Preventive Medicine Reports 20 (2020) 101190

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Physical activity, stress, and cardiovascular disease risk: HCHS/SOL Sociocultural Ancillary Study

Priscilla M. Vásquez[a,*], Ramon A. Durazo-Arvizu[b,c], David X. Marquez[d], Maria Argos[e], Melissa Lamar[c,f,g], Angela Odoms-Young[d], Linda C. Gallo[h], Daniela Sotres-Alvarez[i], Violeta D. Carríon[c], Krista M. Perreira[j], Sheila F. Castañeda[k], Carmen R. Isasi[l], Gregory A. Talavera[h], James P. Lash[m], Martha L. Daviglus[c]

[a] Department of Urban Public Health, Charles R. Drew University of Medicine and Science, Los Angeles, CA, USA
[b] Department of Public Health Sciences, Stritch School of Medicine, Loyola University Chicago, Maywood, IL, USA
[c] Institute for Minority Health Research, University of Illinois at Chicago, USA
[d] Department of Kinesiology, Nutrition, and Rehabilitation Sciences, University of Illinois at Chicago, Chicago, IL, USA
[e] Division of Epidemiology and Biostatistics, School of Public Health, University of Illinois at Chicago, Chicago, IL, USA
[f] Department of Medicine, University of Illinois at Chicago, USA
[g] Rush Alzheimer's Disease Center and the Department of Behavioral Sciences, Rush University Medical Center, Chicago, IL, USA
[h] Department of Psychology, San Diego State University, San Diego, CA, USA
[i] Collaborative Studies Coordinating Center, Department of Biostatistics, University of North Carolina, Chapel Hill, NC, USA
[j] Department of Social Medicine, University of North Carolina School of Medicine, Chapel Hill, NC, USA
[k] Division of Health Promotion and Behavioral Science, Graduate School of Public Health, San Diego State University, San Diego, CA, USA
[l] Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Bronx, NY, USA
[m] Department of Medicine, University of Illinois at Chicago, Chicago, IL, USA

ARTICLE INFO

Keywords:
Physical Activity
Accelerometer
Stress
Cardiovascular Disease Risk Factors
Latino
Hispanic

ABSTRACT

We assess whether the cross-sectional associations between moderate-vigorous physical activity (MVPA) and CVD risk factors are modified by various stress types. Complete baseline data from 4,000 participants, ages 18–74 years, of the Hispanic Community Health Study/Study of Latinos Sociocultural Ancillary Study (HCHS/SOL SCAS) were analyzed using complex survey design methods. Accelerometer-measured MVPA was assessed continuously (average minutes per day). CVD risk factors assessed were diabetes, hypercholesterolemia, hypertension, and obesity. Stress was assessed using the Chronic Burden Scale for chronic stress, Traumatic Stress Schedule for traumatic stress, and the Perceived Stress Scale for perceived stress. Poisson regression models estimated prevalence ratios of CVD risk factors. The interaction was evaluated by cross-product terms with $p < 0.10$. There was a significant interaction between chronic stress and MVPA among those with prevalent diabetes ($p_{interaction} = 0.09$). Among those reporting low chronic stress, higher MVPA was associated with a low prevalence of diabetes, however among those reporting high chronic stress, the prevalence of diabetes remained high even with higher MVPA. We did not observe interactions between chronic stress and MVPA for the remaining CVD risk factors, or interactions between traumatic stress or perceived stress and MVPA. This study provides initial evidence on the role of chronic stress on the association between MVPA and diabetes for Hispanic/Latino adults. Mostly, however, chronic stress, traumatic stress, and perceived stress did not modify the associations between MVPA and CVD risk factors for Hispanic/Latino adults.

Abbreviations: PA, Physical Activity; CVD, Cardiovascular Disease; MVPA, Moderate-Vigorous Physical Activity; US, United States; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; SCAS, Sociocultural Ancillary Study; HbA1c, glycosylated hemoglobin; BMI, Body Mass Index; GED, General Education Development Diploma; NY, New York; IL, Illinois; FL, Florida; CA, California; AHEI, Alternative Healthy Eating Index; CI, Confidence Interval; TX, Texas; PR, Prevalence Ratios; PTSD, Post-Traumatic Stress Disorder

* Corresponding author.
E-mail address: priscillavasquez@cdrewu.edu (P.M. Vásquez).

https://doi.org/10.1016/j.pmedr.2020.101190
Received 11 February 2020; Received in revised form 14 August 2020; Accepted 23 August 2020
Available online 28 August 2020

1. Introduction

Engaging in adequate levels of physical activity (PA) is an established healthy behavior that prevents cardiovascular disease (CVD) by lowering exposure to risk factors such as diabetes, hypercholesterolemia, obesity, and hypertension (HHS, 2008; Report, 2018). PA recommendations for health benefits include engaging in moderate-vigorous physical activity (MVPA) (i.e. brisk walking, running) for at least 150 min per week (HHS, 2008). On a population-level, research shows that even small increases in PA can reduce the prevalence of CVD (Yancey et al., 2007). Compared to other racial/ethnic groups, Hispanic/Latino adults have disproportionately high rates of CVD risk factors and this can lead to future health disparities in CVD morbidity (Daviglus et al., 2014). The difference between CVD morbidity and CVD mortality among Hispanic/Latino adults has been a source of inquiry and has been identified as an epidemiologic phenomenon coined 'the Hispanic Paradox' where the high burden of CVD risk factors does not correspond to CVD mortality in the Hispanic/Latino population (Daviglus et al., 2014; Medina-Inojosa et al., 2014; Lopez-Jimenez and Lavie, 2014). This has led to expanded consideration of factors deleterious to cardiovascular health (e.g. stress) as well as further investigation of protective factors existing within the Hispanic/Latino population.

