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Original Research

Examining Generalizability across Different Surveys: Comparing Nutrient-Based Food Patterns and Their Cross-Sectional Associations with Cardiometabolic Health in the United States Hispanic/Latino Adults

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ABSTRACT

Background: Ethnicity, cultural background, and geographic location differ significantly within the United States Hispanic/Latino population. These variations can greatly define diet and its relationship with cardiometabolic disease, thus influencing generalizability of results.

Objectives: We aimed to examine nutrient-based food patterns (NBFPs) of Hispanic/Latino adults and their association with cardiometabolic risk factors (dyslipidemia, hypertension, obesity, diabetes) across 2 United States population-based studies with differing sampling strategies.

Methods: Data were collected from Mexican or other Hispanic adult participants from 2007–2012 National Health and Nutrition Examination Survey (NHANES) ($n = 3605$) and 2007–2011 Hispanic Community Health Survey/Study of Latinos (HCHS/SOL, $n = 14,416$). NBFPs were derived using factor analysis on nutrient intake data estimated from 24-h dietary recalls and interpreted using common foods in which these nutrients are prominent. Cross-sectional associations between NBFPs (quintiles) and cardiometabolic risk factors, defined by clinical measures and self-report, were estimated using survey-weighted multivariable-adjusted logistic models, accounting for multiple testing.

Results: Five NBFPs were identified in both studies: *1*) meats, *2*) grains/legumes, *3*) fruits/vegetables, *4*) dairy, and *5*) fats/oils. Associations with cardiometabolic risk factors differed by NBFP and study. In HCHS/SOL, the odds of diabetes were lower for persons in the highest quintile of meats NBFP (odds ratio [OR]: 0.73; 95% confidence interval [CI]: 0.58, 0.92) and odds were higher for those in the lowest quintile of fruits/vegetables (OR: 0.71; 95% CI: 0.55, 0.93) compared to those in the third (moderate intake) quintile. Those in the fourth quintile of dairy NBFP had higher odds of hypertension than those in the third quintile (OR: 1.31; 95% CI: 1.01, 1.70). In NHANES, the odds of hypertension were higher for those in the fourth quintile of dairy (OR: 1.88; 95% CI: 1.10, 3.24) than those in the third quintile.

Conclusions: Diet–disease relationships among Hispanic/Latino adults vary according to 2 population-based studies. These differences have research and practical implications when generalizing inferences on heterogeneous underrepresented populations.

Keywords: dietary patterns, Hispanic/Latino diets, NHANES, HCHS/SOL, nutrient intake, factor analysis

Introduction

Since 2010, Hispanic/Latino people have become the largest ethnic minority group in the United States [1]. With uniquely diverse migration and acculturation experiences, factors such as limited access to healthy foods, higher prevalence of food insecurity, and lower socioeconomic status (SES) have been cited as significant determinants of unhealthy diets among United States

Abbreviations: CI, confidence interval; CRF, cardiometabolic risk factor; CVD, cardiovascular disease; GED, general educational development; HCHS/SOL, Hispanic Community Health Study/ Study of Latinos; LCSFA, long-chain saturated fatty acid; MCSFA, medium-chain saturated fatty acid; NBFP, nutrient-based food pattern; OGTT, oral glucose tolerance test; OR, odds ratio; SES, socioeconomic status.

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Hispanics/Latinos compared to other racial and ethnic subgroups [2–4]. Suboptimal diet is associated with health complications including cardiovascular disease (CVD) [5]. Recent research found that Hispanics/Latinos are nearly 10 y younger than non-Hispanic Whites at the time of death from CVD [6]. Thus, understanding the dietary patterns among Hispanics/Latinos in the United States may help better address the CVD-related disparities experienced by this population.

Previous literature has shown that cardiometabolic risk factors (CRFs) differ among Hispanic/Latino ethnic groups due to diverse characteristics between groups such as place/country of birth, citizenship, language, race, culture, food, and other factors [7–12]. Certain United States nationally representative surveys have focused analysis on the larger demographic of this population, choosing to separate Mexican-American participants from other Hispanic/Latino groups. For example, the NHANES, which studies the health and nutritional status of people in the United States across varying SES, race/ethnicity, and geographies, aggregates Hispanic/Latinos into Mexican Americans and other Hispanics. Several studies have mimicked this approach to evaluating the interrelationship of diet and disease across different Hispanic/Latino groups [13–18].

The Hispanic Community Health Study/Study of Latinos (HCHS/SOL) was designed to better understand the health and well-being of this understudied population with data from 6 Hispanic/Latino ethnic backgrounds (Cuban, Dominican, Mexican, Puerto Rican, and Central/South American) across 4 United States urban areas (Bronx, Chicago, Miami, San Diego). Both NHANES and HCHS/SOL contain vital information about Hispanic/Latino diets and CRFs, but little research has been done to compare how consistent these associations are across the 2 studies, in part due to their differing sampling designs [19,20]. Both diet quality and dietary patterns have been examined within the HCHS/SOL cohort [11,21,22]. Diet quality has only been evaluated in a subset of NHANES Hispanic/Latino adults who live with children [23]. Osborn et al. [24] examined the association of dietary patterns of Mexican American and other Hispanic NHANES participants to cardiometabolic biomarkers and health outcomes using food pattern equivalents to define the dietary patterns. However, no study to our knowledge has used nutrients to define their food patterns nor have they been compared or contrasted against another study cohort. This is a significant gap in providing a more comprehensive understanding of diet–disease relationships among United States Hispanic/Latino adults [25].

This study aimed to derive and compare nutrient-based food patterns (NBFPs) and their cross-sectional associations with CRFs among United States Hispanic/Latino adult participants from 2 different survey studies.

Methods

Study population

This study included 2 United States studies that include Hispanic/Latino adults. Data were harmonized, and only measures shared across both surveys were included for analysis. To minimize reverse causality, we excluded participants with previous CVD conditions (such as heart failure, coronary artery disease, angina, heart attack, or stroke) at the time of enrollment.

We also excluded extreme energy intake defined as values below the 0.5th percentile and above the 99.5th percentile. The inclusion criteria for this analysis were adult participants aged 20 to 74 y with ≥1 reliable recall that identify as Mexican American or other Hispanic groups (Supplemental Figure 1).

NHANES

The NHANES program is a nationally representative repeated cross-sectional survey with a stratified, multistage probability sampling design of nonincarcerated residents of the United States. ~5000 persons each year are interviewed and located in counties across the country. Details of the study design are described elsewhere [26]. The data collected include demographic information, dietary intake, and health-related questions along with laboratory tests for 3 NHANES survey cycles (2007–2008, 2009–2010, and 2011–2012). Dietary intake data were assessed via 2 24-h recalls, which collect the types and amounts of foods and beverages consumed and allow estimated intakes of energy, nutrients, and other food components from those foods and beverages. The USDA Food and Nutrient Database for Dietary Studies 4.1 [27], 5.0 [28], and 2011–2012 [29] were used to code dietary intake data and calculate nutrient intakes for the NHANES 2007–2008, 2009–2010, and 2011–2012 survey cycles, respectively.

The first recall was collected in person. The second recall was administered over the telephone 3 to 10 d later. Nutrient intake data collected from the 2 interviews are publicly available on the Centers for Disease Control and Prevention website [30–32]. Due to data being pooled across 3 survey cycles (2007–2008, 2009–2010, 2011–2012), survey-weight adjustment was conducted [33,34]. The inclusion criteria were adult participants (aged 20–74 y) that identify as Mexican American or other Hispanic groups as defined by NHANES, with ≥1 reliable recall [35]. After excluding those with no prior CVD condition or extreme nutrient intake, a total of 1930 Mexican American and 1279 other Hispanic adults were included for analysis (Supplemental Figure 1A). Informed consent was obtained from all participants, and the protocol for NHANES was approved by the National Center for Health Statistics Research Ethics Review Board.

HCHS/SOL

The HCHS/SOL is a multicenter prospective study designed to identify risk factors and disease prevalence rates in a diverse population-based cohort of United States Hispanic/Latino adults in 4 urban communities. From 2008–2011, HCHS/SOL recruited a cohort of 16,415 Hispanic/Latino persons aged 18 to 74 y who self-identified as Cuban, Dominican, Mexican, Puerto Rican, and Central/South American and resided in households across 4 field centers in urban areas of the United States: Bronx, NY, Chicago, IL, Miami, FL, and San Diego, CA. A stratified 2-stage area probability sample of household addresses was selected in each of the 4 field centers. Additional details on the design and sampling methods of HCHS/SOL have been previously described [36]. Data on CRFs, demographic information, and medical history were recorded by questionnaires. Dietary intake was assessed using 2 24-h dietary recalls and then used to calculate nutrient intake using the Nutrition Data System for Research software version 11 [37]. The first recall was collected in person. The second recall was administered via telephone after 6 wk. The inclusion criteria were adult participants aged 20–74 y with ≥1 reliable recall according to the interviewer. After excluding those with no prior CVD condition or extreme nutrient intake, a total of

5308 Mexican American and 7751 other Hispanic adults were included for analysis (Supplemental Figure 1B). Informed consent was provided by all participants, and the protocols for HCHS/SOL were approved by the Institutional Review Boards of each field center, University of North Carolina at Chapel Hill Collaborative Studies Coordinating Center, and the National Heart, Lung, and Blood Institute.

CRFs

Our analysis focused on 4 major modifiable, manageable, or treatable CRFs that were assessed in both surveys during the same collection years described previously: dyslipidemia, obesity, diabetes, and hypertension. Dyslipidemia was defined as having total cholesterol ≥240 mg/dL, LDL cholesterol ≥160 mg/dL, HDL cholesterol <40 mg/dL, self-reported use of cholesterol-lowering medication, or self-reported physician diagnosis of hypercholesterolemia [38]. Obesity was defined as a BMI ≥30 kg/m^2 for participants aged 20 to 44 y and waist circumference (women >88 cm, men >102 cm) for participants aged 45 to 74 y [39–43]. Diabetes was defined as having a fasting time >8 h and fasting plasma glucose ≥126 mg/dL, fasting time ≤8 h and fasting glucose ≥200 mg/dL, or post-oral glucose tolerance test (OGTT) glucose ≥200 mg/dL, HbA1c ≥6.5%, self-reported diabetes medication or insulin use, or self-reported physician diagnosis [44]. Hypertension (high blood pressure) was defined as having systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, or self-reported hypertensive medication use [45].

