 38.2% at Visit 1 and 39.0% at Visit 2 reported elevated depressive symptoms, and 57.8% of individuals with elevated depressive symptoms at Visit 2 also had elevated depressive symptoms at Visit 1.

3.2. Unhealthy behaviors

Significantly higher weighted proportions of Puerto Ricans (33.6%) and Cubans (26.8%), and significantly lower proportions of Dominicans (11.4%), were current smokers at Visit 1 (Table 1). A higher proportion of Puerto Ricans were also binge drinkers (44%), followed by Central Americans (39.7%), Dominicans (39.6%), and Mexicans (38.8%). Except for Cubans (31.9%), most individuals had similar proportions of sedentary behavior ranging between 17.2% (Central Americans) and 19.5% (Mexicans). Poor diet quality was the highest among Puerto Ricans (56.3%) and lowest among Mexicans (5.2%). About half of Mexicans engaged in zero unhealthy behaviors (50.7%) while almost 80% of Puerto Ricans and more than 75% of Cubans engaged in one or more unhealthy behaviors at Visit 1.

3.3. Chronic stress and allostatic load scores

Puerto Ricans reported higher percentages of every chronic stressor at Visit 2 than all other heritages, ranging between 6.2% and 44.2% (Table 2). Dominicans had the second highest percentages of most chronic stressors compared to all other heritages, except for Mexicans and Puerto Ricans who reported similar percentages of having someone close with an ongoing problem with alcohol or drug use or another ongoing problem or a life-threatening illness, respectively.

Biological indicators of stress differed by heritage at both visits (Table 3). Puerto Ricans appeared to have the largest proportions in the high-risk category for half of all biomarkers. Mean allostatic load score was highest among Central Americans (Visit 1: 2.6, Visit 2: 2.7), Puerto Ricans (Visit 1: 2.5, Visit 2: 2.7), and Mexicans (Visit 1: 2.5, Visit 2: 2.6). All comparisons across heritage groups were significant at the $p < 0.0001$ level and results were similar when allostatic load was operationalized using quartile cut points.

In the overall sample, greater chronic stress was significantly associated with greater allostatic load cross-sectionally at Visit 2 (adjusted beta = 0.03, 95% confidence interval [CI] = 0.02, 0.04) as well as with an increase in allostatic load between Visit 1 and Visit 2 (adjusted beta = 0.01, 95% CI = 0.001, 0.02) (Data not shown).

3.4. Multivariable models assessing main effect variables in models 1A–3A

Results from multiple logistic regression models can be found in both Table 4 (beta coefficients) and the Supplemental Table (odds ratios). Across the three main effects, chronic stress at Visit 2, allostatic load at either visit, and unhealthy behaviors at either visit were consistently associated with an increased likelihood of elevated depressive symptoms at Visit 2 among Hispanics/Latinos overall (Table 4 and Supplemental Table, Models 1A, 2A, and 3A) after adjusting for elevated depressive symptoms at Visit 1. Among Mexicans, (a) greater chronic stress at Visit 2 was associated with a 1.51-fold increase in the odds, (b) greater allostatic load at Visit 2 was associated with a 1.14-fold increase in the odds, and (c) greater unhealthy behavior index at Visit 1 was associated with a 1.29-fold increase in the risk of elevated depressive symptoms at Visit 2 (Supplemental Table).

3.5. Multivariable models assessing models 1B–3B among Hispanics/Latinos overall

Significant interactions between allostatic load and two levels of the unhealthy behavior index, both measured at Visit 2, were observed in the total sample cross-sectionally (Table 4, Model 2B and Supplemental Fig. 1). In longitudinal analysis among Hispanics/Latinos overall, the interaction between higher allostatic load at Visit 1 and unhealthy behavior index = 1 significantly decreased the risk of elevated depressive symptoms at Visit 2 (adjusted beta = −0.065, 95% CI = −0.12, −0.007; Table 4, Longitudinal Model 3B and Fig. 2). All other interaction terms among Hispanics/Latinos overall were not observed to be statistically significant (Table 4, Model 1B).

3.6. Multivariable models assessing three-way interaction terms in models 1C–3C

None of the three-way interaction terms between chronic stress or allostatic load, unhealthy behavior index, and heritage were observed to be statistically significant (Table 4, Models 1C, 2C, and 3C).

