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Original Research

Prevalence and Risk Factors of Iron Deficiency and Anemia in Women of Reproductive Age in the Hispanic Community Health Study/Study of Latinos

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ABSTRACT

Background: Women of reproductive age are at elevated risk of iron deficiency (ID) and anemia; in the United States, those of Hispanic/Latino background are at especially high risk. Causes of ID and anemia and variations in risk within Hispanic/Latino women of reproductive age are not well described.

Objectives: To characterize ID and anemia and their risk factors/markers in Hispanic/Latina women.

Methods: Data from the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) were used. HCHS/SOL enrolled participants in 2008–2011 at 4 sites: Bronx, Chicago, Miami, and San Diego; 5386 were non-pregnant women ages 18–49 y. Primary outcomes were ID (ferritin <30 μg/L) and anemia (hemoglobin <12 g/dL). Predictors were background/heritage, Short Acculturation Scale for Hispanics scores, years lived in the United States, and interview language, diet summarized in the Alternate Healthy Eating Index 2010, sociodemographic covariates, and study site. Main analyses used survey log binomial regressions adjusted for age, site, and smoking.

Results: Almost half (42%) of participants were of Mexican background, 15% of Cuban background, and <15% each were of Puerto Rican, Dominican, Central American, or South American background. ID prevalence was 34.4% overall but differed by site-background pairings. The lowest and highest prevalence were 26% and 42% among women of Cuban background in Miami and women of Mexican background in Chicago, respectively. Anemia prevalence was 16% and ranged from 8.9% (Central American background/Miami) to 22% (Dominican background/Bronx). Acculturation, sociodemographic, and diet variables examined did not explain observed prevalence differences by site/background.

Conclusions: Prevalence of ID and anemia were high among HCHS/SOL women and differed by field center and background. These differences highlight the importance of characterizing nutritional risk by background within Hispanic/Latino women.

Keywords: women's health, iron deficiency, nutrition, health disparities, acculturation, diet

Introduction

Iron deficiency (ID) is one of the most common nutritional deficiencies globally; women of reproductive age (WRA) are especially affected [1]. ID is defined as serum ferritin (SF) below age- and life stage-specific cutoffs [2]. Primary factors contributing to ID are insufficient dietary iron intake, impeded iron absorption from inhibitors in the diet or Gastrointestinal conditions, and chronic diseases [3,4]. Physiological conditions with high iron demand, including menstruation and pregnancy, are also associated with high rates of ID [5]. Severe ID can lead to anemia, symptoms of which include fatigue, concentration

Abbreviations: AHEI-2010, Alternate Healthy Eating Index 2010; CI, confidence interval; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; ID, iron deficiency; IDA, iron deficiency anemia; RR, risk ratio; SASH, Short Acculturation Scale for Hispanics; SF, serum ferritin; WRA, women of reproductive age.

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deficits, limited physical work capacity, and dizziness [6,7]. During pregnancy, serious consequences can result from ID directly as well, including preterm labor, maternal mortality and severe maternal morbidity, and neurocognitive impairments and anemia among infants [8–10].

Between 2010 and 2020, the Hispanic population in the United States grew by 23%, whereas the non-Hispanic growth rate was only 4.3% [11]. However, the Hispanic/Latino community remains understudied in United States health research [12]. Studies of disparities in access to healthcare show that Hispanic/Latino individuals face more adversities than their non-Hispanic counterparts [13]. With respect to iron status, a recent study using NHANES data from 2003 to 2010 and 2015 to 2020 reported that overall prevalence of ID was 38.6% and ID anemia (IDA) was 6.3% among girls and young women. ID and IDA prevalence were higher by 34% and 62%, respectively, among Hispanic women and girls compared with non-Hispanic white women and girls [14]. The reasons for these large disparities in ID and IDA in Hispanic compared with white women in the United States are not clear. Research is needed to identify causes and risk factors to protect the health and quality of life of Hispanic/Latino WRA.

The term "Hispanic/Latino" represents a heterogeneous population, including those of Cuban, Mexican, Puerto Rican, and South and Central American heritage [15]. Differences in health and healthcare outcomes among Hispanic/Latino people living in the United States may stem from differences in food cultures, traditions, religious practices, social challenges, etc. [16,17]. Differences may also arise from acculturation, the process by which minorities, when exposed to the majority culture, undergo changes in their dietary habits, behaviors, and customs [18]. Acculturation can also entail disconnection from communities, lower social support, and increased psychosocial stress leading to poorer health outcomes [18]. There are numerous prior studies that link acculturation with poorer health outcomes [19,20]. Conversely, acculturation has positive health-related outcomes as well, one such positive outcome is increased access to and utilization of health care services among Hispanic/Latino adults [21]. Characterizing the variation in ID and anemia risk and associations with acculturation among Hispanic/Latino WRA is needed to identify at-risk groups and opportunities for intervention.

The Hispanic Community Health Study/Study of Latinos (HCHS/SOL) is a multicenter community-based study conducted to characterize the disease burden and health status within the heterogeneous Hispanic/Latino population in the United States. In this study we utilize HCHS/SOL baseline data to examine the prevalence and distribution of ID and anemia in Hispanic/Latino WRA in the United States overall and by background/heritage, acculturation, and dietary habits.