The Framingham CVD 10-y risk score was also calculated in both surveys to estimate a 10-y risk for an atherosclerotic CVD event (e.g., coronary death, nonfatal myocardial infarction, stroke) [46]. This measure is calculated using information on age, sex, total cholesterol, HDL cholesterol, systolic blood pressure, blood pressure-lowering medication use, diabetes status, and smoking status. For NHANES participants, the Framingham CVD risk score was generated using the CVrisk R package [47]. For HCHS/SOL participants, this score was derived by the HCHS/SOL Coordinating Center [48].

Sensitivity analysis was performed to determine the impact of including participants with CVD and/or cancer at baseline to account for potential change in diet due to these diagnoses.

Sociodemographic and behavioral variables

Covariates used in the analysis included age, energy intake, sex, Mexican compared with other Hispanic heritage, educational attainment, annual household income, marital status, years living in the mainland United States, employment status, self-reported smoking status, and self-reported alcohol use. In an effort to provide consistent and parallel analysis for comparison, participants were aggregated in accordance with the NHANES classification, highlighting the larger demographic of Mexican American compared with other Hispanic/Latino groups. Additional medication use to treat conditions other than diabetes, hypertension, and cholesterol, were not included in this analysis due to inconsistencies in reporting medication use across the 2 studies. Physical activity was not included as a covariate due to severe missingness and different instruments used across the 2 studies.

Statistical analysis

Identification of NBFPs

A total of 39 nutrients were included for analysis (Table 1). Nutrient intake was averaged across 24-h dietary recalls, log-transformed via a log(1 + x) transformation, and scaled to achieve normality. Two days of reliable dietary recall were received from 13,059 participants in HCHS/SOL and 2808 NHANES participants. To identify NBFPs, factor analysis that adjusts for survey sampling design [49,50] was performed separately on each study. The number of factors to retain was determined by the following criteria: factor eigenvalue >1, scree plot construction, and factor interpretability. We applied a varimax rotation to achieve a better-defined loading structure. Nutrients with a rotated factor loading ≥|0.60| were considered 'dominant nutrients' and considered in the description and clinical interpretation of that factor. Using Bartlett's weighted least squares method, we computed factor scores that indicate the degree to which each subject's diet conforms to one of the identified patterns. To assess the internal reproducibility of the identified patterns, we calculated Cronbach's α coefficients [51]. Sensitivity analysis was performed to examine the consistency of the results with analysis using ≥1 recall compared with the average of 2 recalls. To ease clinical interpretability, patterns were named using common foods that prominently contain the nutrients of each pattern and are referred to as NBFPs. These names were reached upon the consensus of 3 co-authors with no unresolved disagreements.

Association of NBFP quintiles with CRFs

Quintile-based categories of factor scores were calculated for each survey separately, adjusting for survey design using the *svyquantile* function from the *survey* R package [50]. We used the third quintile, defined within each study as the referent category, to define a moderate intake of each NBFP. A higher quintile indicated higher intake. Survey-weighted logistic regressions were performed for each CRF and each pattern as the primary exposure, and jointly with all derived factors included. Odds ratios (ORs) and corresponding 95% confidence intervals (CIs) were estimated after adjusting for age, energy intake, sex, Mexican compared with other Hispanic heritage, educational attainment, household income, marital status, years living in the mainland United States, employment status, self-reported smoking status, and self-reported alcohol use. To account for multiple testing, we computed false discovery rate *P* values and considered $P < 0.05$ significant for all analyses. All analyses were performed in R version 3.6.3 [52] using *psych* [53], *haven* [54], *survey* [50], *ggplot2* [55], and *tidyverse* [56] packages.

Results

Descriptive analysis

Descriptive information of the 2 studies is provided in Table 2. Similar characteristics were shared between both survey cohorts including approximately half females, most individuals were employed, had lived in the United States >10 y, and were nonsmokers. Differences between the 2 studies were also identified. More individuals in the NHANES than the HCHS/SOL sample identified as Mexican, had higher household income, were more likely to be married, and reported currently using alcohol. A greater proportion of adults in the NHANES were classified with dyslipidemia levels, while similar proportions of adults had diabetes, obesity, hypertension, and mean Framingham CVD 10-y risk scores in both studies. Table 2 shows the geometric mean (SE), adjusted for age, of the 38 nutrients used in

TABLE 1
Nutrient intake summary (geometric mean and 95% CI) for NHANES and HCHS/SOL, adjusting for age, sex, and energy intake

Nutrients	NHANES $n = 3605$ Geometric mean (95% CI)	HCHS/SOL $n = 14,416$ Geometric mean (95% CI)
Total protein, g	81.0 (79.3, 82.7)	73.9 (72.9, 74.9)
Total carbohydrate, g	250.5 (244.3, 256.8)	234.7 (231.8, 237.6)
Total sugars, g	100.0 (95.5, 104.9)	90.9 (88.6, 93.3)
Total dietary fiber, g	16.8 (16.0, 17.6)	15.8 (15.4, 16.2)
Total fat, g	70.5 (68.4, 72.6)	62.3 (61.3, 63.3)
Total MUFA, g	25.6 (24.7, 26.5)	22.7 (22.3, 23.1)
Total PUFA, g	15.5 (14.9, 16.0)	13.0 (12.7, 13.3)
Dietary cholesterol, mg	257.9 (244.2, 272.4)	223.3 (216.8, 230.1)
Vitamin E, mg	6.5 (6.2, 6.8)	6.2 (6.1, 6.4)
Retinol, μg	290.6 (271.8, 310.8)	274.2 (261.8, 287.3)
Vitamin A, μg	442.8 (415.9, 471.5)	626.3 (602.5, 651.0)
α-Carotene, μg	101.9 (85.0, 122.4)	125.0 (112.8, 138.7)
β-Carotene, μg	964.6 (864.3, 1077.3)	1179.4 (1107.4, 1256.3)
β-Cryptoxanthin, μg	42.4 (36.4, 49.5)	42.5 (38.5, 46.8)
Lycopene, μg	1622.6 (1252.9, 2111.2)	1108.5 (924.1, 1333.3)
Lutein + zeaxanthin, μg	740.1 (680.6, 805.0)	640.8 (607.1, 676.5)
Vitamin B1, mg	1.6 (1.6, 1.7)	1.6 (1.6, 1.6)
Vitamin B2, mg	1.9 (1.9, 2.0)	1.8 (1.7, 1.8)
Niacin, mg	23.6 (22.9, 24.3)	20.6 (20.2, 21.0)
Vitamin B6, mg	2.0 (2.0, 2.1)	1.8 (1.8, 1.9)
Total folate, μg	379.7 (365.8, 394.1)	354.2 (346.4, 362.1)
Vitamin B12, μg	4.2 (4.0, 4.4)	3.8 (3.7, 3.9)
Vitamin C, mg	64.0 (59.0, 69.5)	66.1 (62.9, 69.5)
Vitamin D, μg	3.6 (3.3, 3.9)	3.9 (3.7, 4.0)
Vitamin K, μg	63.2 (58.8, 68.0)	55.2 (53.0, 57.4)
Calcium, mg	862.4 (830.3, 895.8)	700.2 (682.2, 718.6)
Phosphorus, mg	1333.4 (1303.5, 1364)	1122.5 (1105.1, 1140.1)
Magnesium, mg	287.8 (279.8, 296.0)	265.3 (260.8, 269.9)
Iron, mg	14.3 (13.9, 14.8)	12.9 (12.6, 13.1)
Zinc, mg	10.8 (10.5, 11.1)	9.9 (9.7, 10.0)
Copper, mg	1.3 (1.3, 1.3)	1.2 (1.2, 1.3)
Sodium, mg	3185.1 (3106.0, 3266.3)	2929.4 (2875.6, 2984.3)
Potassium, mg	2562.2 (2501.0, 2624.9)	2303.7 (2266.2, 2341.8)
Selenium, μg	108.7 (105.7, 111.8)	102.8 (101.2, 104.4)
Caffeine, mg	45.9 (37.4, 56.4)	34.1 (30.5, 38.2)
Butyric acid, g	0.5 (0.4, 0.5)	0.4 (0.4, 0.5)
MCSFA, g	1.2 (1.1, 1.3)	1.2 (1.1, 1.2)
LCSFA, g	19.8 (19.2, 20.6)	17.7 (17.4, 18.0)

Abbreviations: CI, confidence interval; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; LCSFA, long-chain saturated fatty acid; MCSFA, medium-chain saturated fatty acid; MUFA, monounsaturated fatty acid; NHANES, National Health and Nutritional Examination Survey; PUFA, polyunsaturated fatty acid.

the factor analysis. Similar nutrient intake values were observed between the studies.

NBFPs

Five factors were retained for each study and accounted for 68.2% and 67.0% of the variance explained for NHANES and HCHS/SOL, respectively. Factors were similar between the 2 studies, but the proportion of variance explained between similar study-specific factors was different. A heatmap of the factor loadings is provided in Figure 1 and, to facilitate comparisons, both studies were ordered according to how the NHANES factors were retained.

NHANES Factor 1, named "meats," had dominant loadings on total protein, niacin, vitamin B6, selenium, and vitamin B12. This factor alone explained 15.9% of the variance in nutrient intake. NHANES Factor 2, named "fats/oils," had dominant loadings on total MUFAs, total fat, long-chain saturated fatty acids (LCSFAs), total PUFAs, and sodium. This factor explained 14.6% of the variance in nutrient intake. NHANES Factor 3, named "grains/legumes," had dominant loadings on total carbohydrates, copper, magnesium, total dietary fiber, and potassium. This factor explained 14.2% of the variance in nutrient intake. NHANES Factor 4, named "dairy," had dominant loadings on retinol, vitamin A, calcium, butanoic (butyric acid or saturated fatty acid 4:0), and medium-chain saturated fatty acids (MCSFAs). The dairy factor explained 11.9% of the variance in nutrient intake. NHANES Factor 5, named "fruits/vegetables," loaded high on vitamin A, α-carotene, lutein + zeaxanthin, β-carotene, and vitamin K. The fruits/vegetables factor explained 11.6% of the variance in nutrient intake.