3.7. Multivariable models assessing models 1B–3B among Mexicans specifically

For Mexicans, the relationship between greater allostatic load at Visit 2 and elevated depressive symptoms at Visit 2 weakened if they engaged

Table 2
Age-standardized chronic stressors and chronic stress score by Hispanic/Latino heritage: 11,623 participants in the Hispanic Community Health Study/Study of Latinos, 2014–2017 (Visit 2).

Stressors	Total n = 11,623 %[a]	Central American n = 1207 %[a]	Cuban n = 1645 %[a]	Dominican n = 1021 %[a]	Mexican n = 4806 %[a]	Puerto Rican n = 1801 %[a]	p
Chronic stress score[b], mean (SE)	1.57 (0.03)	1.45 (0.05)	1.39 (0.06)	1.86 (0.07)	1.38 (0.04)	2.19 (0.07)	<.0001
Serious ongoing health problem	28.8	26.6	27.6	34.2	23.6	39.7	<.0001
Someone close had a serious ongoing health problem	30.4	26.0	27.3	37.5	26.1	44.2	<.0001
Ongoing difficulties with job or ability to work	11.5	9.4	11.0	13.3	8.9	18.1	<.0001
Ongoing financial strain	28.6	29.2	29.3	35.1	23.1	37.3	<.0001
Ongoing difficulties in a relationship with someone close	15.9	15.1	11.2	18.1	15.3	23.0	<.0001
Someone close has an ongoing problem with alcohol or drug use	15.4	15.4	8.8	16.2	16.3	22.4	<.0001
Helping someone close who is sick, limited, or frail	22.7	19.9	21.4	25.8	21.3	28.7	<.0001
Another ongoing problem or a life-threatening illness[c]	4.3	3.6	2.7	6.2	3.6	6.2	<.0001

Note. SE = standard error.
[a] Percentages based on non-missing values.
[b] Range: 0-8.
[c] Life threatening illness such as heart attack; heart treatment or surgery; heart failure; stroke; stroke-related treatment or surgery; aortic aneurysm, abdominal aortic aneurysm, or ballooning of the aorta; blood clot requiring blood thinning medicine; peripheral arterial disease; liver disease; lung disease; or cancer or a malignant tumor.

Table 3
Age-standardized biological indicators of stress and allostatic load score by Hispanic/Latino heritage: 11,623 participants in the Hispanic Community Health Study/ Study of Latinos, 2008–2011 (Visit 1) and 2014–2017 (Visit 2).