Methods

Study design and participants

HCHS/SOL is a longitudinal study of 16,415 non-institutionalized Hispanic/Latino adults 18–74 y of age. The original study had 2 overarching objectives: *1*) to estimate the disease burden of selected chronic diseases, especially cardiovascular and pulmonary conditions, among Hispanic/Latino adults in the United States; and *2*) to identify risk factors for incident disease during a follow-up period in the same cohort. Participants were enrolled from randomly selected households in 4 United States cities (Chicago, IL; Miami, FL; Bronx, NY; San Diego, CA). Enrollment and baseline examinations were conducted from 2008 to 2011. Details of the HCHS/SOL methodology have been published previously [22]. Briefly, participants were selected through a 2-stage stratified area probability sampling method across the 4 urban communities. To ensure equitable representation of preidentified ethnic backgrounds and socioeconomic statuses, specific strata were intentionally oversampled. The study protocol was approved by the appropriate Institutional Review Board for each study site's academic lead(s). Informed consent was obtained at the baseline examination.

Exposures

Exposure data were collected with interviewer-administered questionnaires. Self-reported country or region of origin was collected in the following categories: Dominican, Central American, Cuban, Mexican, Puerto Rican, South American, more than one/other heritage. More than one/other was not included in statistical analyses due to small sample size ($n = 195$, 4.9%) and interpretation challenges. After preliminary analyses, background and study site (that is, field center) were combined to create a new variable with 25 site-background categories. Nine site-background categories with $\geq$100 participants each were retained in analyses using that variable, in line with a prior publication in the same cohort [23]. Acculturation was measured with the modified 10-item Short Acculturation Scale for Hispanics (SASH) and the respondent's place of birth, duration of residence in the United States mainland, generation level, and selected interview language according to data management guidelines from the HCHS/SOL coordinating center. In accordance with HCHS/SOL guidelines and prior publications, we analyzed SASH responses in 2 dimensions: the Language Use Subscale (SASH-LANG) and the SASH Ethnic Social Relations Subscale (SASH-SOC) [24,25]. For each subscale, higher scores indicate a greater degree of acculturation. On the basis of self-reported place of birth, participants were categorized as either United States born or not (born outside the United States). A duration of residence variable was created by combining place of birth and duration of residence in the United States for foreign-born participants with 3 levels: <10 y, 10+ y, and United States born. Generation level was determined using place of birth data for the respondent, their parents, and their grandparents.

Details of the dietary assessment methodology have been published elsewhere [17]. Dietary data were collected with two 24-h recalls, one in-person at the first visit and the second via telephone or in-person within 90 d of the first. The data were collected and processed using the Nutrition Data System for Research software versions 2007−2010 developed by the University of Minnesota. Usual nutrient intakes were calculated from the 2 recalls using the National Cancer Institute (NCI) method and NCI SAS macros [26,27]. For this study, the Alternate Healthy Eating Index 2010 (AHEI-2010) calculated from the 2 baseline diet recalls was utilized as a measure of diet quality. AHEI-2010 evaluates the level of adherence to the 2010 Dietary Guidelines for Americans [28]. Scores are calculated for 11 diet components, namely: vegetables, fruits, whole grains, sweet beverages, nuts and legumes, red and processed meats, trans fat, long-chain fats, polyunsaturated fats, sodium, and alcohol. Intake of each component is rated from 0 (worst) to 10 (best). The total AHEI-2010 is the sum of the component scores, ranging from 0 to 110. For all components of the AHEI-2010, higher scores indicate higher intake of healthier components and lower intake of less healthy components, such that higher scores indicate greater daily intake of vegetables, fruits, whole grains, nuts and legumes, long-chain fats, and polyunsaturated fats, whereas higher scores indicate lower intakes of sweetened beverages, red and processed meats, trans fats, sodium, and alcohol. Predicted usual intake of total iron from food and supplements and total energy intake produced by Nutrition Data System for Research from the 2 diet recalls were also examined.

Main outcomes

The primary outcome of interest was ID based on SF measured in blood samples from the baseline examination. ID was defined as SF < 30 μg/L to account for the lack of available inflammation data [29]. The main secondary outcome of interest was anemia, defined as Hb < 12 g/dL [30]. IDA was defined as co-occurring anemia (Hb < 12 g/dL) and ID (SF < 30 μg/L). Hb values were adjusted for current smoking status according to WHO guidelines [30]. Alternate definitions of IDA using SF < 15 μg/L or transferrin saturation ≤ 19% to define ID were explored.

Covariates

Potential confounders were prespecified in a conceptual framework based on prior research findings and subject matter knowledge. Covariate information was gathered from questionnaires and examinations conducted during the baseline visit. The potential confounders of interest were age (18−29 y, 30−39 y, 40−49 y), household income (<$20,000, $20,000–$40,000, >$40,000), education (below high school, high school/GED, more than high school), smoking status (never or former smoker, current smoker), parity (0, 1, 2+), BMI calculated from measured weight and height [underweight (BMI < 18.5), normal (18.5 ≤ BMI < 25), overweight (25 ≤ BMI < 30), obese (30 ≤ BMI)], and field center (Bronx, Chicago, Miami, San Diego).

Statistical analysis

The analysis was conducted using SAS software version 9.4 and Stata version 17. Analyses were conducted using survey weights to adjust for sampling probability, in line with the guidelines established by the HCHS/SOL Steering and Data Analysis Committees.

The analytical sample for the present study included 5148 WRA (18–49 y old) who were not pregnant and who had complete SF data from the baseline examination ($n = 255$ and $n = 4$ excluded for missing SF and pregnancy, respectively). Characteristics of the study participants were described with weighted summary statistics for each demographic, socioeconomic, self-reported health, and acculturation measure. Iron status biomarkers were examined for normality and SF was log transformed before analysis. The prevalence of ID and anemia by acculturation and sociodemographic characteristics were summarized and bivariate associations of covariates with ID and anemia prevalence were determined using log binomial regression models. Values of continuous Fe biomarkers by acculturation and sociodemographic characteristics were explored in linear regression models. Next, multivariable log binomial models were developed for each main outcome (ID and anemia) adjusted for potential confounding. A priori potential confounders included age, smoking, parity, and study site. Other covariates were selected based on observed associations with the outcome in bivariate models. Because of large amounts of missingness for parity [$n = 273$ (5.3%)], multivariable models were repeated omitting that variable.