HCHS/SOL Factor 1, named "grains/legumes," had dominant loadings on total protein, total carbohydrate, total dietary fiber, vitamin B1, niacin, vitamin B6, total folate, phosphorus, magnesium, iron, zinc, copper, and potassium. This factor explained 24.6% of the variance in nutrient intake. HCHS/SOL Factor 2, named "fats/oils," had dominant loadings on total fat, MUFA, PUFA, and LCSFA. This factor explained 13.5% of the variance in nutrient intake. HCHS/SOL Factor 3, named "dairy," had dominant loadings on retinol, vitamin B2, vitamin D, calcium, butyric acid, and MCSFA. The dairy factor explained 13.2% of the variance in nutrient intake. HCHS/SOL Factor 4, named "fruits/vegetables," had the greatest loadings on vitamin A, α-carotene, β-carotene, lutein + zeaxanthin, and vitamin K. The fruits/vegetables factor explained 12.5% of the variance in nutrient intake. HCHS/SOL Factor 5, named "meats," had dominant loadings on total protein. This factor explained 0.4% of the variance in nutrient intake.

Standardized Cronbach's α coefficients confirmed most of the nutrients contributed to high reliability and pattern characterization (see Supplemental Tables 1 and 2). Internal reproducibility of the 2 samples was also confirmed by NBFP commonly found in this population using the congruence coefficient (see Supplemental Table 3).

NBFPs comparative analysis

The meats factors of HCHS/SOL and NHANES had one similar dominant nutrient: total protein; however, HCHS/SOL differed in that niacin, vitamin B6, selenium, and vitamin B12 were not included. The fats/oils factor showed strong similarities across both studies, except for sodium (loading value of 0.61) only loading in NHANES. The dairy factor showed similarities across both studies, but HCHS/SOL also included vitamin D, and B2 and NHANES included vitamin A as dominant nutrient. The grains/legumes factors were similar in that they shared 5 nutrients: total carbohydrate, total dietary fiber, magnesium, copper, and potassium. However, total protein, vitamin B1, niacin, vitamin B6, iron, total folate, phosphorus, zinc, copper, and magnesium loading only in HCHS/SOL. Both fruits/vegetable factors reflected consumption of deep-colored fruits and vegetables where both studies had the same dominant nutrients.

TABLE 2
Sociodemographic and behavioral characteristics and cardiometabolic risk factors for NHANES (pooled cycles from 2008–2012) and HCHS/SOL (baseline 2008–2011) adjusting for age

	NHANES $n = 3605$		HCHS/SOL $n = 14,416$	
	mean or %	SE	mean or %	SE
Sex				
Female	50.1	0.86	53.1	0.57
Male	49.9	0.86	46.9	0.57
Age[1], y	38.8	0.27	41.8	0.23
Ethnicity				
Mexican	60.3	3.86	37.2	1.63
Other Hispanic	39.7	3.86	62.9	1.63
Educational attainment				
<HS Diploma/GED	44.8	1.45	32.5	0.78
HS Diploma/GED	20.0	0.92	27.2	0.56
>HS Diploma/GED	35.2	1.64	40.3	0.89
Nativity/residence				
Born in United States	29.0	2.94	19.2	0.67
≤10 y in United States	20.1	1.60	28.3	0.98
>10 y in United States	51.0	2.02	52.6	0.79
Household income				
<$25,000	34.1	1.53	56.3	1.11
$25,000–$75,000	47.1	1.38	37.8	0.75
>$75,000	18.8	1.65	5.9	0.66
Marital status				
Married	65.7	1.61	52.7	0.80
Unmarried	34.3	1.61	47.3	0.80
Employment status				
Employed	63.2	1.22	52.0	0.69
Retired	7.5	0.40	9.6	0.31
Unemployed	29.4	1.24	38.4	0.72
Energy[2], kcal	2061.9	24.01	1910.8	10.93
Alcohol use				
Current	61.8	1.42	51.7	0.75
Former	11.5	0.92	29.8	0.68
Never	26.7	1.30	18.5	0.70
Smoker status				
Nonsmoker	82.2	0.90	79.0	0.57
Smoker	17.8	0.90	21.0	0.57
Framingham CVD 10-y Risk Score	9.9	0.21	10.6	0.14
Cardiometabolic risk factors				
Dyslipidemia	63.3	1.38	43.4	0.58
Diabetes	14.2	0.73	15.2	0.42
Obesity	50.2	1.32	48.8	0.71
Hypertension	22.7	0.80	25.7	0.48

Abbreviations: BMI, body mass index; BP, blood pressure; CVD, cardiovascular disease; GED, general educational development; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; NHANES, National Health and Nutritional Examination Survey; OGTT, oral glucose tolerance test; SE, standard error.
Conditions were defined for dyslipidemia (total cholesterol ≥240 mg/dL, LDL cholesterol ≥160 mg/dL, HDL cholesterol <40 mg/dL, self-reported use of cholesterol-lowering medication, or self-reported hypercholesterolemia), diabetes (fasting >8 h plasma glucose ≥126 mg/dL, fasting ≤8 h plasma glucose ≥200 mg/dL, or post-OGTT glucose ≥200 mg/dL; HbA1c ≥6.5%; self-reported medication use; or self-reported physician diagnosis), hypertension (BP ≥140/90 mm Hg or medication use), obesity (BMI ≥30 kg/m^2 for age 20–44 y; waist circumference >88 cm [women] or >102 cm [men] for age 45–74 y), Framingham CVD 10-y risk score (derived using laboratory predictors based on the Framingham Study criterion), and hypertension (systolic blood pressure >140 mm Hg, diastolic blood pressure ≥90 mm Hg, or self-reported medication use).
[1] Mean age reported with no adjustment.
[2] Log version of energy was used throughout the analyses.

The order of the retained factors differed for each study. In NHANES, meats were the first factor retained and explained most of the variation in nutrient intake, whereas in HCHS/SOL this was the last factor retained, explaining only 0.4% of the nutrient intake variation. Both studies had fats/oils identified as the second retained factor. Grains/legumes was the first factor retained in HCHS/SOL, explaining the largest amount of dietary intake variation (26.4%), but it was the third retained factor in NHANES. Dairy explained more of the variation in HCHS/SOL (third retained factor, 13.2%) compared to NHANES (fourth retained factor, 11.9%). Fruits/vegetables was the fourth retained factor for HCHS/SOL and fifth retained factor in NHANES.

Quintile-based factor score characteristics

Tables 3 and 4 describe sociodemographic, behavioral, and cardiometabolic characteristics among those in the lowest and the highest quintiles of each factor for NHANES and HCHS/SOL, respectively.

In NHANES, those in the highest quintile of meats were more likely to be male, married, have an annual household income <$25,000, current alcohol drinker, or have lived in the United States >10 y. Those in the highest quintile of fats/oils were more likely to be male, of Mexican heritage, have an educational attainment greater than high school/general educational development (GED) diploma, currently drink alcohol, or be employed. Those in the highest quintile of grains/legumes were more likely to be males, be of Mexican heritage, have lived in the United States >10 y, married, employed, or have dyslipidemia. Those in the highest quintile of dairy were mostly composed of individuals with an educational attainment more than a high school/GED diploma, married, and obese. Those in the highest quintile of fruits/vegetables were more likely to be of Mexican heritage, have an educational attainment less than a high school/GED diploma, be a nonsmoker, and have obesity.

In HCHS/SOL, those in the highest quintile of meats were more likely to be male, other Hispanic heritage, employed, or a current drinker. Those in the highest quintile of grains/legumes were more likely to be male, currently use alcohol, and not have hypertension. Those in the highest quintile of dairy were more likely be male and have an educational attainment greater than high school/GED diploma. Those in the highest quintile of fruits/vegetables were more likely to not be married or smoke. Those in the highest quintile of fats/oils were more likely to be male or have an educational attainment level greater than high school/GED diploma and not have diabetes, obesity, or hypertension.

NBFPs association with CRFs

The forest plots in Figure 2 show the ORs and the 95% CIs for all CRFs by quintiles of the retained NBFP scores, adjusted for confounders and comorbidities. An additional heatmap plot for the single factor model with ORs is provided in Supplemental Figure 2. Table 5 gives the ORs (95% CIs) for all CRFs by quintiles of factor scores and all the confounders and comorbidities listed previously.

The associations between the meats NBFP and diabetes were significant in HCHS/SOL. In HCHS/SOL, persons in the highest quintile of meats had lower odds of diabetes, using the third quintile to define a moderate intake of meats for reference. In contrast, persons in the lowest quintile of meats had higher odds of diabetes compared to those in the third quintile. No significant