Based on *Stress in America*, an online survey conducted by the American Psychological Association, Hispanic/Latino adults in the United States (US) have reported higher levels of stress compared to non-Hispanic/Latino whites (APA, 2015). Adverse contextual factors can be sources of psychosocial stress. Psychosocial stress is defined as aversive or demanding conditions that tax or exceed the behavioral resources of the organism (Lazarus, 1966). Examples include financial strains, family-related concerns, or societal pressures. More recently, state of the arts research has shown the linkage between psychological function and CVD (Kubzansky et al., 2018; Levine, 2019). Previous work has demonstrated a link between greater stress and increased CVD risk factors (Kivimäki and Steptoe, 2018). Published research using the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) Sociocultural Ancillary Study (SCAS) has shown that chronic stress among Hispanic/Latino adults is associated with higher prevalence of diabetes (Gallo et al., 2014); fasting glucose, post load glucose, glycosylated hemoglobin (HbA1c) levels (McCurley et al., 2015); and higher odds of obesity (Isasi et al., 2015). In contrast, greater traumatic stress is associated with a lower prevalence of diabetes and hypertension (Gallo et al., 2014). In regard to PA among Hispanic/Latino adults, higher accelerometer-measured MVPA was associated with being normal weight (Palta et al., 2015); but it is unknown how the association of accelerometer-measured MVPA and CVD risk factors is influenced by the presence of stress among Hispanic/Latino adults in the US. The aim of this study is to assess whether stress (i.e., chronic, traumatic, and perceived stress) modifies the cross-sectional association of MVPA and CVD risk factors among Hispanic/Latino adults in the US using the HCHS/SOL SCAS. We hypothesize that the presence of higher stress will attenuate the associations between MVPA and CVD risk factors.

2. Methods

2.1. Study Description of HCHS/SOL Cohort

HCHS/SOL is a community-based cohort study, which aims to evaluate the health risk and protective factors for CVD among a diverse sample of Hispanic/Latino adults (N = 16,415) in the US. HCHS/SOL includes four US study sites (Chicago, IL; Bronx, NY; Miami, FL; San Diego; CA) which enrolled self-identified Hispanic/Latino adults ages 18–74 years between 2008 and 2011. Recruitment was conducted using a stratified two-stage probability sample of household addresses via selected census tracts. Informed consent was obtained from all participants at the beginning of the baseline examination visit. Baseline examinations were standardized across all sites and were conducted in the preferred language of the participant (Spanish/English). The study was approved by the Institutional Review Boards for each study institution, the coordinating center, and reading centers. More detailed information on HCHS/SOL study methods have been published (Sorlie et al., 2010; Lavange et al., 2010).

2.2. The HCHS/SOL Sociocultural Ancillary Study

The Sociocultural Ancillary Study (SCAS) is comprised of a subsample of the HCHS/SOL cohort, and aimed to evaluate the associations between psychosocial factors and CVD prevalence among Hispanic/Latinos adults. At baseline examination, HCHS/SOL participants indicated interest in future studies, and those willing to complete a second visit within 9 months of their baseline examination were eligible to participate in SCAS. Interviewer-administered questionnaires were completed by SCAS participants (N = 5,313) between February 2010 and June 2011 (Gallo et al., 2014). The majority of participants completed this assessment within 6 months (88.3%) and most within 4 months (72.6%) of the baseline examination (Gallo et al., 2014). SCAS participants were comparable to the HCHS/SOL cohort study in representation of study sites, Hispanic/Latino background, and oversampling of adults aged 45–74 years, with the only exception being the lower representation of high socioeconomic status (Gallo et al., 2014). Participants were excluded from the current analysis if they were non-adherent to accelerometer-use (N = 965), were missing data on CVD risk factors (N = 5) or covariates (N = 239). The analytic sample for the present study was 4,000. We observed minor differences between those included and excluded from the analytic sample, including differences in adherence to accelerometer-use which corresponds to previously published data (data provided upon request) (Evenson et al., 2015). Analyses for the present study were conducted between 2016 and 2017.

2.3. Measures

2.3.1. Physical Activity

MVPA was measured with the Actical accelerometer (model 198–0200-03; Minimiter Respironics, Bend, Oregon) and assessed continuously in all analyses. Participants were fitted with a belt and instructed to wear the accelerometer for seven days at the hip above the iliac crest, and to remove it only for swimming, showering, and sleeping. The accelerometer recorded the frequency, duration, and intensity of PA during the time worn. Adherence to accelerometer-use was defined as having at least three days with a minimum of ten hours per day. Accelerometer data were processed with an epoch length of 1 minute and non-wear time was determined by using the Choi algorithm. The Choi algorithm defined non-wear time as 90 consecutive minutes of zero counts, allowing only 1–2 minutes of non-zero counts within a 30-minute window upstream and downstream of the 90-minute timeframe (Choi et al., 2011). Data were processed using cutpoints of ≥1535 counts per minute per day for MVPA. Vigorous activity was defined as ≥3962 counts per minute per day (Colley et al., 2011). The current analyses did not adjust for number of days worn given that the vast majority wore the accelerometer for 6 days. We assessed the average number of minutes spent in MVPA per day across adherent days. The overall prevalence of PA (Arredondo et al., 2016) and adherence to accelerometer-use in HCHS/SOL have been reported (Evenson et al., 2015).

2.3.2. Stress

Stress was assessed by measures of chronic, traumatic, and perceived stress. More detailed information is provided for each measure below.

Chronic Stress was assessed by a count of the number of chronic stressors (count range: 0–8) derived from the 8-item Chronic Burden

Scale (Bromberger and Matthews, 1996). The questionnaire aimed to capture stressors occurring for at least the past six months in the domains of finances, occupation, personal relationships, as well as participants' health status or that of a close individual.

Traumatic Stress was assessed by a count of the number of traumatic events during participants' lifetime (count range: 0–10) and was derived from the 10-item Traumatic Stress Schedule (Norris, 1990). Each item captures a traumatic event that may have occurred at any point during participants' lifetime and includes assault, natural disasters, combat, or serious car accident.