A second analysis was conducted to investigate associations between diet characteristics and risk of ID and anemia. Log binomial regression models adjusted for age, smoking status, and site were developed separately for ID and anemia as outcomes and for each diet variable: AHEI-2010 total score and its 11 component scores. Differences in AHEI-2010 score and subscale scores by background/site combinations were explored in linear regression models. Diet as a mediator of site/background differences in ID and anemia prevalence were explored in multivariable models. Models with outcome IDA and non-IDA (anemia but no ID) were also explored. Log Poisson regression models with robust standard errors were used in select cases where log binomial regressions did not converge.

Results

HCHS/SOL participant characteristics

The present study included 5148 non-pregnant women between the ages of 18 and 49. Participant characteristics are summarized in Table 1. Briefly, participants were evenly distributed across the 3 age categories. In terms of Hispanic/Latino background, the most common was Mexican (42.2%), followed by 15% Cuban, 13% Puerto Rican, 12.6% Dominican, 7.6% Central American, and 4.7% South American, with women of multiple heritages comprising an additional 4.9%. Most individuals in the study were born outside of the United States (70.9%); 41.4% had lived in the United States for a decade or more. Almost 3 quarters (72.9%) of the participants had completed at least high school education, whereas just 18.1% reported a household income exceeding $40,000. Most did not currently smoke (83%), had given birth to 2 or more children (54.1%), and were classified as overweight or obese (72.4%). All measured participant characteristics differed across the site/background groups (Supplemental Table 1).

Predictors of ID

Overall prevalence of ID among the study population was 34%. In crude log binomial regression models, prevalence of ID was 25% higher in women with parity of 0 or 2 or more compared with those with parity equal to 1 (Table 2). WRA with obesity were at 19% lower risk of ID compared with those of healthy weight, whereas overweight was not associated with ID. Site and site/background variables were both significantly associated with ID risk; prevalence of ID ranged from a low of 26% among those of Cuban heritage in Miami to 42% among those of Mexican heritage living in Chicago (Figure 1). WRA who had lived in the United States for ≥10 y were at higher risk compared with those living in the United States for <10 y; no associations with age, income, education, interview language or the modified SASH subscales were observed.

In a multivariable model adjusted for age, parity, and smoking, site/background remained a strong and significant predictor of ID (Table 3). In models further adjusted for education, BMI,

TABLE 1
Sociodemographic characteristics of women of reproductive age in the HCHS/SOL Study baseline interview, 2008–2011

Characteristic	Unweighted (*n*)	Percent (95% CI)[1]
Age (y)		
18–29	1370	38.0 (35.9, 40.1)
30–39	1325	30.5 (28.5, 32.5)
40–49	2453	31.6 (29.8, 33.4)
Background/heritage		
Dominican	531	12.6 (10.8, 14.7)
Central American	573	7.6 (6.4, 9.1)
Cuban	586	15.0 (12.2, 18.3)
Mexican	2259	42.2 (38.7, 45.7)
Puerto Rican	670	13.0 (11.4, 14.8)
South American	319	4.7 (3.9, 5.6)
More than one	195	4.9 (4.0, 6.0)
Missing	15	
Household income		
≤$20,000	2287	48.1 (45.8, 50.5)
$20,001–$40,000	1611	33.8 (31.7, 35.9)
>$40,000	797	18.1 (15.9, 20.5)
Missing	453	
Education		
<High school	1551	27.1 (25.2, 29.1)
High school or GED	1446	30.1 (28.3, 32.0)
>High school	2137	42.8 (40.4, 45.2)
Missing	14	
Health insurance		
Yes	2668	50.7 (48.5, 52.9)
No	2390	49.3 (47.1, 51.5)
Missing	90	
Smoking status		
Not a current smoker	4308	83.0 (81.2, 84.8)
Current smoker	821	17.0 (15.3, 18.8)
Missing	19	
Parity		
0	847	23.0 (21.2, 25.0)
1	911	22.8 (21.0, 24.8)
2+	3117	54.1 (52.1, 56.2)
Missing	273	
BMI		
Underweight (BMI < 18.5)	62	1.8 (1.3, 2.4)
Normal (18.5 < BMI < 25)	1171	25.9 (24.0, 27.8)
Overweight (25 < BMI < 30)	1709	32.6 (30.8, 34.5)
Obese (BMI > 30)	2190	39.8 (37.4, 42.2)
Missing	16	
Study site		
Bronx	1299	30.4 (27.3, 33.7)
Chicago	1252	16.3 (14.4, 18.5)
Miami	1170	24.9 (21.1, 29.1)
San Diego	1427	28.4 (24.9, 32.2)
Interview language		
English	3902	71.3 (68.7, 73.9)
Spanish	1246	28.7 (26.1, 31.3)
Generational status		
1st generation (foreign-born)	3878	70.9 (68.5, 73.2)
2nd+ generation (United States born)	1252	29.1 (26.8, 31.6)
Missing	18	
Years lived in United States		
<10 y	1480	31.2 (28.7, 33.7)
≥10 y	2443	41.4 (39.3, 43.5)
United States born	1197	27.5 (25.4, 29.7)
Missing	28	
SASH social[2] (mean, 95% CI)		2.25 (2.22, 2.28)
Missing	175	
SASH language[2] (mean, 95% CI)		2.21 (2.15, 2.27)
Missing	23	

Abbreviations: BMI, body mass index; CI, confidence interval; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; SASH, Short Acculturation Scale for Hispanics.
[1] Data are weighted according to the complex survey design.
[2] From the modified 10-item Short Acculturation Scale.

and years lived in the United States, the association of site/background with ID was only slightly attenuated.