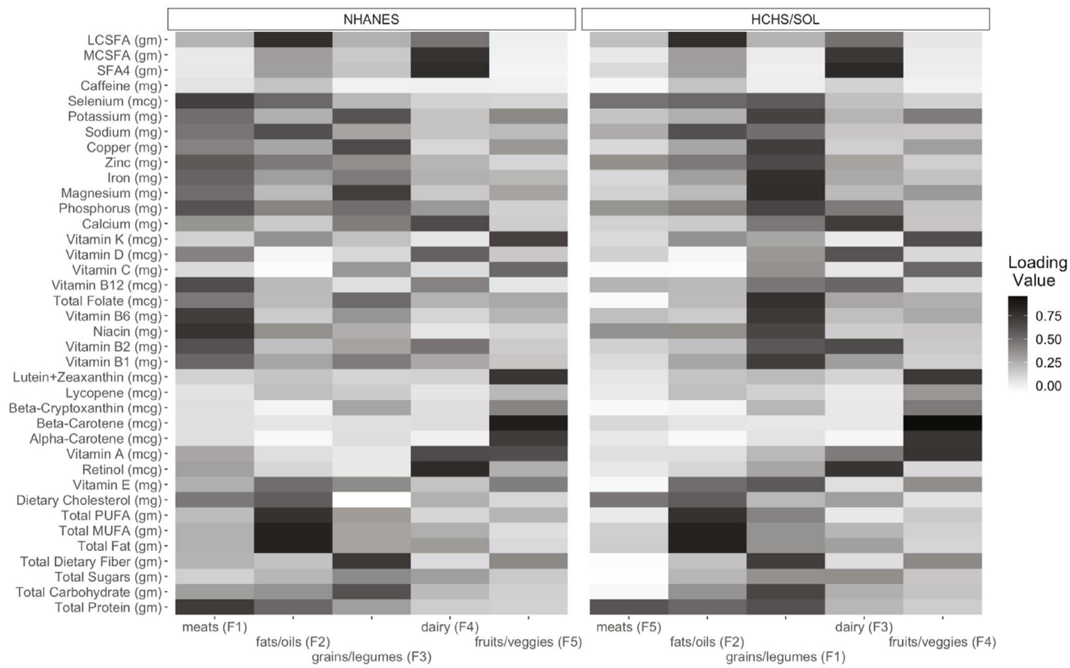

FIGURE 1. Heatmap of factor loading values for the 5 retained factors in NHANES and HCHS/SOL. Proportions of explained variance in nutrient intake for NHANES factors 1–5 are 15.9, 14.6, 14.2,11.9, and 11.6, respectively, while in HCHS/SOL, factors 1–5 are 24.6, 13.5, 13.2, 12.5, and 0.4, respectively. F, factor; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; LCSFA, long-chain saturated fatty acid; MCSFA, medium-chain saturated fatty acid; NHANES, National Health and Nutritional Examination Survey; SFA4, saturated fatty acid 4:0 (butyric acid).

associations were found between meats NBFP and obesity, hypertension, and dyslipidemia in either study.

The dairy NBFP was associated with hypertension in select quintiles in both studies. Compared to those in the third quintile, higher odds of hypertension were observed among those in the fourth quintile of dairy in NHANES. In HCHS/SOL, lower odds of hypertension were observed among those in the fourth quintile compared to the third quintile. No significant association was found between dairy NBFP and diabetes, obesity, or dyslipidemia in either study.

For the fruits/vegetables NBFP, only one significant association was found for those with diabetes in HCHS/SOL. Compared to those in the third quintile of fruits/vegetables, the odds of diabetes were lower for persons in the lowest quintile of fruits/vegetables. No association was found between the fruits/vegetables NBFP and obesity, hypertension, or dyslipidemia in either study.

No significant associations emerged between the fats/oils or the grains/legumes NBFP and any of the CRFs in NHANES or HCHS/SOL.

Discussion

Our analysis identified 5 similar NBFPs in HCHS/SOL and NHANES, which were meats, fats/oils, grains/legumes, dairy, and fruits/vegetables. These factors explained ~70% of the total variance in the nutrient intake. The order (importance) in which retained factors emerged differed between studies, which also indicates nutrient intake differences between studies. For example, the first factor retained in NHANES was meats, while in HCHS/SOL, grains/legumes were retained first. When looking at characteristics by quintiles, defined separately within each respective study sample, we saw differences in intake patterns. For example, those in the highest quintile of meats for NHANES participants were more likely to be male, married, have an annual household income <$25,000, be a current alcohol drinker, or have lived in the United States >10 y, while those in HCHS/SOL that belonged to the highest quintile of meats were more likely to be male, other Hispanic heritage, employed, or current alcohol drinker. Despite these NBFP similarities across studies, the associations between NBFPs and CRFs were distinctively different. Within the HCHS/SOL cohort, those in their highest quintile of meats and lowest quintile of fruits/vegetables were associated with lower odds of diabetes. The dairy NBFP was associated with lower odds of hypertension for those in their fourth quintile of dairy. There were no patterns associated with obesity and dyslipidemia in HCHS/SOL. Within the NHANES cohort, patterns associated with higher odds of hypertension included those in their fourth quintile of dairy.

Although comparison of our findings between the 2 studies is solely qualitative in nature, we highlight some similarities and differences in results. The NBFPs derived shared similarities in nutrient components across the 2 study populations. However, the effects of these patterns to the different CRF outcomes yielded, at times, contradictory and/or null results. Results from NHANES seem to indicate that diet had very minimal effect on CRF outcomes, except for a slightly higher than moderate intake of dairy as it relates to odds of hypertension. HCHS/SOL participants had higher odds of hypertension and diabetes associated with lower intakes (first quintile) of dairy and meats.

A challenge with cross-sectional studies is the loss of information to temporality. It is unknown if persons with diabetes or hypertension changed their diet upon awareness of their diagnosis to better manage their cardiometabolic health. This could mask effects for those who either have not yet been diagnosed or have not changed their dietary habits upon knowledge of their diagnosis. This could explain many of the null associations.

TABLE 3
Comparing NHANES characteristics by lowest and highest quintiles of factor scores

	Meats		Fats/oils		Grains/legumes		Dairy		Fruits/vegetables	
	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5
Female sex, %	54.7 (6.1)	34.6 (2.7)	56.0 (2.9)	26.9 (4.5)	70.1 (4.2)	15.5 (3.0)	40.9 (2.4)	48.1 (5.6)	37.8 (4.2)	45.5 (2.4)
Age, y	44.9 (1.0)	47.1 (0.8)	50.3 (1.0)	41.3 (0.9)	50.8 (0.9)	43.2 (0.8)	48.4 (0.8)	43.2 (1.2)	45.8 (1.0)	48.2 (0.8)
Mexican ethnicity, %	57.4 (6.4)	57.6 (4.3)	55.5 (4.3)	71.7 (6.2)	51.3 (5.4)	71.4 (5.7)	63.0 (5.0)	56.8 (7.0)	56.2 (6.3)	59.4 (5.1)
Educational attainment, %										
< HS diploma/GED	50.0 (5.9)	43.5 (3.4)	57.9 (2.9)	35.3 (7.3)	54.4 (3.8)	39.5 (4.1)	57.3 (3.2)	33.6 (5.2)	54.1 (6.0)	43.6 (3.0)
HS diploma/GED	13.4 (3.2)	20.5 (2.8)	16.4 (2.4)	13.7 (3.6)	15.3 (2.6)	22.8 (3.6)	17.5 (2.3)	21.3 (3.7)	14.8 (3.2)	18.9 (2.1)
> HS diploma/GED	36.6 (5.4)	36.0 (3.4)	25.6 (2.3)	50.9 (7.7)	30.3 (3.8)	37.7 (4.3)	25.2 (2.9)	45.1 (6.3)	31.2 (4.9)	37.5 (2.8)
Nativity/residence, %										
Born in United States	38.2 (6.9)	17.6 (2.8)	21.0 (3.2)	44.4 (8.1)	18.3 (2.8)	42.6 (5.3)	24.0 (3.9)	26.5 (5.4)	26.6 (4.3)	23.7 (3.1)
≤10 y in United States	15.9 (4.3)	19.2 (2.7)	18.7 (2.7)	9.3 (3.8)	20.3 (4.4)	13.3 (3.4)	18.5 (3.4)	20.5 (4.6)	17.9 (4.8)	19.1 (2.6)
>10 y in United States	45.9 (6.0)	63.1 (3.3)	60.4 (3.5)	46.3 (7.7)	61.4 (4.0)	44.1 (5.5)	57.4 (2.4)	53.0 (6.2)	55.5 (5.0)	57.2 (2.9)
Household income, %										
<$25,000	45.2 (4.8)	53.2 (3.9)	48.0 (2.8)	64.9 (5.4)	41.8 (3.8)	48.7 (3.8)	50.6 (3.2)	53.1 (5.6)	45.0 (4.7)	47.5 (2.9)
$25,000–$75,000	34.5 (5.1)	30.9 (3.7)	39.1 (2.9)	11.7 (3.2)	43.9 (5.3)	27.7 (3.7)	35.8 (3.1)	27.9 (4.2)	36.4 (4.1)	34.4 (3.5)
>$75,000	20.3 (4.6)	15.9 (2.3)	12.9 (2.1)	23.3 (4.9)	14.2 (3.2)	23.6 (3.8)	13.6 (1.7)	19.0 (5.0)	18.6 (4.1)	18.2 (2.2)
Married, %	74 (4.1)	71.0 (3.6)	60.1 (3.7)	80.2 (4.6)	58.7 (4.1)	77.3 (3.5)	71.7 (2.9)	75.0 (4.4)	72.7 (3.9)	71.7 (3.1)
Employment status, %										
Employed	60.6 (5.3)	73.2 (3.1)	52.9 (2.6)	85.6 (5.0)	50.7 (4.4)	76.8 (3.8)	70.4 (2.9)	69.2 (4.1)	66.3 (5.0)	64.4 (2.3)
Retired	5.1 (1.6)	5.7 (1.0)	13.0 (1.9)	1.1 (0.9)	11.5 (2.0)	3.1 (1.1)	4.6 (0.8)	3.7 (1.3)	2.5 (0.9)	9.0 (1.7)
Unemployed	34.3 (5.3)	21.1 (3.0)	34.1 (1.9)	13.4 (4.6)	37.8 (4.2)	20.2 (3.8)	25 (2.6)	27.1 (3.7)	31.3 (5.0)	26.6 (2.2)
Energy, kcal	1605.6 (70.5)	2404.9 (52.9)	1604.6 (41.9)	2621.1 (86.2)	1294.9 (34.3)	2798.2 (77.5)	1918.0 (56.5)	2224.3 (78.1)	1713.5 (66.5)	2295.0 (45.3)
Alcohol use, %										
Current	53 (5.9)	63.9 (3.9)	54.7 (3.9)	66.2 (6.0)	43.1 (5.5)	70.5 (4.2)	55.9 (3.2)	57.5 (5.5)	56.9 (4.7)	54.3 (4.0)
Former	10.4 (3.5)	12.3 (2.6)	11.5 (1.9)	13.2 (3.4)	14.8 (3.3)	10.4 (3.2)	14.2 (2.1)	17.0 (4.2)	12.9 (3.4)	14.3 (3.4)
Never	36.6 (5.4)	23.8 (2.7)	33.8 (3.3)	20.6 (5.1)	42.1 (5.6)	19.1 (3.4)	29.9 (3.6)	25.5 (4.3)	30.2 (3.9)	31.4 (2.9)
Smoker, %	13.7 (3.8)	16.7 (1.9)	13.4 (2.1)	16.1 (4.1)	13.7 (2.7)	18.2 (3.7)	23.2 (2.6)	13.5 (3.4)	23.6 (4.1)	11.0 (1.6)
Framingham CVD 10-y Risk Score	7.7 (0.7)	10.0 (0.6)	11.2 (0.8)	7.2 (0.9)	10.1 (0.7)	9.1 (0.9)	11.9 (0.6)	6.3 (0.6)	9.2 (0.7)	10.2 (0.6)
Cardiometabolic risk factors, %										

Abbreviations: BMI, body mass index; BP, blood pressure; CVD, cardiovascular disease; GED, general educational development; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; HS, high school; LDL, low-density lipoprotein; LCSFA, long-chain saturated fatty acid; MCSFA, medium-chain saturated fatty acid; MUFA, monounsaturated fatty acid; NHANES, National Health and Nutritional Examination Survey; OGTT, oral glucose tolerance test; PUFA, polyunsaturated fatty acid; Q, quintile.