Indicators (Using Clinically Relevant Cut Points)	Total $n = 11,623$		Central American $n = 1207$		Cuban $n = 1645$		Dominican $n = 1021$		Mexican $n = 4806$		Puerto Rican $n = 1801$	
	Visit 1[d] %[a]	Visit 2[d] %[a]	Visit 1[d] %[a]	Visit 2[d] %[a]	Visit 1[d] %[a]	Visit 2[d] %[a]	Visit 1[d] %[a]	Visit 2[d] %[a]	Visit 1[d] %[a]	Visit 2[d] %[a]	Visit 1[d] %[a]	Visit 2[d] %[a]
Allostatic load score[b], mean (SE)	2.45 (0.02)	2.54 (0.03)	2.59 (0.05)	2.70 (0.07)	2.36 (0.04)	2.41 (0.07)	2.21 (0.07)	2.34 (0.08)	2.48 (0.04)	2.56 (0.04)	2.52 (0.05)	2.67 (0.06)
Cardiometabolic risk												
Body mass index (kg/m^3)												
Low risk (<25)	22.4	19.5	22.7	20.7	27.2	22.3	20.0	21.4	20.8	17.5	20.4	18.9
Moderate risk (25–29)	37.6	38.0	39.1	38.5	36.6	37.5	38.4	37.3	40.1	41.7	32.8	32.5
High risk (≥30)	40.0	42.5	38.3	40.8	36.2	40.2	41.5	41.3	39.2	40.8	46.7	48.6
Waist/hip ratio												
Low risk[c]	29.9	23.1	29.7	24.8	34.4	29.1	31.3	24.4	25.2	19.4	33.6	25.5
Moderate risk[c]	20.4	19.9	19.7	19.4	22.9	21.9	22.2	18.8	19.8	21.2	17.7	16.1
High risk[c]	49.7	57.0	50.6	55.7	42.8	49.0	46.5	56.8	55.0	59.3	48.7	58.4
Triglycerides (mg/dL)												
Low risk (<150)	69.9	74.0	63.3	70.7	69.6	72.1	82.8	82.5	67.1	73.7	73.0	74.3
Moderate risk (150–199)	14.8	13.3	17.2	14.7	14.2	14.3	8.9	9.8	16.0	12.8	13.8	15.4
High risk (≥200)	15.3	12.7	19.5	14.6	16.2	13.7	8.3	7.8	17.0	13.5	13.2	10.2
HDL cholesterol (mg/dL)												
Low risk (≥60)	17.5	23.3	17.0	19.7	15.7	22.5	20.7	31.2	17.1	21.7	17.0	22.5
Moderate risk (40–59)	58.6	53.2	58.2	55.2	58.1	53.6	61.5	52.0	59.2	55.1	56.5	48.8
High risk (<40)	23.9	23.5	24.8	25.1	26.2	23.9	17.8	16.8	23.7	23.3	26.4	28.7
LDL cholesterol (mg/dL)												
Low risk (<100)	29.9	34.9	26.5	32.5	26.9	30.6	33.5	38.0	28.9	35.2	36.1	40.1
Moderate risk (100–130)	33.5	34.9	34.7	35.0	31.7	37.1	34.0	31.5	35.6	35.1	32.1	33.4
High risk (>130)	36.5	30.2	38.8	32.5	41.4	32.3	32.5	30.4	35.5	29.7	31.8	26.5
Glucose metabolism												
Glucose (mg/dL)												
Low risk (≤99)	66.7	56.6	67.2	55.7	68.9	58.8	69.3	64.0	65.9	52.9	66.1	60.0
Moderate risk (100–125)	24.8	31.4	24.3	32.1	25.1	31.6	23.1	25.9	24.9	34.2	23.9	24.8
High risk (≥126)	8.5	12.0	8.5	12.2	6.0	9.6	7.6	10.1	9.3	12.9	10.0	15.2
Glycosylated hemoglobin (%)												
Low risk (≤5.6)	62.0	50.3	60.6	47.3	67.9	56.6	58.8	48.2	59.7	49.1	59.3	48.6
Moderate risk (5.7–6.4)	26.7	34.6	27.8	35.9	24.1	32.1	28.5	34.5	27.8	35.0	27.5	33.3
High risk (≥6.5)	11.4	15.1	11.6	16.8	8.0	11.3	12.7	17.3	12.5	15.9	13.1	18.1
HOMA-IR (mmol/L)												
Low Risk (<1.8097)	32.5	33.4	25.9	27.0	30.3	33.2	36.5	45.9	33.3	30.0	34.5	35.6
Moderate risk (1.8097 to <3.4218)	33.4	33.5	36.9	36.0	35.5	35.4	36.9	29.1	32.7	34.6	30.1	31.8
High risk (≥3.4218)	34.0	33.2	37.2	37.0	34.3	31.4	26.5	25.1	34.0	35.4	35.4	32.6
Cardiopulmonary functioning												
Systolic blood pressure (mmHg)												
Low risk (<120)	52.0	50.8	49.0	47.6	49.1	47.6	46.3	44.4	57.0	55.4	48.5	49.4
Moderate risk (120–149)	40.9	40.6	42.1	40.7	43.1	43.0	45.0	44.5	37.7	38.4	44.2	42.1
High risk (≥150)	7.1	8.5	8.9	11.7	7.7	9.4	8.7	11.1	5.3	6.2	7.3	8.6
Pulse pressure (mmHg)												
Low risk (<40)	23.4	23.2	20.7	19.7	26.4	21.6	25.1	30.1	22.0	21.7	24.6	26.5
Moderate risk (40–59)	60.8	56.6	60.2	57.0	58.5	57.8	58.6	49.4	63.1	58.6	60.1	54.3
High risk (≥60)	15.7	20.2	19.1	23.3	15.1	20.5	16.4	20.4	14.9	19.6	15.3	19.2
Pulse rate (bpm)												
Low risk (≤60)	32.5	34.9	36.4	39.3	31.9	35.5	31.5	34.1	33.7	35.6	29.4	29.1
Moderate risk (61–89)	65.5	63.7	61.7	59.9	66.6	62.9	67.1	63.8	64.8	63.4	66.9	67.8
High risk (≥90)	2.1	1.4	1.9	0.8	1.5	1.6	1.4	2.0	1.6	1.0	3.8	3.1
Inflammation												
White blood cell count (10^9 cells/L)												
Non-high risk (≤11)	97.8	97.2	98.5	97.9	97.7	96.9	97.3	98.6	98.5	97.8	96.8	95.3
High risk (>11)	2.2	2.8	1.5	2.1	2.3	3.1	2.7	1.4	1.5	2.2	3.2	4.7