Perceived Stress was a total score (range: 0–40) derived from the 10-item Perceived Stress Scale (PSS) (Cohen et al., 1983). The questionnaire aimed to capture perceptions of stress over the past month, and how often participants found their lives to be unpredictable, uncontrollable, and overloaded. Specific information on PSS among Hispanic/Latino adults has been reported (Perera et al., 2017).

2.3.3. Cardiovascular Disease Risk Factors

Data on CVD risk factors are available for HCHS/SOL cohort participants via fasting blood samples and standardized protocol. All CVD risk factors were dichotomized to indicate presence or absence of the risk factor. National standardized cut-points were used for each CVD risk factor: diabetes, hypercholesterolemia, hypertension, and obesity. References can be provided upon request. The prevalence of CVD risk factors in the HCHS/SOL cohort have been reported (Daviglus et al., 2012).

The cut-points are presented below for each of the CVD risk factors. The presence of diabetes was determined by a fasting blood glucose ≥126 mg/dL, glucose tolerance test with a 2-hour postload plasma glucose test ≥200 mg/dL, hemoglobin A1c ≥ 6.5% or taking glucose regulating medications. The presence of hypercholesterolemia was determined by a serum cholesterol ≥240 mg/dL, high-density lipoprotein cholesterol < 40 mg/dL, low-density lipoprotein cholesterol ≥160 mg/dL, or taking cholesterol-lowering medications. The presence of hypertension was determined by an average of three blood pressure readings with systolic blood pressure ≥140 mmHg, or diastolic blood pressure ≥90 mmHg, or taking antihypertensive medications. The presence of obesity was determined by measured height and weight, and calculated body mass index (BMI) of 30 kg/m^2 or more.

2.3.4. Covariates

The following covariates were chosen based on evidence demonstrating the potential of the variable to confound the association between MVPA and CVD risk factors.

Age was assessed continuously, and sex was a dichotomous indicator. Education was categorized into three groups: no high school/General Education Development Diploma (GED), at most high school/GED, and more than a high school/GED. Annual household income was categorized into < $30,000, ≥$30,000, or not reported. Health insurance was dichotomized into being currently insured or not currently insured. We dichotomized the number of years residing in the US to < 10 years or ≥10 years, and we make the assumption that US born participants resided in the US for more than 10 years. HCHS/SOL study sites, assessed categorically, were Bronx, NY; Chicago, IL; Miami, FL; or San Diego, CA. Hispanic/Latino backgrounds, assessed categorically, included Central American, Cuban, Dominican, Mexican, Puerto Rican, South American, or more than one background. Continuous variables included were sleep duration in average hours per night in a week (self-reported); and diet quality per the Alternative Healthy Eating Index (AHEI) 2010 (range: 0–110) with higher scores indicating better diet quality. Alcohol intake was categorized into those who never consumed alcohol, former drinkers, and current drinkers. We did not include variables for anxiety symptoms or depressive symptoms since this paper focuses on how stress modifies the association between MVPA and CVD risk factors. However, we did conduct a sensitivity analysis and estimates were not significantly altered (data provided upon request).

2.4. Statistical Analyses

Descriptive statistics were computed for each CVD risk factor per covariates, accelerometer-measured MVPA, and stress types. First, poisson regression models were used to examine the cross-sectional associations of MVPA and the individual CVD risk factors diabetes, hypercholesterolemia, hypertension, and obesity (data not shown). Second, to examine effect modification by stress types individually, cross-product (multiplicative) interaction terms were created between MVPA and chronic stress, traumatic stress, perceived stress, individually. Poisson regression models were used to determine the presence of effect modification by individual stress types on the association between MVPA and CVD risk factors diabetes, hypercholesterolemia, hypertension, and obesity. In total, there were 12 individual analyses to examine effect modification by stress types.

Given that HCHS/SOL was not powered to examine interactions we used a $p < 0.10$, a relaxed p-value, to detect and determine a statistical interaction. We include the 95% confidence intervals (CI) to provide and allow for meaningful interpretation of the findings. We graphically evaluate and characterize the effect modification detected in this study, and the figure illustrates the differing slopes based on the stress type examined. While all previous analyses use continuous MVPA and continuous stress levels, for the figure and illustrative purposes we use 20-minute intervals and the respective midpoint of the MVPA interval as well as tertiles of stress to ease interpretability of results. Lastly, we provide the corresponding table for this figure which contains prevalence ratios (PR) and 95% CI for the significant interaction detected between MVPA and stress type. We did not have statistical power to examine three-way interactions by sex, however, based on adjusted models examining the association between MVPA and CVD risk factors, with the exception of hypercholesterolemia, overall there were no observed differences by sex.

The distribution of accelerometer-measured MVPA data was skewed such that to improve the symmetry of the distribution we $\log_2$-transformed this variable and thereby increase our statistical power to detect interactions. To account for the complex survey designs of HCHS/SOL we used sampling weights, clusters, and strata in all analyses. To account for missing accelerometer data we used inverse probability weights as previously described (Arredondo et al., 2016). Stata Statistical Software, Release 14 (StataCorp LP, College Station, TX) was used for all analyses.

3. Results

3.1. Descriptive statistics

Overall, 54.7% were female, 39.4% had > high school diploma/GED, and 65.3% had < $30,000 annual household income. The average MVPA was 24.0 (± 0.9) minutes/day. There was an average of 1.8 (± 0.1) chronic stressors (range: 0–8), 2.1 (± 0.1) traumatic stressors (range: 0–10), and an average score of 14.8 (± 0.2) for perceived stress (range: 0–40). Table 1 provides descriptive statistics by CVD risk factors per covariates, MVPA, and stress types.

3.2. Bivariate Associations

We observed significant inverse cross-sectional associations between MVPA and diabetes, hypercholesterolemia, hypertension, and obesity ($p < 0.05$; data not shown).