Conditions were defined for dyslipidemia (total cholesterol ≥240 mg/dL, LDL cholesterol ≥160 mg/dL, HDL cholesterol <40 mg/dL, self-reported use of cholesterol-lowering medication, or self-reported hypercholesterolemia), diabetes (fasting >8 h plasma glucose ≥126 mg/dL, fasting ≤8 h plasma glucose ≥200 mg/dL, or post-OGTT glucose ≥200 mg/dL; HbA1c ≥6.5%; self-reported medication use; or self-reported physician diagnosis), hypertension (BP ≥140/90 mm Hg or medication use), obesity (BMI ≥30 kg/m^2 for age 20–44 y; waist circumference >88 cm [women] or >102 cm [men] for age 45–74 y), Framingham CVD 10-y risk score (derived using laboratory predictors based on the Framingham Study criterion), and hypertension (systolic blood pressure >140 mm Hg, diastolic blood pressure ≥ 90 mm Hg, or self-reported medication use). Dominant nutrients loading onto meats (protein, niacin, vitamin B6, phosphorus, zinc, selenium, vitamin B12), fats/oils (total MUFA, total fat, LCSFA, total PUFA, sodium), dairy (retinol, vitamin A, calcium, butyric acid, MCSFA), grains/legumes (copper, magnesium, total dietary fiber), fruits/vegetables (vitamin K, lutein + zeaxanthin, β-carotene, α-carotene). Reference levels are male, other Hispanic, >HS Diploma/GED, born in United States, annual income >$75,000, married, employed, never drinker, and nonsmoker. 90 mm Hg, or self-reported medication use). Dominant nutrients loading onto meats (protein, niacin, vitamin B6, phosphorus, zinc, selenium, vitamin B12), fats/oils (total MUFA, total fat, LCSFA, total PUFA, sodium), dairy (retinol, vitamin A, calcium, butyric acid , MCSFA), grains/legumes (copper, magnesium, total dietary fiber), fruits/vegetables (vitamin K, lutein + zeaxanthin, β-carotene, α-carotene). Reference levels are male, other Hispanic, >HS Diploma/GED, born in United States, annual income >$75,000, married, employed, never drinker, and nonsmoker.

TABLE 4

Comparing HCHS/SOL characteristics by lowest and highest quintiles of factor scores

	Grains/Legumes		Fats/Oils		Dairy		Fruits/Veggies		Meats	
	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5
Female sex, %	73.6 (1.4)	37.3 (1.7)	67.3 (1.4)	36.6 (1.6)	64.8 (1.5)	31.4 (1.6)	54.5 (1.7)	51.6 (1.5)	60.8 (1.6)	43.0 (1.5)
Age, y	48.4 (0.5)	45.9 (0.4)	48.5 (0.4)	45.6 (0.4)	47.4 (0.4)	45.7 (0.4)	46.7 (0.4)	47.0 (0.4)	47.3 (0.4)	46.2 (0.4)
Mexican ethnicity, %	33.7 (2.0)	42.1 (2.2)	39.4 (2.1)	35.5 (2.3)	29.4 (2.0)	44.4 (2.5)	22.0 (1.7)	49.1 (2.5)	39.5 (2.5)	34.1 (2.1)
Educational attainment (%)										
< HS diploma/GED	41.2 (1.6)	29.0 (1.7)	38.3 (1.4)	28.1 (1.5)	44.8 (1.6)	24.2 (1.4)	36.8 (1.7)	28.7 (1.5)	31.8 (1.8)	34.6 (1.4)
HS diploma/GED	21.8 (1.3)	25.7 (1.4)	26.1 (1.5)	27.8 (1.5)	24.8 (1.5)	26.5 (1.5)	25.7 (1.5)	25.4 (1.4)	24.9 (1.5)	27.6 (1.5)
> HS diploma/GED	37.0 (1.7)	45.3 (1.8)	35.5 (1.7)	44.1 (1.7)	30.4 (1.6)	49.3 (1.8)	37.5 (1.7)	45.9 (1.9)	43.2 (2.0)	37.8 (1.6)
Nativity/residence, %										
Born in United States	12.7 (1.1)	18.4 (1.4)	10.0 (1.1)	19.3 (1.5)	17.4 (1.3)	17.3 (1.5)	18.9 (1.6)	7.7 (0.8)	18.7 (1.6)	12.7 (1.2)
≤10 y in United States	22.9 (1.4)	24.2 (1.6)	23.6 (1.5)	25.5 (1.5)	20.9 (1.3)	26.7 (1.7)	21.3 (1.5)	31.3 (1.7)	21.2 (1.4)	29.9 (1.7)
>10 y in United States	64.5 (1.6)	57.4 (1.6)	66.4 (1.6)	55.2 (1.6)	61.7 (1.6)	56.0 (1.6)	59.8 (1.8)	61.0 (1.7)	60.0 (1.7)	57.4 (1.7)
Household income, %										
<$25,000	62.2 (1.8)	52.2 (2.1)	60.4 (1.8)	54.5 (1.9)	66.9 (1.6)	46.6 (2.0)	64.1 (1.7)	52.4 (2)	56.5 (2)	60.6 (1.6)
$25,000–$75,000	34.3 (1.7)	38.9 (1.6)	35.0 (1.5)	38.2 (1.6)	30.4 (1.5)	44.4 (1.7)	30.6 (1.5)	40.9 (1.7)	36.3 (1.5)	35.3 (1.6)
>$75,000	3.5 (0.7)	8.9 (1.7)	4.6 (0.8)	7.3 (1.1)	2.8 (0.6)	9.0 (1.5)	5.2 (0.9)	6.7 (1.0)	7.2 (1.2)	4.1 (0.7)
Married, %	49.4 (1.6)	40.5 (1.9)	44.4 (1.6)	44.5 (1.7)	47.2 (1.7)	38.6 (1.7)	50.7 (1.8)	37.3 (1.6)	43.6 (1.8)	44.6 (1.6)
Employment status, %										
Employed	50.6 (1.6)	59.5 (1.9)	55.6 (1.6)	55.5 (1.7)	52.8 (1.7)	61.4 (1.7)	49.3 (1.8)	62.7 (1.6)	56.4 (1.8)	55.4 (1.6)
Retired	14.2 (1.4)	8.7 (0.9)	13.7 (1.1)	7.0 (1.0)	12.7 (0.9)	7.1 (0.9)	10.5 (0.9)	9.1 (1.0)	10.4 (1)	8.8 (0.9)
Unemployed	36.4 (1.4)	33.5 (1.8)	36.1 (1.4)	34.1 (1.6)	41.1 (1.4)	30.2 (1.6)	39.3 (1.7)	34.2 (1.5)	38.3 (1.8)	33.2 (1.6)
Energy, kcal	1267.2 (18.5)	2368.6 (27.3)	1361.5 (16.5)	2530.4 (28.7)	1283.1 (15.7)	2739.4 (31.1)	1669.8 (27.8)	2091.7 (23.6)	1516.5 (22.1)	2244.4 (29.0)
Alcohol use, %										
Current	42.6 (1.6)	53 (1.9)	41.5 (1.6)	56.9 (1.8)	42.2 (1.6)	59.2 (1.7)	48.3 (1.7)	50.6 (1.8)	50.1 (2.1)	50.5 (1.6)
Former	35.0 (1.7)	32.3 (1.6)	38.1 (1.6)	27.2 (1.6)	36.2 (1.6)	26.0 (1.3)	33.2 (1.7)	30.5 (1.4)	30.5 (1.7)	32.0 (1.5)
Never	22.4 (1.4)	14.7 (1.2)	20.4 (1.3)	15.9 (1.4)	21.6 (1.5)	14.8 (1.2)	18.5 (1.5)	18.9 (1.2)	19.4 (1.4)	17.5 (1.1)
Smoker, %	16.9 (1.4)	22.9 (1.5)	11.6 (0.9)	26.3 (1.5)	20.8 (1.2)	24.9 (1.4)	26.4 (1.5)	16.3 (1.2)	19.3 (1.5)	21.3 (1.3)
Framingham CVD 10-yr Risk Score	9.7 (0.4)	9.8 (0.4)	9.8 (0.3)	10.0 (0.3)	9.6 (0.3)	10.0 (0.4)	9.9 (0.3)	9.2 (0.3)	10.1 (0.4)	9.4 (0.3)
Cardiometabolic risk factors, %										
Dyslipidemia	46.3 (1.5)	46.8 (1.7)	50.2 (1.5)	45.9 (1.7)	46.4 (1.7)	46.6 (1.5)	46.6 (1.7)	47.2 (1.5)	44.3 (1.7)	49.0 (1.7)
Diabetes	19.3 (1.2)	14.9 (1.1)	21.2 (1.1)	15.2 (1.2)	19.3 (1.1)	15.0 (1.1)	14.9 (1.0)	17.6 (1.2)	22.0 (1.2)	12.6 (0.9)
Obesity	59.6 (1.6)	48.2 (1.7)	53.3 (1.6)	49.7 (1.8)	56.3 (1.7)	43.5 (1.7)	54.3 (1.7)	49.3 (1.7)	55.7 (1.9)	46.1 (1.5)
Hypertension	33.6 (1.5)	27.1 (1.6)	34.3 (1.5)	28.7 (1.5)	31.3 (1.4)	24.6 (1.4)	32.1 (1.6)	26.4 (1.5)	32.9 (1.6)	26.7 (1.3)

Abbreviations: BMI, body mass index; BP, blood pressure; CVD, cardiovascular disease; GED, general educational development; HbA1c, glycated hemoglobin; HCHS/SOL, Hispanic Community Health Study/ Study of Latinos; HDL, high-density lipoprotein; HS, high school; LDL, low-density lipoprotein; LCSFA, long-chain saturated fatty acid; MCSFA, medium-chain saturated fatty acid; MUFA, monounsaturated fatty acid; OGTT, oral glucose tolerance test; PUFA, polyunsaturated fatty acid; Q, quintile.

