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Childhood food insufficiency and adulthood cardiometabolic health conditions among a population-based sample of older adults in Puerto Rico

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ABSTRACT

Childhood food insufficiency negatively influences physical and psychosocial health in children, but less is known about long-term health implications. This study aimed to elucidate the association of childhood food insufficiency with older adulthood cardiometabolic conditions. We conducted cross-sectional analyses using data from the Puerto Rican Elderly: Health Conditions Project (n = 2712), a population-based sample of elderly adults (>60 y) living in Puerto Rico. Childhood food insufficiency was ascertained with a proxy question on childhood economic hardships that prevented eating. Participants self-reported hypertension, diabetes, and cardiovascular disease (CVD; including heart attack, heart disease, or stroke). Obesity was assessed as body mass index using measured height and weight. Multivariable-adjusted, sex-stratified, complex survey logistic regression models tested associations of childhood food insufficiency with each condition, number of cardiometabolic conditions (0–6), and age of onset. Nearly a third (29.4%) of the sample reported childhood food insufficiency; 68.7% reported hypertension, 29.6% reported type 2 diabetes, 34.2% reported CVD, 29.9% were categorized with obesity, and 55.4% had two or more cardiometabolic conditions. In men, but not women, childhood food insufficiency was associated with higher odds of hypertension (Odds Ratio (OR) (95% Confidence Intervals (CI)): 1.7 (1.1, 2.7)), CVD (1.7 (1.1, 2.6)), and having two (1.9 (1.0, 3.4) or three to four (2.3 (1.2, 4.4)) cardiometabolic conditions. Childhood food insufficiency was marginally associated with higher odds of early age of onset of CVD among men (2.2 (1.0, 4.7)). Childhood food insufficiency may increase the likelihood of having cardiometabolic conditions in Puerto Rican older men. Programs that enable access to sufficient, healthy food in childhood may help prevent eventual cardiovascular-related diseases.

1. Introduction

Cardiovascular disease (CVD) and diabetes are two of the leading causes of death from non-communicable diseases worldwide, contributing to half of non-communicable disease deaths, and overweight and obesity were recently estimated to account for 3.4 million deaths per year worldwide (World Health Organization, 2014). Although lifestyle factors like a healthy diet are widely recognized as modifiable targets to reduce cardiometabolic disease risk and prevent cardiometabolic diseases, achieving a healthy lifestyle is not equally accessible across economic, racial, and ethnic groups (Havranek et al., 2015). Addressing the social determinants of CVD development is foundational for effectively reducing the inequitable burden of disease (Havranek et al., 2015).

One social determinant of interest is food security, or "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Food and Agriculture Organization of the United Nations, 2009). When these conditions are not met, a person or household is categorized as food insecure. High-income countries in North America and Europe have a substantially lower prevalence of the most severe form of food insecurity (1.4%) compared to middle- and low-income countries in Africa (29.8%), Asia (6.9%), and Latin America (9.8%) (FAO et al., 2018). Food insecurity at the household level has been linked to increased risk of poor cardiometabolic outcomes in adults, including higher 10-year CVD risk (Vercammen et al., 2019), hypertension (Seligman et al., 2010; Vercammen et al., 2019),

Abbreviations: BMI, Body mass index; CVD, Cardiovascular disease; OR, Odds Ratio; PAN, Programa de Asistencia Nutritional; PREHCO, The Puerto Rican Elderly: Health Conditions.

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hyperlipidemia (Seligman et al., 2010), obesity in women (Larson & Story, 2011), and diabetes (Seligman et al., 2010). However, less is understood about the relationship of exposure to food insecurity in childhood with development of cardiometabolic conditions over the life course. Most studies have explored childhood experiences of adversity related to abuse, parental unemployment, parental substance abuse, and school expulsions (Friedman et al., 2015), but not food insecurity. Specifically, academic interruptions and physical and sexual abuse have been linked to increased risk of diabetes, obesity, and heart disease in adulthood (Friedman et al., 2015). Identifying specific influential aspects of socioeconomic conditions in childhood, like food insecurity, can inform prevention efforts among vulnerable children and households.