3.3. Effect Modification by Stress Types

Table 2 presents the adjusted PR and 95% CI for main effects of MVPA, stress type, and MVPA*stress type interactions for each of the examined models. We observed an interaction between chronic stress and MVPA for prevalent diabetes 1.02 (1.00, 1.05), $p_{\text{interaction}} = 0.09$,

Table 1
Descriptive statistics for demographic characteristics, accelerometer-measured MVPA, and stress types by CVD risk factors: HCHS/SOL Sociocultural Ancillary Study

	All	CVD Risk Factors							
		Diabetes		Hypercholesterolemia		Hypertension		Obesity	
		No	Yes	No	Yes	No	Yes	No	Yes
Unweighted N[a]	4,000	3,189	811	2,156	1,844	2,693	1,307	2,308	1,692
Age (yrs), M (se)	42.2 (0.4)	40.0 (0.4)	54.4 (0.8)	39.1 (0.4)	46.4 (0.6)	37.6 (0.3)	55.2 (0.6)	41.1 (0.4)	43.9 (0.6)
Female (%)	54.7	54.6	55.6	62.0	45.0***	55.3	53.3	53.1	57.2
Education (%)									
< HS/GED	32.5	30.2	45.3***	29.2	36.8**	30.5	38.2**	28.9	37.8**
HS/GED	28.1	29.2	21.9	29.9	25.8	29.5	24.2	28.9	27.0
> HS/GED	39.4	40.6	32.8	40.9	37.5	40.1	37.6	42.2	35.3
Income (%)									
< $30,000	65.3	63.4	75.5***	62.7	68.7*	63.5	70.2**	64.4	66.5
≥ $30,000	28.7	30.6	18.5	31.4	25.2	30.8	22.8	29.6	27.5
Not Reported	6.0	6.0	6.0	5.9	6.1	5.7	7.0	6.0	6.0
Alcohol Intake (%)									
Never	20.4	19.5	25.2***	19.5	21.6	18.2	26.5***	20.7	19.9
Former	29.8	28.4	37.3	29.0	30.8	29.4	30.9	28.5	31.6
Current	49.8	52.1	37.5	51.5	47.7	52.4	42.6	50.7	48.5
Years Living in US (%)									
< 10	27.9	29.7	17.9***	30.8	24.0**	29.8	22.4***	31.8	22.1***
≥ 10	72.1	70.3	82.1	69.2	76.0	70.2	77.6	68.2	77.9
Health Insurance (%)									
Yes	51.9	49.8	63.0***	51.0	53.0	48.0	62.7***	50.4	53.9
Study Site (%)									
Bronx	29.7	30.08	27.6	31.9	26.8***	30.0	28.9***	28.4	31.7
Chicago	16.1	15.7	18.0	16.3	15.8	18.1	10.3	16.0	16.2
Miami	29.0	28.4	32.3	24.5	34.8	24.8	40.7	29.0	28.9
San Diego	25.3	25.9	22.1	27.3	22.6	27.1	20.2	26.6	23.3
Hispanic/Latino Background (%)									
Dominican	11.3	11.6	9.2**	12.8	9.3***	11.4	10.7***	12.1	10.0*
Central Am.	7.7	7.9	6.8	8.0	7.4	8.2	6.3	8.0	7.3
Cuban	20.3	19.6	24.5	16.5	25.4	16.0	32.6	20.1	20.6
Mexican	37.1	37.6	34.6	39.9	33.4	41.6	24.5	39.1	34.2
Puerto R.	14.9	14.0	19.7	13.2	17.0	13.1	19.8	12.5	18.4
South Am.	4.8	5.0	3.8	4.3	5.4	5.1	4.0	5.1	4.3
Multiple	3.9	4.4	1.4	5.4	2.0	4.6	2.1	3.1	5.2
Sleep Duration (hours/day), M (se)	8.0 (0.04)	8.0 (0.1)	7.9 (0.1)	8.0 (0.1)	7.9 (0.1)	8.0 (0.1)	7.8 (0.1)	8.1 (0.04)	7.8 (0.1)
Diet Quality, M (se)	47.7 (0.2)	47.3 (0.2)	50.3 (0.4)	47.1 (0.3)	48.6 (0.3)	47.2 (0.2)	49.2 (0.3)	47.9 (0.3)	47.5 (0.3)
Moderate-Vigorous Physical Activity (minutes/day), M (se)	24.0 (0.9)	25.3 (1.0)	16.7 (1.0)	24.8 (1.0)	22.7 (1.4)	26.2 (1.1)	17.5 (0.8)	25.7 (1.0)	21.4 (1.3)
Psychosocial Stressors									
Chronic Stress, M (se)	1.8 (0.1)	1.7 (0.1)	2.4 (0.1)	1.8 (0.1)	1.9 (0.1)	1.7 (0.1)	2.1 (0.1)	1.7 (0.1)	2.0 (0.1)
Traumatic Stress, M (se)	2.1 (0.1)	2.1 (0.1)	2.1 (0.1)	2.1 (0.1)	2.1 (0.1)	2.1 (0.1)	2.2 (0.1)	2.1 (0.1)	2.1 (0.1)
Perceived Stress, M (se)	14.8 (0.2)	14.7 (0.2)	15.0 (0.4)	15.0 (0.3)	14.4 (0.2)	14.8 (0.2)	14.6 (0.3)	14.6 (0.3)	15.0 (0.2)

*p < 0.05, **p < 0.01, ***p < 0.001
[a] Abbreviations: HS, High School; Central Am., Central American; Puerto R., Puerto Rican; South Am., South American; Multiple, More than one Hispanic/Latino background.

and no interactions between chronic stress and MVPA for the remaining CVD risk factors, or for traumatic stress or perceived stress and MVPA. To characterize the detected interaction, we assessed graphically the nature of the chronic stress effect modification on the association between MVPA and prevalent diabetes (Fig. 1). Those reporting low chronic stress had a low prevalence of diabetes with higher MVPA, while those reporting high chronic stress had a high prevalence of diabetes even with higher MVPA. In Table 3, we provide PR and 95% CI of diabetes for given tertiles of chronic stress and intervals of MVPA. Overall, the inverse association between MVPA and diabetes was attenuated with higher numbers of chronic stressors.