Conditions were defined for dyslipidemia (total cholesterol ≥240 mg/dL, LDL cholesterol ≥160 mg/dL, HDL cholesterol <40 mg/dL, self-reported use of cholesterol-lowering medication, or self-reported hypercholesterolemia), diabetes (fasting >8 h plasma glucose ≥126 mg/dL, fasting time ≤8 h plasma glucose ≥200 mg/dL, or post-OGTT glucose ≥200 mg/dL; HbA1c ≥6.5%; self-reported medication use; or self-reported physician diagnosis), hypertension (BP ≥140/90 mm Hg or medication use), obesity (BMI ≥30 kg/m^2 for age 20–44 y; waist circumference >88 cm [women] or >102 cm [men] for age 45–74 y), Framingham CVD 10-y risk score (derived using laboratory predictors based on the Framingham Study criterion), and hypertension (systolic blood pressure >140 mm Hg, diastolic blood pressure ≥90 mm Hg, self-reported medication use, or self-reported physician diagnosis). Dominant nutrients loading onto grains/legumes (total carbohydrate, total dietary fiber, total folate, magnesium, copper, potassium, vitamin B1, vitamin B6, iron), meats (total protein, selenium), dairy (retinol, vitamin B2, vitamin D, calcium, butyric acid, MCSFA), fats/oils (total fat, MUFA, PUFA, LCSFA), fruits/vegetables (vitamin A, α-carotene, β-carotene, lutein + zeaxanthin, vitamin K). Reference levels are male, other Hispanic, > HS diploma/GED, born in United States, annual income >$75,000, married, employed, never drinker, and nonsmoker.

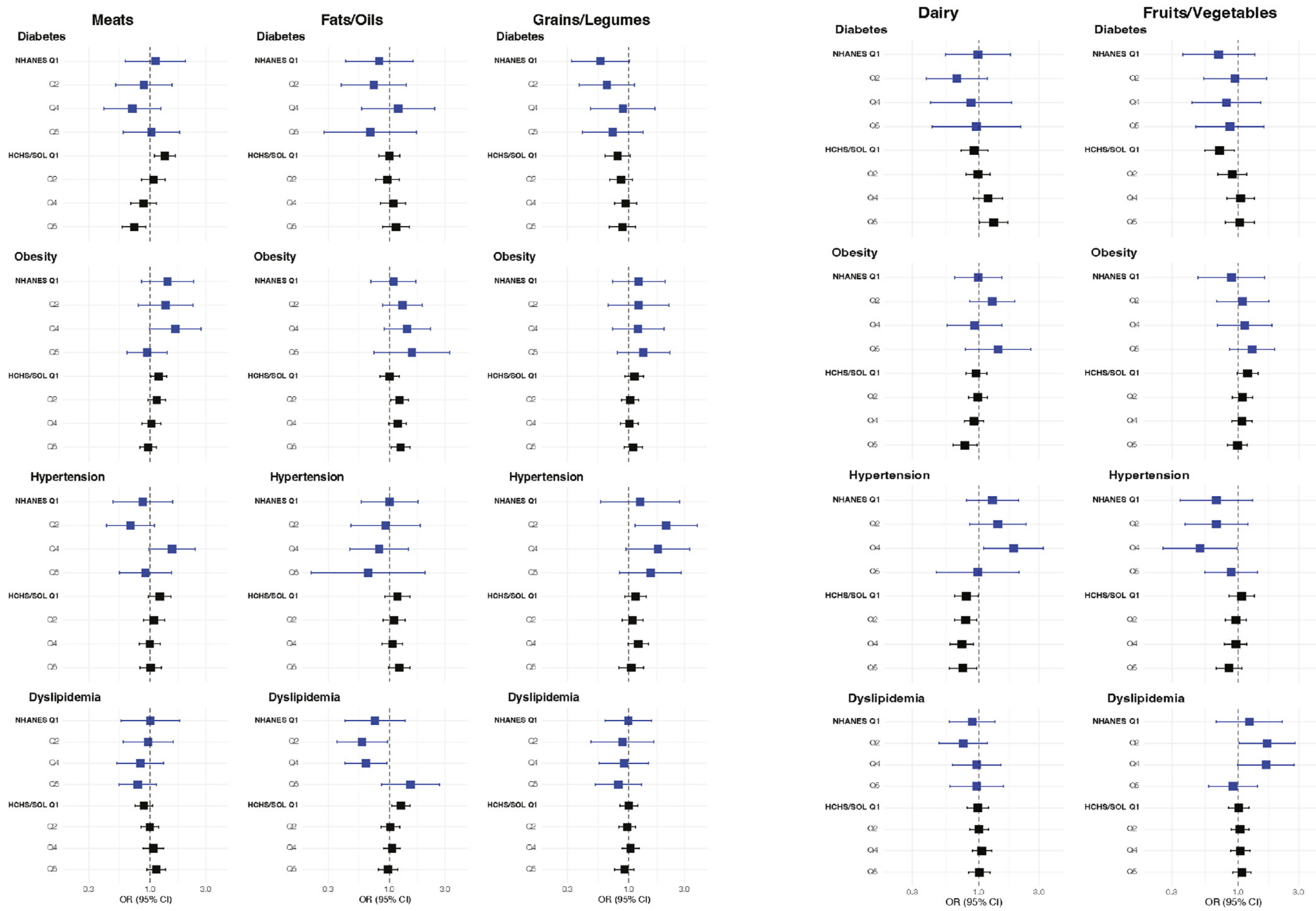

FIGURE 2. Forest plots of single factor models (OR and 95% CI) by NBFPs and cardiometabolic risk factors for NHANES (n = 3605) and HCHS/SOL (n = 14,416) respondents. The third quintile, calculated separately for each study sample and each NBFP, is the defined referent category. Conditions were defined for dyslipidemia (total cholesterol ≥240 mg/dL, LDL cholesterol ≥160 mg/dL, HDL cholesterol <40 mg/dL, self-reported use of cholesterol-lowering medication, or self-reported hypercholesterolemia), diabetes (fasting >8 h plasma glucose ≥126 mg/dL, fasting 8 h plasma glucose ≥200 mg/dL, or post-OGTT glucose ≥200 mg/dL; HbA1c ≥6.5%; self-reported medication use; or self-reported physician diagnosis), hypertension (BP ≥140/90 mm Hg or medication use), obesity (BMI ≥30 kg/m^2 for age 20–44 y; waist circumference >88 cm [women] or >102 cm [men] for age 45–74 y), Framingham CVD 10-year risk score (derived using laboratory predictors based on the Framingham Study criterion), and hypertension (systolic blood pressure >140 mm Hg, diastolic blood pressure ≥90 mm Hg, or self-reported medication use). BMI, body mass index; CI, confidence interval; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; NBFP, nutrient-based food pattern; NHANES, National Health and Nutritional Examination Survey; OGTT, oral glucose tolerance test; OR, odds ratio; Q, quintile.

Differing results between the 2 studies require further exploration of potential confounding to explain the conflicting relationships. We analyzed CRF outcomes independently, but significance was found among CRF comorbidities for both studies. This illustrates the complexity of how CRFs may interact with one another when exposed to different intake patterns. The nutrients characterized in this study were labeled with broad food groups but fall short of explicitly identifying the actual food(s) that drive or dominate a single pattern and subsequently CRF association over another. With the exception of age, all other sociodemographic covariates found little agreement across both studies, indicating that associations made for each study may be sensitive to the sampled study population.

These discrepancies between studies raise concern of how best to generalize these differing results in characterizing dietary behaviors of United States Hispanic/Latino adults [19,20]. Each study is limited in its participants' representation, which is partially explained by the study sampling design. This is further highlighted in Table 5, where additional demographic covariates included in the model yielded varying ORs between the 2 studies. HCHS/SOL implemented a sampling design aimed to collect an interpretable sized distribution of 7 identifiably different ethnic backgrounds in 4 large urban areas, omitting populations in nonurban areas. NHANES implemented a sampling design that aimed to collect an interpretable sized distribution relative to the United States population. However, these sampling strategies differed for those that identify as Mexican and other Hispanic, as well as residential geographies that included nonurban areas, but are not made publicly available [54]. Further, although ample information about nativity and acculturation of participants was available for HCHS/SOL participants, this was largely unknown in NHANES. Differences in nativity and acculturation could potentially explain differences in the nutrients contained in the different foods consumed from the 2 studies, which could impact risks such as diabetes [3,11,21,57,58]. These challenges limit the information we can obtain

TABLE 5
Odds ratio (95% CIs) for association of NHANES and HCHS/SOL respondent characteristics and dietary factors with cardiometabolic risk factors