Note. HDL = high-density lipoprotein; HOMA-IR = homeostatic model assessment of insulin resistance; LDL = low-density lipoprotein; SE = standard error.
[a] Percentages based on non-missing values.
[b] Range: 0-12.
[c] Low, moderate, and high risk for men (≤0.95, >0.95 to <1.0, and ≥1.0) and women (≤0.80, >0.80 to <0.85, and ≥0.85).
[d] $p < 0.001$ for the difference between heritages at Visit 1 or Visit 2.

in one unhealthy behavior (adjusted beta = −0.16, 95% CI = −0.32, −0.01) compared to those who did not engage in unhealthy behaviors (Table 4, Model 2B and Supplemental Fig. 1). All other interaction terms among Mexicans were not observed to be statistically significant (Table 4, Model 1B and Model 3B, Fig. 2, and Supplemental Fig. 2).

4. Discussion

We found that Hispanic/Latino individuals with higher allostatic load at Visit 1 had slightly attenuated depressive symptoms at six to nine years of follow-up when they engaged in one unhealthy behavior versus

Table 4
Adjusted coefficients from logistic regression modeling of elevated depressive symptoms[a] at Visit 2 among 11,623 participants in the Hispanic Community Health Study/Study of Latinos, 2008–2011 (Visit 1) and 2014–2017 (Visit 2).