Predictors of anemia

Overall prevalence of anemia in the study is 16%. Similar to ID, differences in the prevalence of anemia were evident across various site-background combinations; among WRA of Central American background living in Miami, the prevalence of anemia was the lowest at 8.9%, whereas Dominican WRA in the Bronx exhibited the highest prevalence at 22% (Figure 1). Modified SASH acculturation scales were not associated with prevalence of anemia; foreign-born participants who had lived in the United States for <10 y had lower prevalence and those who were foreign-born but lived in the United States for >10 y had higher prevalence compared with United States born participants. In crude log binomial regression models, statistically significant differences ($P < 0.05$) in anemia prevalence were observed by age, parity, site, background, site-by-background, and years lived in the United States.

In multivariable models for anemia adjusted for age, smoking status, and parity, the site-by-background exposure remained highly significant (Table 3). Compared with those of Central American background living in Miami, risk of anemia was greater by 78% {risk ratio [RR]: 1.78 [95% confidence interval (CI): 1.16, 2.73]}, 114% [RR: 2.14 (1.49, 3.07)], and 150% [RR: 2.5 (1.68, 3.7)] in those of Puerto Rican heritage in the Bronx, Mexican heritage/Chicago, and Dominican heritage/ Bronx, respectively. In models additionally adjusted for education, BMI, and years in the United States, which could explain some site/background differences, coefficients for site/background were barely attenuated.

In risk factor models separating IDA from non-IDA, the site-by-background variable was predictive of both outcomes (Supplemental Figure 1), as was parity, but no other risk factors. Risk factors did not differ substantially when IDA was defined using transferrin saturation or a lower SF cutoff (not shown).

Associations of diet with ID and anemia prevalence

To explore whether differences in diet patterns may explain differences in ID and anemia risk within site/background groups, we first examined differences in AHEI-2010 and its subscales by site/background in linear regression models adjusted for age (Supplemental Table 2). AHEI-2010 and its subscales differed significantly by site/background ($P < 0.001$). AHEI-2010 was

TABLE 2

Bivariate associations of sociodemographic and acculturation characteristics with ID and anemia status among Hispanic/Latino women of reproductive age in the HCHS/SOL Study