	Diabetes		Obesity		Hypertension		Dyslipidemia	
	NHANES	HCHS/SOL	NHANES	HCHS/SOL	NHANES	HCHS/SOL	NHANES	HCHS/SOL
Female	0.56 (0.33, 0.97)	0.77 (0.65, 0.92)	2.12 (1.29, 3.47)	2.38 (2.07, 2.74)	0.65 (0.37, 1.12)	0.68 (0.58, 0.8)	0.37 (0.23, 0.58)	0.37 (0.32, 0.42)
Age, y	1.04 (1.02, 1.07)	1.05 (1.04, 1.06)	1.03 (1.01, 1.04)	1.02 (1.01, 1.02)	1.11 (1.09, 1.13)	1.09 (1.08, 1.1)	1.01 (0.99, 1.03)	1.02 (1.01, 1.02)
Mexican	0.97 (0.5, 1.87)	1.41 (1.19, 1.67)	1.35 (0.92, 1.98)	1.07 (0.93, 1.24)	1.16 (0.75, 1.79)	0.56 (0.47, 0.67)	0.91 (0.64, 1.31)	1.09 (0.95, 1.24)
Energy, kcal	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)
< HS diploma/GED	1.5 (0.83, 2.71)	1.26 (1.05, 1.52)	0.84 (0.57, 1.24)	1.13 (0.99, 1.29)	1.08 (0.66, 1.77)	1.08 (0.91, 1.27)	1.34 (0.99, 1.82)	1.03 (0.9, 1.18)
HS diploma/GED	1.17 (0.57, 2.42)	1.1 (0.89, 1.36)	0.81 (0.47, 1.4)	1.1 (0.96, 1.27)	1.9 (1.04, 3.44)	1.11 (0.93, 1.32)	1.1 (0.79, 1.52)	1.03 (0.9, 1.17)
≤10 y in United States	0.78 (0.37, 1.61)	0.76 (0.56, 1.03)	0.59 (0.4, 0.88)	0.55 (0.46, 0.65)	0.57 (0.29, 1.13)	1.03 (0.8, 1.32)	1.04 (0.67, 1.61)	1.1 (0.92, 1.33)
>10 y in United States	1.08 (0.63, 1.86)	1.15 (0.91, 1.44)	0.81 (0.59, 1.12)	0.73 (0.62, 0.87)	0.51 (0.32, 0.83)	0.9 (0.73, 1.11)	1.08 (0.71, 1.64)	1.14 (0.97, 1.34)
Income <$25,000	1.2 (0.56, 2.56)	1.76 (1.06, 2.9)	1.17 (0.75, 1.82)	1 (0.71, 1.41)	0.91 (0.47, 1.76)	1.21 (0.87, 1.69)	0.86 (0.54, 1.38)	1.04 (0.8, 1.37)
Income $25,000–$75,000	1.16 (0.61, 2.21)	1.61 (0.98, 2.65)	1.57 (1.02, 2.43)	1.09 (0.8, 1.48)	0.77 (0.41, 1.45)	1.19 (0.86, 1.64)	0.82 (0.51, 1.34)	1.03 (0.8, 1.33)
Unmarried	0.84 (0.54, 1.31)	0.91 (0.77, 1.06)	0.86 (0.61, 1.22)	1.02 (0.92, 1.14)	1.19 (0.85, 1.68)	1.08 (0.95, 1.23)	0.56 (0.39, 0.8)	0.89 (0.78, 1.01)
Retired	1.27 (0.79, 2.06)	1.26 (0.96, 1.66)	1.48 (1, 2.2)	0.72 (0.57, 0.91)	1 (0.58, 1.7)	1.3 (0.98, 1.71)	1 (0.73, 1.35)	1.05 (0.81, 1.37)
Unemployed	0.93 (0.44, 1.93)	1.28 (1.08, 1.51)	0.64 (0.3, 1.37)	1.06 (0.93, 1.21)	0.71 (0.34, 1.52)	1.03 (0.87, 1.22)	1.61 (0.76, 3.39)	1.14 (1, 1.3)
Current drinker	0.89 (0.51, 1.54)	1.11 (0.9, 1.36)	0.96 (0.61, 1.51)	1.1 (0.94, 1.28)	0.92 (0.58, 1.44)	0.95 (0.78, 1.15)	0.83 (0.55, 1.25)	0.85 (0.72, 1)
Former drinker	1.71 (1.01, 2.88)	0.76 (0.62, 0.92)	0.52 (0.26, 1.04)	1 (0.85, 1.18)	0.76 (0.37, 1.59)	0.95 (0.79, 1.15)	2.17 (1.25, 3.75)	0.81 (0.69, 0.94)
Smoker	0.87 (0.42, 1.78)	0.98 (0.8, 1.2)	0.8 (0.56, 1.14)	1.03 (0.89, 1.2)	1.21 (0.72, 2.04)	0.84 (0.7, 1)	1.22 (0.8, 1.84)	1.05 (0.92, 1.2)
Dyslipidemia	1.37 (0.76, 2.46)	2.04 (1.74, 2.38)	2.08 (1.49, 2.92)	1.90 (1.66, 2.17)	1.87 (1.38, 2.52)	1.44 (1.24, 1.67)	—	—
Obesity	2.69 (1.78, 4.09)	1.89 (1.61, 2.22)	—	—	2.36 (1.45, 3.85)	2.21 (1.92, 2.56)	1.65 (1.17, 2.31)	1.38 (1.19, 1.59)
Hypertension	2.92 (1.64, 5.21)	2.15 (1.84, 2.53)	2.00 (1.29, 3.09)	2.02 (1.76, 2.32)	—	—	1.26 (0.66, 2.39)	1.98 (1.69, 2.33)
Diabetes	—	—	2.52 (1.60, 3.97)	1.68 (1.44, 1.97)	2.94 (1.69, 5.11)	2.15 (1.84, 2.52)	2.04 (1.46, 2.85)	1.91 (1.67, 2.18)
Meats								
Q1	1.03 (0.45, 2.35)	1.48 (1.19, 1.84)	1.29 (0.7, 2.37)	1.24 (1.03, 1.48)	0.89 (0.41, 1.92)	1.34 (1.07, 1.68)	0.9 (0.48, 1.68)	0.91 (0.76, 1.09)
Q2	0.81 (0.44, 1.5)	1.11 (0.88, 1.41)	1.3 (0.72, 2.35)	1.16 (0.97, 1.39)	0.67 (0.35, 1.27)	1.13 (0.92, 1.39)	0.86 (0.51, 1.44)	1.01 (0.85, 1.19)
Q4	0.73 (0.39, 1.37)	0.86 (0.66, 1.1)	1.64 (0.94, 2.85)	1 (0.83, 1.2)	1.64 (0.94, 2.85)	0.93 (0.76, 1.15)	0.9 (0.51, 1.56)	1.05 (0.86, 1.29)
Q5	1.12 (0.57, 2.22)	0.68 (0.53, 0.88)	1.01 (0.61, 1.67)	0.9 (0.75, 1.09)	0.96 (0.46, 2.01)	0.87 (0.67, 1.11)	0.89 (0.53, 1.49)	1.09 (0.88, 1.34)
Fats/Oils								
Q1	0.87 (0.38, 1.99)	1.23 (0.96, 1.57)	1.08 (0.64, 1.82)	1.13 (0.91, 1.41)	0.9 (0.44, 1.84)	1.4 (1.06, 1.86)	0.8 (0.37, 1.72)	1.22 (0.99, 1.51)
Q2	0.78 (0.37, 1.66)	1.05 (0.83, 1.33)	1.27 (0.84, 1.93)	1.27 (1.06, 1.52)	0.82 (0.4, 1.66)	1.18 (0.95, 1.47)	0.62 (0.34, 1.14)	1.01 (0.84, 1.23)
Q4	1.26 (0.54, 2.97)	1 (0.78, 1.29)	1.43 (0.88, 2.33)	1.11 (0.93, 1.32)	0.81 (0.41, 1.6)	0.98 (0.8, 1.21)	0.64 (0.41, 1.01)	1.06 (0.9, 1.26)
Q5	0.77 (0.32, 1.85)	0.92 (0.7, 1.2)	1.63 (0.72, 3.71)	1.08 (0.88, 1.33)	0.66 (0.2, 2.22)	0.99 (0.77, 1.29)	1.48 (0.71, 3.09)	1.02 (0.82, 1.26)
Grains/legumes								
Q1	0.55 (0.27, 1.1)	1.12 (0.87, 1.46)	1.23 (0.65, 2.31)	0.91 (0.75, 1.12)	1.09 (0.47, 2.51)	0.78 (0.62, 0.98)	0.99 (0.64, 1.56)	1 (0.8, 1.25)
Q2	0.65 (0.34, 1.23)	1.06 (0.85, 1.32)	1.16 (0.59, 2.28)	0.97 (0.82, 1.16)	1.91 (0.9, 4.05)	0.79 (0.65, 0.96)	0.89 (0.46, 1.69)	1.01 (0.84, 1.21)
Q4	0.92 (0.44, 1.92)	1.14 (0.88, 1.48)	1.31 (0.71, 2.4)	0.91 (0.77, 1.08)	1.97 (0.91, 4.24)	0.73 (0.58, 0.91)	0.85 (0.49, 1.48)	1.05 (0.88, 1.25)
Q5	0.81 (0.4, 1.67)	1.15 (0.88, 1.5)	1.51 (0.82, 2.77)	0.74 (0.59, 0.93)	1.93 (0.88, 4.25)	0.68 (0.52, 0.9)	0.7 (0.41, 1.22)	1 (0.8, 1.24)
Dairy								
Q1	0.99 (0.49, 1.98)	0.89 (0.68, 1.16)	1.09 (0.65, 1.82)	1.25 (1.02, 1.53)	1.31 (0.67, 2.56)	1.35 (1.06, 1.72)	0.87 (0.54, 1.4)	0.98 (0.82, 1.18)
Q2	0.66 (0.35, 1.25)	0.9 (0.72, 1.13)	1.32 (0.81, 2.15)	1.07 (0.9, 1.28)	1.51 (0.8, 2.84)	1.16 (0.94, 1.44)	0.74 (0.43, 1.28)	0.96 (0.81, 1.15)
Q4	0.85 (0.39, 1.85)	0.9 (0.72, 1.12)	0.87 (0.49, 1.54)	0.99 (0.83, 1.17)	2.1 (1.12, 3.92)	1.14 (0.93, 1.39)	0.93 (0.55, 1.57)	1.04 (0.88, 1.24)
Q5	0.88 (0.37, 2.07)	0.8 (0.61, 1.06)	1.37 (0.7, 2.68)	1.02 (0.84, 1.24)	1.07 (0.48, 2.39)	0.88 (0.69, 1.13)	0.93 (0.5, 1.71)	0.92 (0.75, 1.12)

(*continued on next page*)

TABLE 5 (*continued*)