4. Discussion

The benefits of MVPA on multiple health outcomes have been established (Report, 2018). In the present study we aimed to expand this area of research by examining the role of chronic stress, traumatic stress, and perceived stress on the association between MVPA and various CVD risk factors. In sum, we observed effect modification by chronic stress on the association between MVPA and prevalent diabetes. Among those reporting low chronic stress, we observed an inverse association between MVPA and prevalent diabetes. However, among those reporting high chronic stress, the inverse association between MVPA and diabetes was attenuated. We observed no additional interactions between chronic stress and MVPA for prevalent hypertension, hypercholesterolemia, or obesity. We observed no interactions between traumatic stress and MVPA, or perceived stress and MVPA for any of the prevalent CVD risk factors examined.

Chronic stress is persistent and long-lasting, and stems from a variety of sources where solutions are not readily available. Research has demonstrated stress' deleterious effects on cardiovascular health and the continued need for its inclusion when examining CVD risk

Table 2
Main effects and interactions of accelerometer-measured MVPA and stress types by CVD risk factors: HCHS/SOL Sociocultural Ancillary Study

	CVD Risk Factors							
	Diabetes		Hypercholesterolemia		Hypertension		Obesity	
	PR (95% CI)	p-value	PR (95% CI)	p-value	PR (95% CI)	p-value	PR (95% CI)	p-value
Chronic Stress								
MVPA	0.88 (0.81, 0.95)	< 0.01	0.93 (0.89, 0.97)	< 0.01	0.95 (0.90, 1.00)	0.05	0.91 (0.87, 0.95)	< 0.01
Chronic Stress	1.06 (0.97, 1.16)	0.17	0.97 (0.90, 1.04)	0.34	1.01 (0.95, 1.08)	0.73	1.00 (0.93, 1.09)	0.93
MVPA × Chronic Stress	**1.02 (1.00, 1.05)**	**0.09**	1.01 (0.99, 1.03)	0.17	1.01 (0.99, 1.03)	0.26	1.01 (0.99, 1.03)	0.42
Traumatic Stress								
MVPA	0.91 (0.85, 0.98)	0.01	0.96 (0.91, 1.01)	0.11	1.00 (0.95, 1.04)	0.86	0.96 (0.91, 1.01)	0.11
Traumatic Stress	0.99 (0.90, 1.10)	0.91	0.99 (0.93, 1.06)	0.77	1.05 (0.99, 1.11)	0.11	1.05 (0.98, 1.13)	0.16
MVPA × Traumatic Stress	1.00 (0.98, 1.03)	0.86	1.00 (0.98, 1.01)	0.60	0.99 (0.97, 1.00)	0.11	0.98 (0.96, 1.00)	0.11
Perceived Stress								
MVPA	0.89 (0.80, 0.99)	0.02	0.97 (0.91, 1.03)	0.32	0.95 (0.89, 1.02)	0.16	0.88 (0.82,0.95)	< 0.01
Perceived Stress	1.01 (0.98, 1.03)	0.64	1.00 (0.99, 1.02)	0.75	1.00 (0.99, 1.01)	0.97	0.99 (0.97,1.01)	0.20
MVPA × Perceived Stress	1.00 (1.00, 1.01)	0.50	1.00 (0.99, 1.00)	0.58	1.00 (1.00, 1.01)	0.58	1.00 (1.00,1.01)	0.18

[a]Adjusted for age, sex, education, annual household income, health insurance, years living in the US, study site, Hispanic/Latino background, sleep duration, diet quality, and alcohol intake.

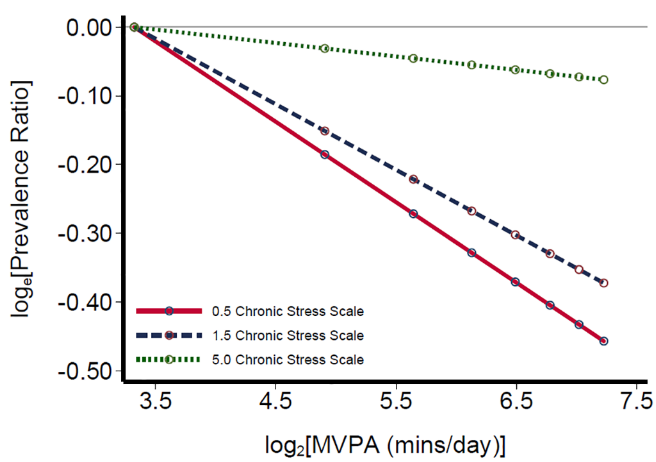

Fig. 1. Association between accelerometer-measured MVPA and diabetes modified by tertiles of chronic stress: HCHS/SOL Sociocultural Ancillary Study

factors (Hackett and Steptoe, 2016). Our study provides initial evidence on the extent to which the association between MVPA and prevalent diabetes differs or is modified by the reported number of chronic stressors among Hispanic/Latino adults. Previous research has shown that under the strong regimens of controlled studies, MVPA has been more effective than prescribed medications in preventing diabetes (Diabetes Prevention Program Research Group, 2011); and that low amounts of PA are associated with diabetes (Brugnara et al., 2016). Challenges arise when the studies are implemented in community-based settings, and often the studies are limited in the substantial inclusion of broader psychosocial factors, such as chronic stress, among Hispanic/Latino groups. Chronic stress has been implicated in physiological mechanisms involved with the development of diabetes and cardiometabolic health (Tamashiro et al., 2011), and studies have shown associations of chronic stress with poor glucose regulation among Hispanic/Latino adults prior to onset of diabetes (McCurley et al., 2015). Continued inclusion of chronic stress when examining MVPA and diabetes are warranted.

Furthermore, diabetes is the singular CVD risk factor examined that

Table 3
Association between accelerometer-measured MVPA and diabetes, stratified by tertiles of chronic stress: HCHS/SOL Sociocultural Ancillary Study.