Puerto Rico is a notable example of a country with a high proportion of its population experiencing food insecurity and at risk of food insecurity; 33.2% are food insecure (Torres et al., 2019), 44.4% live below the poverty level, 10.8% are unemployed, and 26.1% have less than a high school education (Economic Research Service, USDA, 2018). A large proportion of Puerto Rico's residents are also affected by cardiometabolic diseases, including hypertension (43.9% of women and 40.5% of men), diabetes (16.4% in women and 14.8% of men), and obesity (26.8% of women and 26.9% of men) (Pan American Health Organization, 2016). Almost one-half of deaths on the island are attributable to cardiovascular (24%) or endocrine (13%) diseases, specifically heart disease (116.1 per 100,000 inhabitants) and diabetes (71.9 per 100,000 inhabitants) (Pan American Health Organization, 2016). Furthermore, the devastation by hurricane María in September 2017 exacerbated poor social and health conditions (Ramphal, 2018), underscoring the importance of elucidating the potential cardiometabolic implications of food insecurity over the life course. We aimed to determine the relationship between childhood food insecurity and hypertension, diabetes, CVD, and obesity in adulthood among older adults living in Puerto Rico. As a secondary aim, we explored the association of childhood food insecurity with early onset of hypertension, diabetes, or CVD in adulthood.

2. Methods

2.1. Study design and participants

The Puerto Rican Elderly: Health Conditions (PREHCO) study investigated the health status of a multistage, stratified sample (n = 4291) of noninstitutionalized older adults (≥60 y) living in Puerto Rico, with oversampling in regions with high concentrations of African descent and with individuals over 80 years of age. Participants, or a proxy in the case that a participant had cognitive limitations, completed face-to-face interviews with study staff. These interviews collected data on retrospective childhood conditions and experiences, sociodemographic characteristics, family structure, migration, self-reported health conditions, anthropometric measures, and physical performance. Wave 1 of data collection occurred between 2002 and 2003 with a response rate of 93.9% (Mceniry & Palloni, 2010), and a Wave 2 follow-up occurred between 2006 and 2007, with a 90% response rate (Palloni et al., 2013). The institutional review boards at the University of Wisconsin-Madison and the University of Puerto Rico approved the study. Anonymized data and materials are publicly-available from the University Consortium for Political and Social Research Data Sharing for Demographic Research project, and can be accessed at https://www.icpsr.umich.edu/web/DSDR/studies/34596.

2.2. Food insufficiency

Food insufficiency was assessed during Wave 2 with the self-report question, "did you suffer economic hardships [in childhood] that prevented you from eating regularly?' Because standardized measures of retrospective childhood food insecurity are limited, we are referring to this assessment as a proxy measure of food insecurity, referred to as food insufficiency. Self-reported food insecurity experiences in childhood have been shown to remain salient into adulthood; low-income adults expressed strong emotional responses to and recalled vivid details of their childhood experiences of food insecurity (Rosa et al., 2018). In addition, previous studies have shown that a single-item, self-reported assessment tool was effective at identifying food-insecure households, including those with children (Bayoumi et al., 2021; Urke et al., 2014), and was highly correlated with the 18-, 10-, and 6-item (r = 0.948, 0.972, and 0.948, respectively) U.S. Department of Agriculture's validated self-report Food Security Survey Modules (McKechnie et al., 2018).