	Diabetes		Obesity		Hypertension		Dyslipidemia	
	NHANES	HCHS/SOL	NHANES	HCHS/SOL	NHANES	HCHS/SOL	NHANES	HCHS/SOL
Fruits/vegetables								
Q1	0.6 (0.27, 1.33)	0.69 (0.53, 0.9)	0.82 (0.43, 1.56)	1.21 (1, 1.46)	0.66 (0.34, 1.27)	1.14 (0.91, 1.42)	1.3 (0.66, 2.58)	1.03 (0.86, 1.24)
Q2	0.97 (0.49, 1.92)	0.87 (0.67, 1.13)	1.04 (0.6, 1.82)	1.08 (0.9, 1.3)	0.69 (0.36, 1.31)	0.97 (0.81, 1.17)	1.74 (0.95, 3.18)	1.05 (0.89, 1.23)
Q4	0.84 (0.38, 1.84)	1.04 (0.81, 1.33)	1.18 (0.67, 2.09)	1.07 (0.89, 1.29)	0.48 (0.22, 1.03)	0.95 (0.78, 1.17)	1.64 (0.9, 2.98)	1.03 (0.86, 1.24)
Q5	0.93 (0.44, 1.96)	1.01 (0.78, 1.32)	1.45 (0.88, 2.4)	1 (0.84, 1.2)	0.77 (0.4, 1.49)	0.83 (0.65, 1.06)	0.95 (0.53, 1.7)	1.07 (0.9, 1.27)

Note: BMI, body mass index; BP, blood pressure; CI, confidence interval; CVD, cardiovascular disease; GED, general educational development; HbA1c, glycated hemoglobin; HCHS/SOL, Hispanic Community Health Study/ Study of Latinos; HDL, high-density lipoprotein; HS, high school; LDL, low-density lipoprotein; NHANES, National Health and Nutritional Examination Survey; OGTT, oral glucose tolerance test; Q, quintile.

This analysis includes all factors simultaneously. Reference levels are Q3, male, other Hispanic, > HS diploma/GED, born in United States, annual income >\$75,000, married, employed, never drinker, and nonsmoker. Conditions were defined for dyslipidemia (total cholesterol ≥240 mg/dL, LDL cholesterol ≥160 mg/dL, HDL cholesterol <40 mg/dL, self-reported use of cholesterol-lowering medication, or self-reported hypercholesterolemia), diabetes (fasting >8 h plasma glucose ≥126 mg/dL, fasting ≥8 h plasma glucose ≥200 mg/dL, or post-OGTT glucose ≥200 mg/dL; HbA1c ≥6.5%; self-reported medication use; or self-reported physician diagnosis), hypertension (BP ≥140/90 mm Hg or medication use), obesity (BMI ≥30 kg/m^2 for age 20–44 y; waist circumference >88 cm [women] or >102 cm [men] for age 45–74 y), Framingham CVD 10-y risk score (derived using laboratory predictors based on the Framingham Study criterion), and hypertension (systolic blood pressure >140 mm Hg, diastolic blood pressure ≥90 mm Hg, or self-reported medication use).

regarding nutrition and cardiometabolic health of this population from a single study in isolation.

Methods such as factor analysis, implemented in this study, or adherence scores to examine diet quality [16,59], rely on the composition of the study population. Greater representation of demographics that are known to influence diet (e.g., cultural background, geographical location) can drive the overall patterns identified in data-driven methods such as principal component analysis. Both studies include different Hispanic/Latino backgrounds, but the representation of these backgrounds vary between the 2 studies. With nutrient intake previously reported to differ by ethnic background in HCHS/SOL [60], different population compositions can yield different patterns between the 2 studies.

Prior work examining diets of Hispanic/Latino adult participants of NHANES or HCHS/SOL have focused primarily on diet quality, via dietary adherence scores and its association to CVD by ethnic background [16,18,22,58,59,61]. Although useful, adherence scores are a summation of components and fail to provide insight on which dietary components may be driving a higher or lower score in the study population.

Other studies have examined the association of individual nutrients on CVD risk factors [60,61], but are unable to account for the practicality of multiple nutrients being consumed together from different food sources. Maldonado et al. [22,62], De Vito [R. De Vito, B. Stephenson, D. Sotres-Alvarez, A.M. Siega-Riz, J. Mattei, M. Parpinel, B.A. Peters, S.A. Bainter, M.L. Daviglus, L. Van Horn, V. Edefonti, 2022, unpublished results], and Stephenson et al. [12] took a joint approach, deriving food-based dietary patterns in the HCHS/SOL cohort. Dietary patterns derived by De Vito et al. [R. De Vito, B. Stephenson, D. Sotres-Alvarez, A.M. Siega-Riz, J. Mattei, M. Parpinel, B.A. Peters, S.A. Bainter, M.L. Daviglus, L. Van Horn, V. Edefonti, 2022, unpublished results] and Stephenson et al. [12] accounted for both ethnic and geographic differences but did not examine associations with CVD risk factors. Maldonado et al. [11] generated food-based patterns stratified by ethnic background. The second Maldonado et al. [62] study examined pattern differences by diabetes outcomes but did not consider other CVD risk factors. Stephenson et al. [63] also derived dietary patterns using the NHANES cohort, looking at racial and ethnic differences, but focused on a low-income female adult population and did not include associations to CVD risk factors. Osborn et al. [24] used food pattern equivalents to derive dietary patterns and explored associations with varyingly different CRF outcomes among Hispanic/Latino NHANES participants from 2013–2018. Our results saw similar null effects in our grains/legumes dietary pattern as they saw with the plant-based dietary pattern. However, our associations differed with dairy and hypertension and cholesterol, but this may be due to the inclusion of refined carbohydrates in their fats and cheese dietary pattern.

This study is strengthened by its specific focus on nutrient intake of Hispanic/Latino adults across the 2 study cohorts and examining their association with 4 major CVD risk factors. Our study focused on deriving dietary patterns from nutrient intake to allow better comparability between the 2 survey cohorts, as different foods, which comprise of multiple nutrients, may have been consumed and reported differently [64,65].

Given the unknown distribution of other Hispanic/Latino ethnic groups in NHANES, it is difficult to know how representative these results are over the growing diverse makeup of Hispanic/Latino adults in the United States. Advanced methods have been applied to HCHS/SOL to examine dietary differences by ethnicity and region [12, (R. De Vito, B. Stephenson, D. Sotres-Alvarez, A.M. Siega-Riz, J. Mattei, M. Parpinel, B.A. Peters, S.A. Bainter, M.L. Daviglus, L. Van Horn, V. Edefonti, 2022, unpublished results)], but similar approaches have not yet been explored with NHANES Hispanic/Latino participants for comparison.

We implemented an exploratory factor analysis in both studies to illustrate how a commonly used approach for deriving NBFPs can impact the generalized results of study populations with similar ethnic backgrounds but different survey sampling strategies. A strength of this study is the use of 2 24-h dietary recalls from 2 large studies such as NHANES and HCHS/SOL. Due to NHANES oversampling Hispanic/Latino adults, we had a moderately large sample size, allowing us enough power to analyze these 2 samples separately and compare results. The differences in sampling strategies permitted us to examine how different sampled populations can sometimes yield conflicting results. However, the different survey designs prevented us from being able to pool the data and perform a direct comparison, such as a 2-group confirmatory factor analysis, as this method requires both groups source from the same survey and share the same sampling design and survey components. Further methodological extensions are needed to allow pooling across multiple surveys with different sampling designs.

A limitation of our study is the use of 24-h intake recall data, which may affect the derivation of nutrient patterns when they fail to capture the participant's usual diet and consumed nutrients, but this was ameliorated to a certain extent by taking the average of 2 recalls. Although diet instruments are prone to underestimating energy intake, 24-h recalls have strength given their granularity of capturing cultural and ethnic dietary differences compared with food frequency questionaries [66]. Thus, dietary recalls can be useful tools for studies of diverse ethnic composition. We acknowledge that self-reported dietary assessment tools and CRFs are prone to measurement error and reporting bias [67,68]. Another limitation is that nutrient patterns can differ by sex; however, in our derivation of NBFPs, we did not adjust for sex. Although sex was not used to derive NBFPs, it was adjusted for in the associations with CRFs. The results reported in this study are based on a cross-sectional study design. Consequently, the associations found are fixed at the time points listed. Changes in dietary behaviors or incidence of CRFs over time are beyond the scope of this study. Finally, we summarized our diet–CRF relationship using ORs in favor of interpretability across the different studies. However, the use of adjusted ORs in cross-sectional studies may overestimate the true underlying relationship [69,70]. Associations made in this article should be considered with this nuance in mind.

In conclusion, this study demonstrates the sensitivity of dietary patterns and their relation to CRFs in United States Hispanic/Latino adults, when different sampling strategies are implemented. Although no single study can address all sampling strategy limitations, further methodological research should be explored to leverage already existing surveys that target underrepresented populations and account for study design differences to generate appropriate population-based inference. For example, as mentioned previously, pooling studies focused on Hispanic/Latino adults whose sampling strategies differ by geography, race, ethnicity, and income would allow us to better examine the true heterogeneity of diet behaviors in the United States for this emerging demographic. This strategy will greatly improve population health disparities research by providing a more comprehensive understanding of nutrition and CVD epidemiology in populations at greatest risk.

Author contributions

The authors' responsibilities were as follows – JV, BJKS: designed the overall research plan; JV: performed the statistical analysis, interpretation of the data, and drafting of the manuscript; DSA: assisted with the design of the research, data interpretation, and critical revisions of the manuscript; JM: provided nutritional expertise, assisted with the design of the research and critical revisions of the manuscript; YMR, MD, AM, LM: provided critical review of this manuscript; BJKS: assisted with data interpretation, providing critical review and revisions of the manuscript, and had primary responsibility for the final content of the manuscript; and all authors: read and approved the final manuscript.

Conflict of interest

The authors report no conflicts of interest.

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Data availability

HCHS/SOL data are available upon request from the study website: http://www.cscc.unc.edu/hchs/. NHANES data are publicly available from the study website: https://www.cdc.gov/nchs/nhanes/index.htm. Code used to replicate analysis is available on GitHub: https://github.com/jvarela10/NHANES.HCHSSOL.MS1220Code/.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cdnut.2024.103797.

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