Intervals of MVPA (minutes/day)	Midpoint of Interval (minutes/day)	0.5 Chronic Stressors (Low Chronic Stress) PR (95% CI)	1.5 Chronic Stressors (Medium Chronic Stress) PR (95% CI)	5.0 Chronic Stressors (High Chronic Stress) PR (95% CI)
[0, 20)	10	1	1	1
[20, 40)	30	0.83 (0.74, 0.93)	0.86 (0.79, 0.94)	0.97 (0.85, 1.11)
[40, 60)	50	0.76 (0.64, 0.90)	0.80 (0.70, 0.91)	0.96 (0.79, 1.16)
[60, 80)	70	0.72 (0.59, 0.88)	0.77 (0.65, 0.90)	0.95 (0.75, 1.20)
[80, 100)	90	0.69 (0.55, 0.87)	0.74 (0.62, 0.88)	0.94 (0.72, 1.22)
[100, 120)	110	0.67 (0.52, 0.86)	0.72 (0.59, 0.87)	0.93 (0.70, 1.25)
[120, 140)	130	0.65 (0.50, 0.85)	0.70 (0.57, 0.87)	0.93 (0.68, 1.27)
[140, 160)	150	0.63 (0.48, 0.84)	0.69 (0.55, 0.86)	0.93 (0.67, 1.28)

[a]Adjusted for age, sex, education, annual household income, health insurance, years living in the US, study site, Hispanic/Latino background, sleep duration, diet quality, and alcohol intake.

is irreversible, and the chronicity of these type of stressors may be an important distinction from both traumatic stress and perceived stress. The measure of chronic stress includes stress from ongoing health conditions, such that concerns about diabetes may contribute to this stress type. In the present study, the largest descriptive difference is observed with the reported number of chronic stressors between those with diabetes and those without diabetes. An important consideration may also be the qualitative differences between domains of MVPA, specifically transportation-based, occupation-based, and leisure time MVPA (Marquez et al., 2009); and their particular associations with diabetes. The role of chronic stress on the association between MVPA and diabetes merits further investigation given the many dynamics present. The role of chronic stress can also be extended by incorporating and examining the potential contributions of the weathering hypothesis (Forde et al., 2019).

While we did not observe an interaction between MVPA and perceived stress, there is evidence of perceived stress and stressful life events being linked to diabetes, however this evidence is derived from mainly clinical samples and non-Hispanic/Latino populations (Madhu et al., 2019). In regard to traumatic stress, there is emerging longitudinal evidence on the links between post-traumatic stress disorder (PTSD) and cardiometabolic health and diabetes, in particular among veterans (Levine et al., 2013; Vaccarino et al., 2014). One study observed that environment and health behavior can explain much of the link between PTSD and diabetes, while another study observed long-term effects of PTSD alone on the development of diabetes (Vaccarino et al., 2014; Miller-Archie et al., 2014). In our study, the lack of interaction between perceived and traumatic stress may be due to the global nature of perceived stress and traumatic stress examined versus more specific sources of traumatic or perceived stress such as stress due to PTSD or discrimination (Molina and Simon, 2014).

For the vast majority of MVPA and CVD risk factors combinations, we did not observe effect modification by perceived, chronic, or traumatic stress. Engaging in high MVPA was associated with lower prevalence of the diabetes, hypertension, hypercholesterolemia, and obesity regardless of perceived, chronic, or traumatic stress. Research on the benefits of PA on CVD are well established, and preventive efforts centered on reducing CVD risk factors highlight PA as one of the leading modifiable behaviors (Mozaffarian et al., 2015). Examining the role of different stress types on the association between MVPA and CVD risk factors allows for inclusion of contextual factors that more resembles everyday circumstances. Previous evidence has shown that perceived stress was associated with poor general health among Mexican American adults (Flores et al., 2008). Based on the findings from our study, perceived stress did not modify the association between MVPA and lower prevalence of CVD risk factors. Interestingly, in a previous HCHS/SOL SCAS study, traumatic stress was associated with lower prevalence of diabetes and hypertension among Hispanic/Latino adults (Gallo et al., 2014). Pointedly, taken together with the present study, there is a need for further investigation on the examined factors as their associations remain to be elucidated. Still, the majority of analyses provide evidence on the link between MVPA and lower prevalence of CVD risk factors. Importantly, the accelerometer-measured MVPA includes all domains of PA such that future studies that disentangle and characterize possible nuanced associations and longitudinal patterns may reveal more granular protective factors among Hispanic/Latino adults.

Finally, other research has examined PA as a moderator of the stress-disease relationship and has shown PA to be protective against the negative effects of chronic stress (Gerber and Pühse, 2009). Hispanic/Latino adults engage in an average of 23.8 minutes per day of accelerometer-measured MVPA which equates to meeting PA guideline recommendations (Arredondo et al., 2016) thus, engagement in MVPA is not necessarily low. Our study provides a different perspective and explores scenarios with high MVPA and high stress. Our study provides initial evidence for the inclusion of chronic stress in studies examining MVPA and diabetes. Longitudinal studies are needed given that the effect modification observed in this study is marginal. Future studies would benefit from examining the presence of multiple stress types in tandem as well as additional stress types (i.e. stress due to discrimination) (Molina and Simon, 2014). Studies can benefit from examining the clustering of these CVD risk factors in the form of the metabolic syndrome or cardiovascular disease risk scores. Future studies can also include those at risk for diabetes given the sensitivity of glucose regulation to PA (Castro et al., 2009). Lastly, this body of research could also benefit from examining well-being and positive measures of psychosocial health in addition to stress types (Kubzansky et al., 2018).