Characteristic	ID			Anemia		
	% (95% CI)	RR (95% CI)[1]	*P* value	% (95% CI)	RR (95% CI)	*P* value
Age			0.7303			0.0017
18–29	35.5 (32.1, 39.0)	1		13.4 (11.4, 15.6)	1	
30–39	33.8 (30.1, 37.6)	0.95 (0.82, 1.10)		16.1 (13.4, 19.2)	1.2 (0.95, 1.52)	
40–49	33.9 (31.2, 36.6)	0.95 (0.84, 1.09)		18.9 (16.8, 21.2)	1.41 (1.17, 1.7)	
Household income			0.3805			0.6725
≤$20,000	32.3 (29.3, 35.5)	1		16.6 (14.6, 18.8)	1	
$20,001–$40,000	35.7 (32.3, 39.2)	1.10 (0.96, 1.27)		15.2 (12.8, 18.)	0.92 (0.74, 1.14)	
>$40,000	35.3 (30.2, 40.8)	1.09 (0.90, 1.32)		15.1 (11.3, 19.8)	0.91 (0.66, 1.25)	
Education			0.3417			0.105
<High school	36.6 (33.2, 40.2)	1		17.3 (14.9, 19.9)	1	
High school or GED	34.2 (30.7, 37.9)	0.93 (0.81, 1.07)		17.4 (14.6, 20.6)	1.01 (0.8, 1.27)	
>High school	33.3 (30.5, 36.1)	0.91 (0.79, 1.03)		14.2 (12.3, 16.4)	0.82 (0.67, 1.01)	
Health insurance			0.9761			0.5573
Yes	34.2 (31.4, 37.2)	1.00 (0.89, 1.12)		15.3 (13.5, 17.2)	1.06 (0.88, 1.28)	
No	34.2 (31.6, 36.8)	1		16.2 (14. , 18.6)	1	
Current smoker			0.0018			0.2643
No	35.9 (33.9, 38.1)	1		15.6 (14.1, 17.2)	1	
Yes	27.8 (23.8, 32.2)	0.77 (0.66, 0.91)		17.7 (14.4, 21.7)	1.14 (0.91, 1.42)	
Parity			0.0134			0.0024
0	35.8 (31.1, 40.8)	1.24 (1.02, 1.50)		14.6 (11.7, 18.1)	1.25 (0.90, 1.73)	
1	20.0 (24.9, 33.4)	1		11.7 (9.1, 14.9)	1	
2+	36.5 (34.2, 38.9)	1.26 (1.08, 1.47)		18.3 (16.5, 20.3)	1.56 (1.19, 2.05)	
BMI			0.0098			0.1069
Underweight	44.6 (28.5, 62.0)	1.17 (0.77, 1.77)		11. (5.1, 22.1)	0.73 (0.35, 1.55)	
Normal	38.1 (34.4, 42.0)	1		15. (12.6, 17.8)	1	
Overweight	35.0 (31.5, 38.6)	0.91 (0.80, 1.06)		14.5 (12.4, 16.9)	0.97 (0.77, 1.22)	
Obese	31.1 (28.2, 34.1)	0.81 (0.71, 0.93)		18.1 (15.8, 20.7)	1.21 (0.98, 1.49)	
Study site			0.000			0.0009
Bronx	34.1 (30.0, 38.4)	1		20.1 (17, 23.7)	1	
Chicago	38.8 (35.3, 42.5)	1.13 (0.98, 1.33)		18.6 (15.9, 21.7)	0.93 (0.74, 1.16)	
Miami	27.7 (25.0, 30.5)	0.81 (0.69, 0.95)		12.6 (10.1, 15.5)	0.63 (0.48, 0.82)	
San Diego	37.8 (34.1, 41.7)	1.11 (0.95, 1.30)		14.1 (11.7, 16.8)	0.7 (0.55, 0.9)	
Background/heritage			0.000			0.0014
Dominican	34.9 (28.6, 41.7)	1			1	
Central American	29.0 (24.2, 34.4)	0.83 (0.64, 1.08)		22. (17.4, 27.4)	0.45 (0.31, 0.65)	
Cuban	25.6 (22.0, 29.7)	0.74 (0.58, 0.93)		10. (7.5, 13.2)	0.63 (0.45, 0.9)	
Mexican	39.0 (36.1, 42.0)	1.12 (0.91, 1.37)		13.9 (10.7, 17.9)	0.71 (0.55, 0.93)	
Puerto Rican	32.0 (27.8, 36.6)	0.92 (0.72, 1.17)		15.7 (13.7, 17.8)	0.79 (0.57, 1.08)	
South American	38.7 (30.5, 47.7)	1.11 (0.83, 1.49)		17.3 (13.9, 21.3)	0.54 (0.31, 0.96)	
Site* background/heritage			0.000			0.0000
Bronx/Dominican	34.9 (28.6, 41.7)	1.01 (0.72, 1.43)		22. (17.4, 27.4)	1.01 (0.72, 1.43)	
Bronx/Puerto Rican	33.1 (28.2, 38.5)	0.96 (0.69, 1.33)		17.8 (13.8, 22.6)	0.96 (0.69, 1.34)	
Chicago/Central American	34.4 (25.2, 45.0)	1		15.4 (8.5, 26.4)	1	
Chicago/Mexican	42.0 (37.8, 46.2)	1.22 (0.89, 1.67)		19.7 (16.6, 23.3)	1.22 (0.9, 1.67)	
Chicago/Puerto Rican	28.4 (20.8, 37.6)	0.83 (0.54, 1.27)		15.5 (10.4, 22.5)	0.83 (0.54, 1.27)	
Miami/Central American	27.9 (22.5, 34.1)	0.81 (0.57, 1.16)		8.9 (6.4, 12.2)	0.81 (0.57, 1.16)	
Miami/Cuban	25.6 (22.0, 29.7)	0.75 (0.54, 1.03)		13.9 (10.7, 17.9)	0.75 (0.54, 1.04)	
Miami/South American	38.7 (30.5, 47.7)	1.12 (0.78, 1.63)		11.9 (7., 19.7)	1.13 (0.78, 1.63)	
San Diego/Mexican	37.8 (34.1, 41.7)	1.10 (0.81, 1.49)		14.1 (11.7, 16.8)	1.1 (0.81, 1.49)	
SASH social[2]			0.9588			0.8428
1 (Very low)	35.5 (31.6, 39.7)	1		16.8 (14.2, 19.8)	1	
2	35.5 (31.9, 39.3)	1.00 (0.85, 1.17)		16. (13.8, 18.5)	0.95 (0.77, 1.19)	
3	34.4 (31.1, 37.8)	0.97 (0.83, 1.12)		14.8 (11.6, 18.7)	0.88 (0.66, 1.17)	
4 (Very high)	34.5 (30.3, 38.9)	0.97 (0.82, 1.15)		16.2 (13.4, 19.6)	0.97 (0.75, 1.25)	
SASH language[2]			0.5571			0.9798
1 (Very low)	34.8 (31.3, 38.6)	1		16.2 (13.7, 19.2)	1	
2	32.5 (29.4, 35.7)	0.93 (0.81, 1.07)		15.5 (13., 18.3)	0.95 (0.75, 1.22)	
3	34.3 (30.3, 38.5)	0.98 (0.84, 1.16)		16.1 (13.3, 19.5)	0.99 (0.77, 1.28)	
4 (Very high)	36.2 (31.9, 40.7)	1.03 (0.88, 1.22)		16.1 (13.6, 18.9)	0.99 (0.78, 1.25)	
Interview language			0.5423			0.7562
English	35.5 (31.4, 39.8)	1.04 (0.91, 1.2)		15.8 (14.3, 17.4)	1.03 (0.84, 1.26)	
Spanish	34.0 (32.0, 36.2)	1		16.3 (13.6, 19.5)	1	
Generational status			0.6644			0.7574
1	34.7 (32.6, 36.9)	1		15.8 (14.3, 17.4)	1	

(*continued on next page*)

TABLE 2 (*continued*)

Characteristic	ID			Anemia		
	% (95% CI)	RR (95% CI)[1]	*P* value	% (95% CI)	RR (95% CI)	*P* value
2+	33.7 (30.0, 37.7)	0.97 (0.85, 1.10)		16.3 (13.7, 19.1)	1.03 (0.86, 1.24)	
Years lived in United States			0.02			0.047
<10 y	30.7 (27.7, 34.0)	1		13.5 (11.3, 16.0)	1	
≥10 y	37.2 (34.3, 40.3)	1.21 (1.06, 1.38)		17.6 (15.6, 19.9)	1.31 (1.06, 1.62)	
United States born	34.1 (30.4, 38.2)	1.11 (0.96, 1.29)		16.1 (13.6, 19.0)	1.19 (0.95, 1.5)	

Abbreviations: CI, confidence interval; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; ID, iron deficiency; SASH, Short Acculturation Scale for Hispanics.
[1] Risk ratios, 95% CIs, and *P* values are from survey-adjusted log binomial regression models.
[2] From the modified 10-item Short Acculturation Scale.