2.3. Cardiometabolic health conditions

Individuals self-reported physician-diagnosed hypertension, diabetes, and CVD (heart disease, heart attack, and stroke) at Wave 1. At Wave 2, individuals reported only newly-diagnosed cases since Wave 1. Thus, we retrieved self-reported physician-diagnosed cardiometabolic conditions from across the two waves to capture any self-reported conditions up to Wave 2. Because we were interested in type 2 diabetes, we excluded participants who reported a diabetes diagnosis before age 30y (n = 19) to reduce the likelihood that type 1 diabetes cases were in our analytical sample. Approximately ≥85% of type 1 diabetes cases in youth are diagnosed by age 20y (Maahs et al., 2010). After age 20y, type 1 diabetes becomes more difficult to diagnose, particularly among adults >30y (Diaz-Valencia et al., 2015), often because type 2 diabetes prevalence also increases after age 30y (Thomas et al., 2018). Body mass index (BMI) was calculated as kilograms divided by meters squared (kg/m^2) from measured height and weight. Participants were classified with obesity if they had a BMI of ≥30 kg/m^2.

2.4. Early onset of cardiometabolic health conditions

At Wave 1, individuals reporting physician-diagnosed cardiometabolic conditions also reported the age in which they were diagnosed with hypertension, diabetes, or CVD. At Wave 2, individuals reported age of onset only for newly-diagnosed cases since baseline. Individuals were then classified for each cardiometabolic condition as having no onset, early onset, or typical onset of disease. The following cutoffs were used to define early onset status for each disease: hypertension (<55 years old), type 2 diabetes (<45 years old), and cardiovascular disease (males: <55 years old; females: <65 years old). Those diagnosed with any of the three conditions later in life were defined as typical onset and those who reported no diagnoses were defined as no onset. Some variability remains in the literature on setting cutoff points for early onset of chronic disease. Thus, these cutoffs were selected based on standards used in previous epidemiologic studies and recommendations provided by advising organizations. Based on recent American Heart Association guidelines as well as other relevant epidemiologic studies, we set the cutoff for early onset CVD as <55y for males and <65y for females (Mosca et al., 2011). Given that race is socially constructed, and thus effects on health are likely to be context-dependent, and that race is relatively homogeneous in our sample (Puerto Ricans are less likely to report African heritage and more likely to report White or Hispanic, regardless of heritage and/or phenotype) (Landale & Oropesa, 2002), we did not stratify by race for early onset hypertension, defined in our study as age at first diagnosis of hypertension, and instead used general standards developed from the Framingham Heart Study (Niiranen et al., 2017). We used the cut-off for early onset hypertension as <55y. Similarly, cutoffs for early onset type 2 diabetes, defined in our study by age at first diagnosis of type 2 diabetes, varies widely and appears to differ by race (Bo et al., 2018), but we did not stratify based on race (Krieger, 2006). Limited data exist for implications and outcomes of diagnosis in ages 19-45y, but <45y is generally considered as the cutoff for early onset of type 2 diabetes (Wilmot & Idris, 2014) and, thus, used in this study.