Independent Variables	Total β[b] (95% CI)	Mexican β[c] (95% CI)[d]
Model 1A		
Chronic stress score at Visit 2[e]	**0.49 (0.44, 0.54)**	**0.47 (0.36, 0.58)**
Unhealthy behavior index at Visit 2[f]	**0.11 (0.02, 0.20)**	0.14 (−0.099, 0.39)
Model 1B		
Chronic stress score at Visit 2[e]	**0.48 (0.41,0.55)**	**0.41 (0.28,0.55)**
Unhealthy behavior index at Visit 2[f]	0.15 (−0.068,0.22)	−0.089 (−0.44,0.26)
Interaction term: Chronic stress score at UBI (both at Visit 2) =		
0	Reference	Reference
1	−0.005 (−0.085, 0.08)	0.073 (−0.13, 0.27)
2	0.093 (−0.026, 0.21)	0.33 (−0.01, 0.68)
3 or 4	−0.028 (−0.20, 0.15)	0.16 (−0.42, 0.73)
Model 1C		
Chronic stress score at Visit 2[e]	**0.50 (0.44, 0.56)**	—
Unhealthy behavior index at Visit 2[f]	**0.13 (0.023, 0.24)**	—
Heritage		
Central American	**0.25 (-0.008, 0.50)**	—
Cuban	**0.43 (0.22, 0.63)**	—
Dominican	**0.30 (0.008, 0.59)**	—
Puerto Rican	**0.64 (0.39, 0.90)**	—
Mexican	Reference	—
Interaction term: Chronic stress score at Visit 2 X UBI at Visit 2 X Heritage	−0.005 (−0.017, 0.008)	—
Model 2A		
Allostatic load score at Visit 2[g]	**0.066 (0.030, 0.10)**	0.065 (−0.033, 0.16)
Unhealthy behavior index at Visit 2[f]	**0.12 (0.035, 0.21)**	0.16 (−0.087, 0.41)
Model 2B		
Allostatic load score at Visit 2[g]	**0.11 (0.057,0.17)**	**0.13 (0.0004,0.26)**
Unhealthy behavior index at Visit 2[f]	**0.24 (0.10,0.39)**	0.34 (−0.072,0.74)
Interaction term: Allostatic load score at UBI (both at Visit 2) =		
0	Reference	Reference
1	**−0.082 (-0.14, -0.02)**	**−0.16 (-0.32, -0.01)**
2	−0.071 (−0.16, 0.02)	−0.02 (−0.28, 0.25)
3 or 4	**−0.14 (-0.27, -0.002)**	−0.37 (−0.79, 0.051)
Model 2C		
Allostatic load score at Visit 2[g]	**0.073 (0.030, 0.12)**	—
Unhealthy behavior index at Visit 2[f]	**0.14 (0.032, 0.25)**	—
Heritage		
Central American	0.25 (−0.004, 0.51)	—
Cuban	**0.40 (0.20, 0.61)**	—
Dominican	**0.53 (0.21, 0.85)**	—
Puerto Rican	**0.84 (0.60, 1.08)**	—
Mexican	Reference	—
Interaction term: Allostatic load score at Visit 2 X UBI at Visit 2 X Heritage	−0.003 (−0.014, 0.007)	—
Model 3A (Longitudinal)		
Allostatic load score at Visit 1[g]	**0.05 (0.013, 0.098)**	0.072 (−0.04, 0.18)
Unhealthy behavior index at Visit 1[h]	**0.17 (0.082, 0.25)**	**0.26 (0.009, 0.51)**
Model 3B (Longitudinal)		
Allostatic load score at Visit 1[g]	**0.093 (0.033,0.15)**	0.11 (−0.018,0.24)
Unhealthy behavior index at Visit 1[h]	**0.23 (0.089,0.38)**	0.28 (−0.12,0.69)
Interaction term: Allostatic load score at UBI (both at Visit 1) =		
0	Reference	Reference
1	**−0.065 (-0.12, -0.007)**	−0.09 (−0.24, 0.06)
2	−0.065 (−0.16, 0.033)	−0.066 (−0.32, 0.19)
3 or 4	−0.034 (−0.20, 0.13)	0.188 (−0.40, 0.78)
Model 3C (Longitudinal)		
Allostatic load score at Visit 1[g]	**0.070 (0.019, 0.12)**	—
Unhealthy behavior index at Visit 1[h]	**0.21 (0.097, 0.32)**	—
Heritage		
Central American	0.24 (−0.018, 0.50)	—
Cuban	**0.40 (0.19, 0.60)**	—
Dominican	**0.57 (0.26, 0.89)**	—
Puerto Rican	**0.86 (0.63, 1.08)**	—
Mexican	Reference	—
Interaction term: Allostatic load score at Visit 1 X UBI at Visit 1 X Heritage	−0.007 (−0.018, 0.003)	—

Note. CI = confidence interval, UBI = unhealthy behavior index; Bold denotes statistical significance.

[a] Based on a score of ≥10 on the 10-item Center for Epidemiologic Studies Depression (CES-D) Scale.

[b] Models were adjusted for age, gender, educational attainment, birthplace, heritage, and elevated depressive symptoms at Visit 1.

[c] Models were adjusted for age, gender, educational attainment, birthplace, and elevated depressive symptoms at Visit 1.

[d] Bonferroni correction was conducted for the Mexican-stratified model due to the potential for increased Type I error.

[e] Chronic stressors included serious ongoing health problem; someone close had a serious ongoing health problem; ongoing difficulties with job or ability to work; ongoing financial strain, ongoing difficulties in a relationship with someone close; someone close has an ongoing problem with alcohol or drug use; helping someone close who is sick, limited, or frail; and another ongoing problem or a life-threatening illness such as heart attack; heart treatment or surgery; heart failure; stroke; stroke-related treatment or surgery; aortic aneurysm, abdominal aortic aneurysm, or ballooning of the aorta; blood clot requiring blood thinning medicine; peripheral arterial disease; liver disease; lung disease; or cancer or a malignant tumor.

[f] Unhealthy behavior index at Visit 2 included current smoking and excessive/binge drinking.