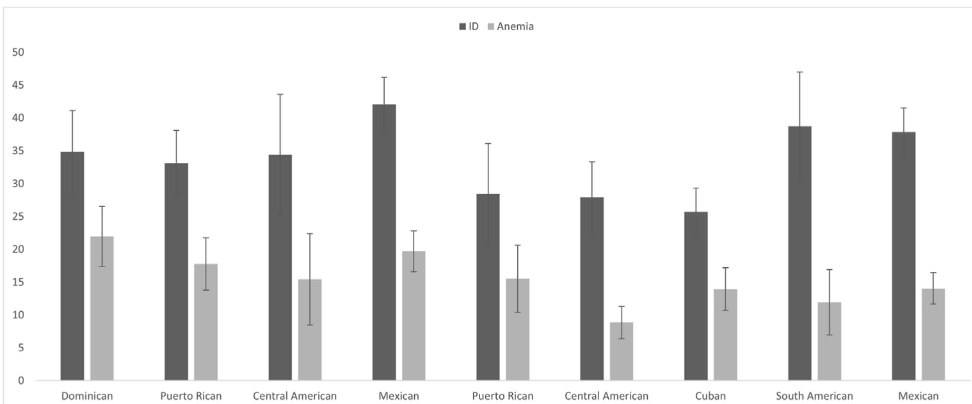

FIGURE 1. ID, anemia, and IDA prevalence by study site and background in Hispanic/Latino WRA in the HCHS/SOL Study. HCHS/SOL, Hispanic Community Health Study/Study of Latinos; ID, iron deficiency; IDA, iron deficiency anemia; WRA, women of reproductive age.

TABLE 3
Multivariable models of ID and anemia risk by Hispanic/Latino background and study site in Hispanic/Latino women of reproductive age in the HCHS/SOL Study

	Bronx		Chicago			Miami			San Diego	*P* value
	Dominican	Puerto Rican	Central American	Mexican	Puerto Rican	Central American	Cuban	South American	Mexican	
RR (95% CI)[1]										
ID										
Crude	1.01 (0.72, 1.43)	0.96 (0.69, 1.34)	Ref	1.22 (0.9, 1.67)	0.83 (0.54, 1.27)	0.81 (0.57, 1.16)	0.75 (0.54, 1.04)	1.13 (0.78, 1.63)	1.1 (0.81, 1.49)	0.000
Adjusted[2]	1.03 (0.73, 1.44)	1.05 (0.75, 1.47)	Ref	1.21 (0.89, 1.64)	0.85 (0.55, 1.32)	0.81 (0.57, 1.15)	0.75 (0.54, 1.06)	1.15 (0.79, 1.66)	1.1 (0.81, 1.49)	0.0004
Adjusted[3]	1.02 (0.71, 1.46)	1.07 (0.74, 1.54)	Ref	1.22 (0.89, 1.69)	0.88 (0.55, 1.4)	0.83 (0.58, 1.2)	0.79 (0.55, 1.12)	1.18 (0.81, 1.73)	1.12 (0.82, 1.55)	0.0018
Anemia										
Crude	2.48 (1.67, 3.67)	2.01 (1.34, 3.01)	1.74 (0.9, 3.36)	2.22 (1.55, 3.19)	1.75 (1.06, 2.89)	Ref	1.57 (1.04, 2.38)	1.35 (0.8, 2.26)	1.59 (1.1, 2.29)	0.0003
Adjusted[2]	2.5 (1.68, 3.7)	1.78 (1.16, 2.73)	1.73 (0.9, 3.29)	2.14 (1.49, 3.07)	1.63 (0.99, 2.68)	Ref	1.33 (0.82, 2.13)	1.27 (0.73, 2.22)	1.53 (1.06, 2.2)	0.0000
Adjusted[3]	2.34 (1.57, 3.49)	1.67 (1.05, 2.66)	1.73 (0.9, 3.33)	2. (1.39, 2.89)	1.52 (0.9, 2.56)	Ref	1.33 (0.83, 2.13)	1.32 (0.76, 2.29)	1.47 (1.02, 2.12)	0.0020

Abbreviations: CI, confidence interval; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; ID, iron deficiency.
[1] Risk ratios, 95% CIs, and *P* values are from survey-adjusted log binomial regression models.
[2] Adjusted for age, smoking, and parity.
[3] Adjusted for age, smoking, parity, education, BMI, and years in the United States.

TABLE 4

Associations of AHEI-2010 total and component scores with ID and anemia risk in Hispanic/Latino WRA in the HCHS/SOL Study