5. Strengths and limitations

This study has several strengths including the methodology for recruitment, and examination of study participants. We used accelerometer-measured MVPA as well as multiple measures of stress. Participants in this study are a rapidly growing segment of the US population, and their diversity was reflected in this cohort. Limitations include the cross-sectional design where temporality or causality cannot be determined. Multiple comparisons were not accounted for in the analyses since we tested pre-specified hypotheses. While we assessed different domains of stress, the measures did not allowed us to examine the severity of stress. Another limitation includes the time gap in data collection of accelerometer-measured MVPA and the administration of the stress questionnaires. We have made the assumption that the stress reported during the ancillary study is reflective of stress at time of the baseline examination. There may also be differences by sex, occupation, and Hispanic/Latino background; however, we did not have statistical power to examine these important three-way interactions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank the participants and staff of HCHS/SOL for their important contributions. http://www.cscc.unc.edu/hchs/PMV was funded by the T32 Training in CVD Epidemiology and Related Chronic Diseases in Minority Populations program (NIH/NHLBI T-32-HL-125-294-01A1) to complete the present study at the University of Illinois at Chicago. PMV was most recently supported by the National Institutes of Health (3R01AG048642-04S1; P30AG059299; and 5T32HL079891-13). The Hispanic Community Health Study/Study of Latinos is a collaborative study supported by contracts from the National Heart, Lung, and Blood Institute (NHLBI) to the University of North Carolina (HHSN268201300001I/N01-HC-65233), University of Miami (HHSN268201300004I/N01-HC-65234), Albert Einstein College of Medicine (HHSN268201300002I/N01-HC-65235), University of Illinois at Chicago – HHSN268201300003I/N01-HC-65236 Northwestern Univ), and San Diego State University (HHSN268201300005I/N01-HC-65237). The following Institutes/Centers/Offices have contributed to the HCHS/SOL through a transfer of funds to the NHLBI: National Institute on Minority Health and Health Disparities, National Institute on Deafness and Other Communication Disorders, National Institute of Dental and Craniofacial Research, National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Neurological Disorders and Stroke, NIH Institution-Office of Dietary Supplements.

PMV developed the research question, provided the proposal and manuscript for this study to the HCHS/SOL Publications Committee, worked with RADA on all analyses, prepared the manuscript with the

necessary changes based on co-authors feedback, and finalized the manuscript. RADA provided invaluable guidance to PMV throughout this study for the statistical analysis, and conducted the analyses for this work. RADA, MA, ML, AOY, MLD, and DXM were PMV's dissertation committee and were involved throughout the development of this manuscript and provided feedback at every stage of the research. VDC assisted with the statistical analysis for this work. LCG and DSA were instrumental in the development of the proposal and drafts of this manuscript. KMP, SFC, CRI, GAT, and JPL provided feedback on the manuscript that allowed for the finalization of this research. This study was part of PMV's dissertation and was a poster presentation at the 2017 AHA/EPILIFESTYLE meeting.

Data accessibility

The study website is http://www.cscc.unc.edu/hchs/ provides detailed information on data accessibility.

References

APA, 2015. Stress in America: Paying With Our Health. http://www.apa.org/news/press/releases/stress/2014/stress-report.pdf.

Arredondo, E.M., Sotres-Alvarez, D., Stoutenberg, M., et al., 2016. Physical Activity Levels in U.S. Latino/Hispanic Adults. Am. J. Prev. Med. 50, 500–508.

Bromberger, J.T., Matthews, K.A., 1996. A longitudinal study of the effects of pessimism, trait anxiety, and life stress on depressive symptoms in middle-aged women. Psychol. Aging 11, 207–213.

Brugnara, L., Murillo, S., Novials, A., et al., 2016. Low physical activity and its association with diabetes and other cardiovascular risk factors: A nationwide, population-based study. PLoS ONE 11, 1–12.

Castro, F.G., Shaibi, G.Q., Boehm-Smith, E., 2009. Ecodevelopmental contexts for preventing type 2 diabetes in Latino and other racial/ethnic minority populations. J. Behav. Med. 32, 89–105.

Choi, L., Liu, Z., Matthews, C.E., Buchowski, M.S., 2011. Validation of accelerometer wear and nonwear time classification algorithm. Med. Sci. Sport Exerc. 43, 357–364.

Cohen, S., Kamarck, T., Mermelstein, R., 1983. A global measure of perceived stress. J. Health Soc. Behav. 24, 385–396.

Colley, R., Garriguet, D., Janssen, I., Craig, C., Clarke, J., Tremblay, M., 2011. Physical activity of Canadian adults: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. Heal Rep. 22, 7–14.

Daviglus, M.L., Talavera, G.A., Avilés-Santa, M.L., et al., 2012. Prevalence of Major Cardiovascular Risk Factors and Cardiovascular Diseases Among Hispanic/Latino Individuals of Diverse Backgrounds in the United States. JAMA 308, 1775.

Daviglus, M.L., Pirzada, A., Talavera, G.A., 2014. Cardiovascular Disease Risk Factors in the Hispanic/Latino Population: Lessons From the Hispanic Community Health Study/Study of Latinos (HCHS/SOL). Prog. Cardiovasc. Dis. 57, 230–236.

Diabetes Prevention Program Research Group, 2011. 10-year follow-up of diabetes incidence and weight loss in the Diabetes Prevention Program Outcomes Study. NIH Public Access 374, 1677–1686.

Evenson, K.R., Sotres-Alvarez, D., Deng, Y., et al., 2015. Accelerometer Adherence and Performance in a Cohort Study of US Hispanic Adults. Med. Sci. Sport Exerc. 47, 725–734.

Flores, E., Tschann, J.M., Dimas, J.M., Bachen, E.A., Pasch, L.A., de Groat, C.L., 2008. Perceived Discrimination, Perceived Stress, and Mental and Physical Health Among Mexican-Origin Adults. Hisp. J. Behav. Sci. 30, 401–424.

Forde, A., Crookes, D., Suglia, S., Demmer, R., 2019. The weathering hypothesis as an explanation for racial disparities in health: a systematic review. Ann. Epidemiol. 33, 18.

Gallo, L.C., Penedo, F.J., Carnethon, M., et al., 2014. The Hispanic Community Health Study/Study of Latinos Sociocultural Ancillary Study: sample, design, and procedures. Ethn. Dis. 24, 77–83.