[g] Allostatic load included body mass index, waist/hip ratio, triglycerides, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, glucose, glycosylated hemoglobin, homeostatic model assessment of insulin resistance, systolic blood pressure, pulse pressure, pulse rate, and white blood cell count.

[h] Unhealthy behavior index at Visit 1 included current smoking, excessive/binge drinking, sedentary behavior, and poor diet quality.

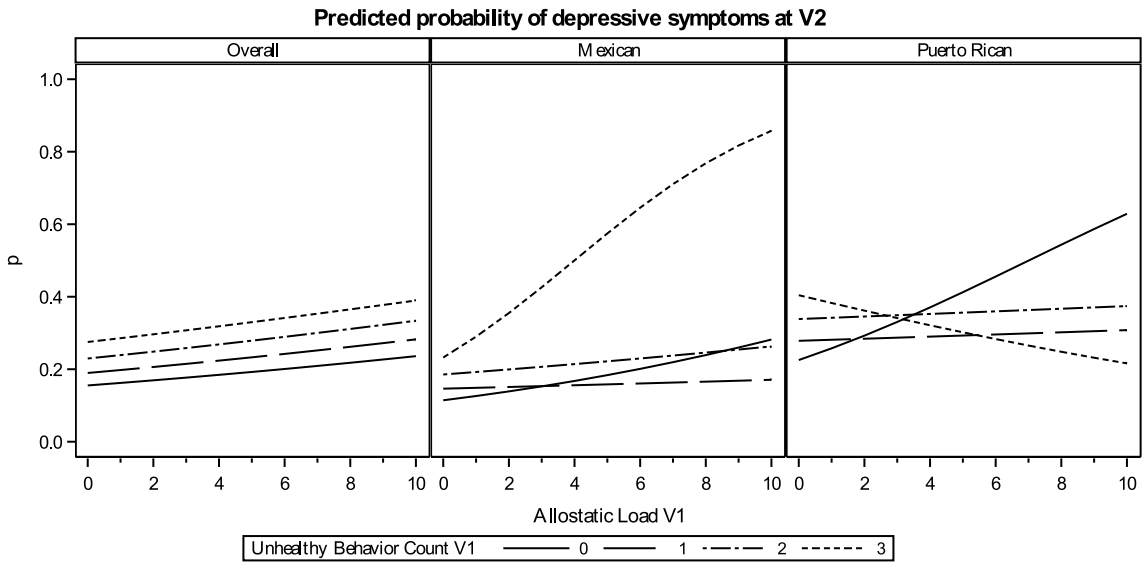

Fig. 2. Predicted probability of elevated depressive symptoms at Visit 2 by allostatic load score at Visit 1 for each level of unhealthy behavior index at Visit 1 for the total sample shown in the Overall panel ($n = 11{,}623$, $p < 0.027$ for unhealthy behavior index = 1); similar data are shown for Mexicans ($n = 4806$) and Puerto Ricans ($n = 1801$) in separate panels. Data are from the Hispanic Community Health Study/Study of Latinos, 2008–2011 (Visit 1) and 2014–2017 (Visit 2).

none. However, the interaction between chronic stress, or allostatic load, with unhealthy behaviors on elevated depressive symptoms among diverse heritages of Hispanics/Latinos revealed only partial support for the Environmental Affordances Model (Mezuk et al., 2013). Similar findings were also observed among Mexicans in cross-sectional analyses. Despite differing social structures and contexts among Hispanics/Latinos, results suggested that such factors did not moderate the general relationship between chronic stress and unhealthy behaviors for other heritages. These observations partially identify modifiable behavioral mechanisms that influence how cumulative physiologic stress affects depressive symptoms among Hispanics/Latinos overall and highlight only limited potential for assessing such relationships among specific Hispanic/Latino heritages.