Diet characteristic	ID		Anemia	
	RR (95% CI)[1]			
	Crude	Adjusted[2]	Crude	Adjusted[2]
AHEI-2010 total score	1.01 (1.00, 1.02)	1.0 (0.99, 1.01)	1.01 (1.0, 1.03)	1.01 (0.99, 1.03)
AHEI-2010 component scores				
Vegetables	0.97 (0.93, 1.02)	0.94 (0.89, 1.00)	0.93 (0.86, 1.0)	0.97 (0.88, 1.07)
Fruit	1.01 (0.98, 1.05)	0.98 (0.95, 1.02)	1.0 (0.94, 1.06)	0.98 (0.92, 1.05)
Whole grains	1.04 (1.02, 1.06)	1.0 (0.96, 1.04)	0.99 (0.95, 1.03)	0.97 (0.92, 1.02)
Sugar-sweetened beverages	1.0 (0.97, 1.03)	1.0 (0.97, 1.03)	1.09 (1.04, 1.15)	1.08 (1.03, 1.14)
Nuts and legumes	0.98 (0.96, 1.01)	0.98 (0.95, 1.01)	0.98 (0.94, 1.02)	1.0 (0.95, 1.05)
Red and processed meats	1.04 (1.01, 1.08)	1.02 (0.98, 1.06)	1.11 (1.04, 1.18)	1.06 (0.99, 1.14)
Trans fat	0.91 (0.84, 1.0)	0.95 (0.86, 1.05)	1.17 (1.04, 1.32)	1.12 (0.97, 1.3)
Long-chain (n-3) fats	0.95 (0.89, 1.02)	0.93 (0.87, 1.00)	0.94 (0.85, 1.04)	0.92 (0.82, 1.03)
PUFA	0.99 (0.93, 1.05)	1.01 (0.94, 1.08)	0.92 (0.84, 1.01)	1.0 (0.91, 1.11)
Sodium	1.04 (1.02, 1.06)	1.02 (1.00, 1.04)	1.07 (1.03, 1.11)	1.03 (0.99, 1.07)
Alcoholic	1.03 (1.0, 1.07)	1.03 (0.99, 1.07)	0.97 (0.9, 1.05)	0.99 (0.93, 1.06)

Abbreviations: AHEI-2010, Alternate Healthy Eating Index 2010; CI, confidence interval; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; ID, iron deficiency; PUFA; polyunsaturated fatty acid; WRA, women of reproductive age.

[1] Risk ratios and 95% CIs are from survey-adjusted log binomial regression models.

[2] Adjusted for age, smoking, and site.

highest among individuals of Mexican heritage in both Chicago (51.0 [50.5, 51.5]) and San Diego (48.4 [47.8, 48.9]) and those of Central American heritage in Chicago (48.8 [47.3, 50.3]). In contrast, individuals of Puerto Rican heritage in the Bronx and Chicago and those of Cuban heritage in Miami had the lowest median AHEI-2010 scores. Individuals of Dominican heritage living in the Bronx had the highest median consumption of red and processed meat, whereas those of Cuban heritage in Miami reported the lowest median meat consumption. The same pattern was observed for sodium intake subscales, whereas the whole grain subscale was lowest in individuals of Cuban background living in Miami.

An analysis of the extent to which measured dietary characteristics are associated with prevalence of ID and anemia in this population is presented in Table 4. Mean predicted usual iron intake from food and supplements was identical in those with and without ID, but was lower by ~4% (mean predicted iron intake 12.9 mg/d; difference β: −0.55 mg/d; 95% CI: −0.9, −0.2) in those with anemia compared with no anemia. In unadjusted models, there were small positive associations observed between the AHEI-2010 score and its subscales with both the risk of ID and anemia. AHEI-2010 scores were positively associated with the risk of ID (RR: 1.01; 95% CI: 1.00, 1.02) and anemia (1.01, 1.00, 1.03), indicating a marginally increased risk of ID and anemia with increasing (healthier) AHEI-2010 scores. Associations were most pronounced for subscales related to red meat consumption and sodium intake. Higher red and processed meat subscale scores (indicating lower intakes) were positively associated with the prevalence of ID and anemia in crude models. Associations were also observed between greater sodium intake scale score (lower sodium intake) and greater prevalence of ID and anemia and between sugar-sweetened beverage and trans fat intakes and prevalence of anemia only. In the models for ID adjusted for age, smoking, and site small associations of AHEI scores and ID were attenuated, except for a small positive association remained between the sodium subscale and risk of ID. In the models for anemia, the subscales for red and processed meats, sodium, and sweetened beverages remained significant after adjustment for confounders. Associations were not observed between AHEI-2010 or its subscales and IDA or non-IDA in models adjusted for age, smoking, and site (not shown).

Discussion

In the present study, cross-sectional data from the HCHS/SOL cohort were utilized to examine the prevalence of ID and anemia and their respective risk factors within non-pregnant Hispanic/Latino WRA in the United States. Concordant with prior research, Hispanic/Latino WRA had slightly higher prevalence of ID and substantially higher prevalence of anemia relative to estimates for United States women overall [14,31–33]. When subgroups by study site and background/heritage were examined, prevalence of ID and anemia varied substantially within Hispanic/Latino WRA; however, few of the risk factors examined explained risk of ID and anemia overall or differences between site/background groups. In sum, risk of ID and anemia were elevated among Hispanic/Latino WRA and differ markedly by site/background, which to our knowledge has not been described previously in the literature, but the specific acculturation, health, and diet factors examined were not associated with the prevalence or variability within this population.

Prior studies from the HCHS/SOL cohort describe substantial disparities in risk of outcomes, including hypertension, hypercholesterolemia, diabetes mellitus, and obesity among Hispanic/Latino subgroups defined by site and heritage as in this analysis [34]. In addition to health outcomes, studies have examined within-group variability in health behaviors and diet, for example, alcohol consumption and smoking habits [35], and dietary patterns in connection to insulin resistance and diabetes mellitus [36]. The results of the present study concur and expand on prior findings by investigating site/background differences in ID and anemia and potential drivers of those differences related to acculturation and diet.