Gallo, L., Roesch, S.C., Fortmann, A.L., et al., 2014. Associations of Chronic Stress Burden, Perceived Stress, and Traumatic Stress With Cardiovascular Disease Prevalence and Risk Factors in the Hispanic Community Health Study/Study of Latinos Sociocultural Ancillary Study. Psychosom. Med. 76, 468–475.

Gerber, M., Pühse, U., 2009. Review Article: Do exercise and fitness protect against stress-induced health complaints? A review of the literature. Scand. J. Public Health 37, 801–819.

Hackett, R.A., Steptoe, A., 2016. Psychosocial Factors in Diabetes and Cardiovascular Risk. Curr. Cardiol. Rep. 18, 95.

HHS, 2008. 2008 Physical Activity guidelines for Americans. U.S. Department of Health and Human Services, http://health.gov/paguidelines/pdf/paguide.pdf.

Isasi, C.R., Parrinello, C.M., Jung, M.M., et al., 2015. Psychosocial stress is associated with obesity and diet quality in Hispanic/Latino adults. Ann. Epidemiol. 25, 84–89.

Kivimäki, M., Steptoe, A., 2018. Effects of stress on the development and progression of cardiovascular disease. Nat. Rev. Cardiol. 15, 215–229.

Kubzansky, L.D., Huffman, J.C., Boehm, J.K., et al., 2018. Positive Psychological Well-Being and Cardiovascular Disease: JACC Health Promotion Series. J. Am. Coll. Cardiol. 72, 1382–1396.

Lavange, L.M., Kalsbeek, W.D., Sorlie, P.D., et al., 2010. Sample design and cohort selection in the Hispanic Community Health Study/Study of Latinos. Ann. Epidemiol. 20, 642–649.

Lazarus, R., 1966. Psychological stress and the coping process. McGraw-Hill, New York, NY.

Levine, G.N., 2019. The Mind-Heart-Body Connection. Circulation 140, 1363–1365.

Levine, A.B., Levine, L.M., Levine, T.B., 2013. Posttraumatic stress disorder and cardiometabolic disease. Cardiology 127, 1–19.

Lopez-Jimenez, F., Lavie, C.J., 2014. Hispanics and cardiovascular health and the 'hispanic paradox': What is known and what needs to be discovered? Prog. Cardiovasc. Dis. 57, 227–229.

Madhu, S.V., Siddiqui, A., Desai, N.G., Sharma, S.B., Bansal, A.K., 2019. Chronic stress, sense of coherence, and risk of type 2 diabetes mellitus. Diabetes Metab. Syndr. Clin. Res. Rev. 13, 18–23.

Marquez, D.X., Neighbors, C.J., Bustamante, E.E., 2009. Leisure Time and Occupational Physical Activity among Racial/Ethnic Minorities. Med. Sci. Sport Exerc. 42, 1.

McCurley, J.L., Mills, P.J., Roesch, S.C., et al., 2015. Chronic stress, inflammation, and glucose regulation in U.S. Hispanics from the HCHS/SOL Sociocultural Ancillary Study. Psychophysiology 52, 1071–1079.

Medina-Inojosa, J., Jean, N., Cortes-Bergoderi, M., Lopez-Jimenez, F., 2014. The Hispanic Paradox in Cardiovascular Disease and Total Mortality. Prog. Cardiovasc. Dis. 57, 286–292.

Miller-Archie, S.A., Jordan, H.T., Ruff, R.R., et al., 2014. Posttraumatic stress disorder and new-onset diabetes among adult survivors of the World Trade Center disaster. Prev. Med. (Baltim) 66, 34–38.

Molina, K.M., Simon, Y., 2014. Everyday discrimination and chronic health conditions among Latinos: the moderating role of socioeconomic position. J. Behav. Med. 37, 868–880.

Mozaffarian, D., Benjamin, E.J., Go, A.S., et al., 2015. Heart Disease and Stroke Statistics—2016 Update. Circulation (accessed Aug 9, 2017). http://circ.ahajournals.org/content/early/2015/12/16/CIR.0000000000000350.

Norris, F., 1990. Screening for traumatic stress: A scale for use in the general population. J. Appl. Soc. Psychol. 20, 1704–1715.

Palta, P., McMurray, R.G., Gouskova, N.A., et al., 2015. Self-reported and accelerometer-measured physical activity by body mass index in US Hispanic/Latino adults: HCHS/SOL. Prev. Med. Rep. 2, 824–828.

Perera, M.J., Brintz, C.E., Birnbaum-Weitzman, O., et al., 2017. Factor structure of the Perceived Stress Scale-10 (PSS) across English and Spanish language responders in the HCHS/SOL Sociocultural Ancillary Study. Psychol. Assess. 29, 320–328.

Report 2018 Physical Activity Guidelines Advisory Committee Scientific, 2018. 2018 Physical Activity Guidelines Advisory Committee Scientific Report. Washington, DC, Doi: 10.1111/j.1753-4887.2008.00136.x.

Sorlie, P.D., Avilés-Santa, L.M., Wassertheil-Smoller, S., et al., 2010. Design and Implementation of the Hispanic Community Health Study/Study of Latinos. Ann. Epidemiol. 20, 629–641.

Tamashiro, K.L., Sakai, R.R., Shively, C.A., Karatsoreos, I.N., Reagan, L.P., 2011. Chronic stress, metabolism, and metabolic syndrome. Stress 14, 468–474.

Vaccarino, V., Goldberg, J., Magruder, K.M., et al., 2014. Posttraumatic stress disorder and incidence of type-2 diabetes: A prospective twin study. J. Psychiatr. Res. 56, 158–164.

Yancey, A.K., Fielding, J.E., Flores, G.R., Sallis, J.F., McCarthy, W.J., Breslow, L., 2007. Creating a Robust Public Health Infrastructure for Physical Activity Promotion. Am. J. Prev. Med. 32, 68–78.