The prevalence of depression has been previously observed to be highest among Puerto Ricans, compared to other heritages, with about 12% reporting 12-month major depression (González et al., 2010), 22% reporting lifetime major depression (González et al., 2010), and 38% reporting past week elevated depressive symptoms (Perreira et al., 2015; Wassertheil-Smoller et al., 2014) in HCHS/SOL from Visit 1. We also observed that Puerto Ricans were the only heritage group to not experience a decrease in this prevalence after six to nine years of follow-up at Visit 2. Puerto Ricans have also been observed to have higher prevalence of unhealthy behaviors such as cigarette smoking (Kaplan et al., 2014), alcohol use disorders (Rios-Bedoya & Freile-Salinas, 2014), obesity as a partial proxy for less physical activity (Isasi et al., 2015), and poor diet quality (Mattei et al., 2016). In our analyses, almost 80% of Puerto Ricans engaged in at least one of these unhealthy behaviors. Although this prevalence was only slightly lower among Cubans, the prevalence of engaging in at least one unhealthy behavior was at least 28% lower among other heritages. Lastly, Puerto Ricans experience some of the highest levels of discrimination, poverty, and unemployment compared to other heritages (Arellano-Morales et al., 2015; Dominguez et al., 2015). Findings from chronic stress and allostatic load data revealed that Puerto Ricans reported greater mean chronic stress scores, as well as allostatic load scores, than most other heritages. Even though these items do not measure the same aspects of personal experience, their likely relationship is cause for further research and intervention at the structural level.

Previous research has established that life stressors throughout the life course may increase the risk of depression in adulthood (Estrada-Martinez et al., 2012; Hammen, 2005; Llabre et al., 2017; Mandelli et al., 2015; Perreira et al., 2019; Tennant, 2002). In past meta-analyses and reviews, cigarette smoking (Quattrocki et al., 2000), alcohol drinking (Sullivan et al., 2005), poor diet quality (Li et al., 2017; Molendijk et al., 2018), and sedentary behavior (Teychenne et al., 2010; Zhai et al., 2015) have also been associated with depression or depressive symptoms. In analyses conducted among the overall sample, we observed consistent findings in cross-sectional and longitudinal models that chronic stress, as measured by self-report or by allostatic load score, and number of unhealthy behaviors independently increased the odds of elevated depressive symptoms. Among older aged Hispanics/Latinos in a nationally representative longitudinal study, self-reported chronic stress was found to increase the risk of elevated depressive symptoms two years after baseline (Rodriquez et al., 2016). Cross-sectional analyses among Hispanics/Latinos in general failed to identify a significant relationship between greater allostatic load and being at-risk for depressive disorder (Rodriquez et al., 2018). However, in a longitudinal study of older, mostly Mexican, Hispanics/Latinos in Northern California, greater allostatic load was found to predict elevated depressive symptoms at 24-30-months of follow-up (Rodriquez et al., 2019). Findings from HCHS/SOL support previous research and allowed for the opportunity to assess potential moderation among these relationships.

The Environmental Affordances Model provides a framework, based on neurobiological research and sociological theory, to assess whether stress-related individual and societal factors interact with health behaviors to influence health among racial/ethnic minorities (Mezuk et al., 2013). The initial analysis among African Americans found that engaging in more unhealthy behaviors blunted the effect of greater levels of self-reported chronic stress on meeting criteria for major depression in the future (Jackson et al., 2010). Although three subsequent studies failed to observe that unhealthy behaviors similarly modified the relationship between self-reported chronic stress and depression or depressive symptoms among African Americans (Keyes et al., 2011; Rodriquez et al., 2016; Walsh et al., 2013), research among Hispanics/Latinos in general has found that engaging in unhealthy behaviors strengthened the relationship between greater chronic stress and future depressive symptoms (Lipton, 1997; Rodriquez et al., 2016). Results from our present study did not support these findings, where engaging in one to four unhealthy behaviors did not moderate the relationship in either direction between greater self-reported chronic stress and elevated depressive symptoms. Therefore, these results did not support the Environmental Affordances Model in this context.