Whereas striking differences in ID and anemia prevalence by site and background were observed, risk factors for the outcome were not readily identified. Beyond well-described predictors of SF and/or hemoglobin—age, parity, smoking—few characteristics were strongly associated with risk of the outcomes. Although the Hispanic/Latino United States population differs markedly in acculturation metrics by location and place of origin, associations were not observed between ID or anemia and generational status, duration of residence in the United States, or the SASH acculturation scales. The only difference was by years lived in the United States, with non-United States born WRA who lived in the United States for ≥10 y at higher risk of both ID and anemia compared with those who lived in the United States for <10 y. In a systematic review, Ayala et al. [37] described that Hispanic/Latino immigrants tend to have healthier dietary patterns compared with the typical American diet. However, as their duration of residence in the United States increases and they undergo greater acculturation, their dietary patterns tend to change. This shift may explain why those who had lived longer in the United States exhibit higher prevalence of ID and anemia. In total, these results contrast prior studies linking acculturation to poorer physical and mental health in immigrant populations [24,25,38,39]. Furthermore, studies showing BMI and risk of obesity increase with longer residence in the United States [40–42] and known links between obesity and ID and anemia [43] suggest that BMI and years lived in the United States might compound in their effects on anemia. In the present study, however, duration of residence in the United States was associated with greater risk of ID and anemia, but obesity (but not overweight) was associated with lower prevalence of ID and not associated with anemia. Some aspects of acculturation that may be important for diet and healthcare access were not included in the study; for example, the composition of neighborhoods, individual and familial attitudes toward assimilation, experiences of discrimination or other adversities in their living and working environments, and availability and accessibility of resources including government assistance programs (for example, Special Supplemental Nutrition Program for Women, Infants and Children (WIC), Temporary Assistance for Needy Families (TANF)). Further research with different measures of acculturation may reveal a more nuanced understanding of associations between acculturation and iron status in this population.

Differences in diet by site and background have been described previously in the HCHS/SOL cohort, although not specifically in WRA. Because physiologic iron needs are met primarily through dietary iron, differences in diets were hypothesized to explain a portion of the observed differences in ID and anemia between site/background groups. In the present study, differences in AHEI-2010 score and component scores were observed between site/background groups, but they accounted for very small differences in ID and anemia risk and a negligible portion of the differences in ID and anemia prevalence between groups. One factor may be that the AHEI-2010, which was developed to characterize diet quality with respect to the risk of chronic diseases like cardiovascular disease, does not necessarily capture variations in diet that predict iron status. For example, we saw that lower sodium intake, one component of the AHEI-2010, is linked to a slightly greater risk of ID and anemia, and lower red and processed meat intake was weakly associated with higher anemia risk. Whereas sodium and red and processed meat intakes are associated with elevated risk of cardiovascular disease, hence their reverse coding in the AHEI-2010 (that is, lower intakes are given higher component scores), red meat does provide heme, a highly bioavailable form of iron [44]. The AHEI-2010 also does not capture eating occasions or group foods into meals. This is a limitation for linking diet and iron status, because combinations of foods have been shown to enhance or inhibit dietary iron absorption when consumed in the same meal. For example, coffee, tea, and milk may inhibit iron absorption, whereas foods containing vitamin C can enhance it [45]. Cookware material, for example, cast iron, may also affect dietary iron intake but was not recorded as part of this study. Although examining individual foods and meals was outside of the scope of this study, detailed diet assessments in HCHS/SOL would enable a future study that examines diet in relation to ID and anemia in more detail.

Of note, the present study observed a relatively high prevalence of non-IDA among WRA of certain site-background combinations. This suggests that other causes of anemia may be important to consider in Hispanic/Latino WRA of certain backgrounds. Other causes of anemia are chronic inflammatory conditions, folate deficiency, vitamin B12 deficiency, genetic polymorphisms and types of thalassemia, and idiopathic conditions [46]. High rates of chronic kidney disease have been reported previously in this population, which could contribute to higher rates of non-IDA [25]. Further research is required to comprehensively understand the underlying factors contributing to ID and anemia rates in Hispanic/Latino WRA of different backgrounds toward effective screening and interventions.

The strengths of this study include recruitment of a large sample and systematic sampling from United States urban areas with large and diverse Hispanic/Latino populations. High fidelity to study protocols produced questionnaire and examination data and biospecimen samples with few missing values. Iron status measured with multiple biomarkers in a research context rather than due to a clinical indication enables us to estimate population prevalence of ID and anemia. The study has several limitations, as well. The data used for this study were cross-sectional. Not all site/background groups were populous enough to include in the analysis. Furthermore, the cohort did not have enough pregnant women to examine ID and anemia prevalence and risk factors among pregnant women. Finally, lack of data on inflammation concurrent with the iron biomarker assessments precluded incorporating a marker of inflammation into the assessment of ID and anemia, which is considered best practice [47]. Despite limitations, HCHS/SOL provided data of excellent quality and representativeness with which to produce a unique assessment of iron status and variation within the Hispanic/Latino United States population.

Hispanic/Latino WRA exhibit a heightened risk of ID and anemia relative to United States WRA, especially among specific location/background subgroups. Targeted screening for anemia and its cause(s) are warranted, especially in pre-pregnancy and prenatal clinical care. Further studies are also needed to elucidate the modifiable determinants of ID and anemia in this population to enable the development of more tailored and effective interventions toward primary and secondary prevention.

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Author contributions

The authors' responsibilities were as follows – RKC: conceptualization; RKC, BGD: analysis; CC, LEM, DS-A, MLD, MA: investigation; RKC, BGD: writing—original draft; all authors: writing—review and editing; CC, LEM, DS-A, MLD, MA: project funding and administration; 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

Data described in the manuscript, code book, and analytic code will not be made available because they belong to the HCHS/SOL Study. Data are available to researchers directly from HCHS/SOL by request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cdnut.2024.104419.

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