Recent research has advanced our understanding of these relationships by assessing allostatic load as a measure of physiological dysregulation due to the cumulative burden of stress on the body. Using allostatic load as a measure of chronic stress, research has investigated the potential interaction between allostatic load and unhealthy behaviors in their relationship with elevated depressive symptoms. In analyses assessing whether unhealthy behaviors moderated the relationship between allostatic load at baseline and elevated depressive symptoms at two-year follow-up (Rodriquez et al., 2019), investigators observed similar results to those previously found when self-reported chronic stress was assessed among Hispanics/Latinos in general. In that study of older, mostly Mexican, Hispanics/Latinos, engaging in one or more unhealthy behaviors increased the effect of allostatic load on future elevated depressive symptoms (Rodriquez et al., 2019). Furthermore, a dose-response relationship was observed, where the relationship between allostatic load and future elevated depressive symptoms strengthened, through moderation, with increased number of unhealthy behaviors. In the present study, we did not observe that engaging in a greater number of unhealthy behaviors strengthened the relationship between allostatic load and elevated depressive symptoms in either cross-sectional or longitudinal analyses. However, we did observe that engaging in some number of unhealthy behaviors may weaken the relationship between allostatic load and elevated depressive symptoms among Hispanics/Latinos overall. These results are somewhat like those previously reported among African Americans when assessing self-reported chronic stress and criteria for major depression. Consequently, the Environmental Affordances Model was partially supported.

This study was limited by having only self-reported depressive symptoms available to assess, as opposed to a diagnostic measure or a clinical diagnosis of depression. This distinction is important as racial differences in psychopathology (i.e., major depression) were originally proposed to be explained in the Environmental Affordances Model and therefore this may limit the generalizability of our findings. However, the relationships found among Hispanics/Latinos overall were minimally consistent with the Environmental Affordances Model. Study participants were adults aged 18 and over and although 50% of our analytic sample was 40 years or older, we may have been limited in our ability to replicate some findings from previous research. For our cross-sectional analyses, only two unhealthy behaviors were captured at Visit 2, which may have prevented us from observing significant interactions between chronic stress or allostatic load and the unhealthy behavior index. Additionally, bidirectional relationships, leading to reverse causality, may have existed between unhealthy behaviors and chronic stress or allostatic load, all at Visit 1, as well as between chronic stress or allostatic load and depressive symptoms, all at Visit 1. Since some of the items of chronic stress and allostatic load are likely to be influenced by unhealthy behaviors, including these variables in the same models may have led to reverse causality. However, the longitudinal design of our latter models, which included elevated depressive symptoms at Visit 1 as a covariate, reduced the chance of reverse causality being a major problem in predicting future elevated depressive symptoms. Future research should evaluate these relationships among diverse Hispanics/Latinos with a diagnostic measure of depression and at least three unhealthy behaviors.

In conclusion, our findings suggest that differences in the relationships between chronic stress or allostatic load, unhealthy behaviors, and elevated depressive symptoms may exist among Hispanics/Latinos overall. The Environmental Affordances Model was only somewhat supported by our results, suggesting a possibly blunting of elevated depressive symptoms. Among Mexicans, however, for whom social structures and context may differ compared to other heritages, the model was generally not supported. In our descriptive findings, Puerto Ricans appeared to be a population at particular risk for elevated depressive symptoms, unhealthy behaviors, and cumulative stress. It is important that these results be used to inform policymakers on the downstream health consequences of upstream factors such as social structures and contextual experiences. Puerto Ricans may be one of the first populations where intervention efforts would potentially have a large impact. Overall, our findings advance our understanding of how modifiable behavioral mechanisms, in the context of social structures experienced by Hispanics/Latinos, may influence chronic stress and depressive symptoms. These findings can be used by policymakers to inform their decisions on the allocation of resources and opportunities to Hispanic/Latino communities, such as Puerto Ricans, as well as by clinicians to inform their decisions in the support and resources they provide to diverse Hispanic/Latino patients.

Author statement

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Ethical statement

Erik J. Rodriquez: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Software, Visualization, Writing – Original draft. **Saida I. Coreas**: Visualization, Writing – Original draft. **Linda C. Gallo**: Writing – Review & editing. **Carmen R. Isasi**: Writing – Review & editing. **Christian R. Salazar**: Writing – Review & editing. **Frank C. Bandiera**: Writing – Review & editing. **Shakira F. Suglia**: Writing – Review & editing. **Krista M. Perreira**: Writing – Review & editing. **Rosalba Hernandez**: Writing – Review & editing. **Frank Penedo**: Writing – Review & editing. **Gregory A. Talavera**: Data curation, Writing – Review & editing. **Martha L. Daviglus**: Data curation, Writing – Review & editing. **Eliseo J. Pérez-Stable**: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – Review & editing.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2021.100917.

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