2.5. Covariates

When building our models, we considered covariates representing conditions across the life course, as our exposure of interest was in childhood and our outcomes of interest were in adulthood. Basic sociodemographic information was collected at Wave 2, including age, sex, current participation in Puerto Rico's supplemental nutrition assistance program (Programa de Asistencia Nutritional (PAN)), and educational attainment. Individuals also self-reported (yes/no) if they had the following economic indicators: checking account, savings account, stocks, own a car, and own property. We used these indicators to create a cumulative wealth score, which sought to capture accumulated economic resources over time (rather than current household income, which would not accurately reflect current economic status for an older population), by tallying the number of wealth indicators (range: 0–5). We then categorized these scores into a 3-category wealth variable: no indicators (33.5%), one indicator (31.9%), or more than one indicator (34.6%). We also created variables to capture current employment status and primary occupation during adulthood using data collected at both Wave 1 and Wave 2. We categorized current employment status as never worked for pay, homemaker, retired, currently working, and currently not working. Data for the primary occupation during adulthood was recorded according to the 2000 Census Standard Occupational Classification Equivalents. Using these, we then categorized primary occupation during adulthood as 1) never worked for pay or homemaker, 2) management, professional, office and administrative support, 3) services, sales, military, and 4) manual labor. Manual labor combined the following occupations: farming, fishing, forestry, construction, extraction, maintenance, production, transportation, and material moving. Self-rated health and household economic conditions in childhood were also collected at Wave 2. Individuals reported childhood self-rated health as excellent, very good, fair, or bad, and childhood household economic conditions as good, fair, or bad. Two additional childhood variables were collected at Wave 1; paternal educational attainment and birth season. Birth season was categorized according to previous research in this cohort, whereby differential exposure to poor nutrition through a lean agricultural season during the third trimester of gestation (July–December) was a risk factor for heart disease among older adults in the cohort who reported living in the countryside, versus urban areas, before the age of 18 years (Mceniry & Palloni, 2010). Mceniry & Palloni defined birth season exposure as follows: 1) partial late exposure (January–March), 2) partial early exposure (July–September), 3) full exposure (October–December), or 4) no exposure (April–June) (Mceniry & Palloni, 2010). For lifestyle behaviors, individuals self-reported smoking status at Wave 1 and Wave 2 and physical activity at Wave 2. We constructed a 3-category variable from the two waves of smoking data to represent smoking status (never, current, past). Individuals also responded (yes/no) at Wave 2 to the question, "Do you exercise at least three times a week?" We constructed a binary alcohol variable from the two waves of alcohol data to represent alcohol consumption (do not consume alcohol/consume alcohol) based on the reported average number of alcoholic drinks consumed per week in the past three months. Those who reported "did not consume any" were classified as "do not consume alcohol" and those reporting any consumption were classified as "consume alcohol".

2.6. Statistical analysis

We conducted cross-sectional analyses using 2712 individuals that reported retrospective childhood food insufficiency at Wave 2. When modeling type 2 diabetes and total number of cardiometabolic conditions, the sample size was 2671 because we excluded possible type 1 diabetes cases. Missing data were imputed with multiple imputation for chained equations using predictive mean matching (947 missing at least one covariate; 5 missing hypertension; 20 missing CVD; 11 missing diabetes; 3 missing obesity). Unadjusted descriptive differences in participant characteristics by childhood food insufficiency were tested using Rao-Scott chi-square tests for categorical variables and ANOVA for continuous variables. Multivariate logistic regression models determined associations between childhood food insufficiency and individual or total number of cardiometabolic conditions. Model 1 adjusted for age. Model 2 adjusted for Model 1 covariates plus childhood socioeconomic and health factors (birth season, perceived household economics conditions in childhood, self-rated health in childhood, and father's educational attainment). Model 3 adjusted for Model 2 covariates plus adulthood socioeconomic factors (current participation in PAN, educational attainment, number of wealth markers, and primary occupation during adulthood). Model 4 adjusted for Model 3 covariates plus lifestyle behaviors (smoking status and physical activity behavior). Similarly, multivariate logistic regression models determined associations between childhood insufficiency and early (vs. typical) onset of each cardiometabolic condition (sample size 2662). We adjusted for the same set of covariates as those mentioned above for each model, except Model 3 was not adjusted for primary occupation and Model 4 was additionally adjusted for alcohol intake. All models were stratified by sex, as a recent systematic review and meta-analysis showed that socioeconomic status had stronger inverse relationships with CVD risk in women, compared to men (Backholer et al., 2017). Food insecurity has also shown consistent relationships with higher body weight in women, but not men (Larson & Story, 2011). Likewise, sex differences in diabetes development appear to be due to distinct sex- and gender-related biological and psychosocial factors (Kautzky-Willer et al., 2016). In both the unadjusted descriptive tests and in the regression models, we accounted for complex survey design and sampling weights using SAS version 9.4 (SAS Institute, Cary, NC, USA). Significance was set at $P < 0.05$.

3. Results

Of the PREHCO participants completing both Wave 1 and 2 of data collection, 29.4% responded affirmatively to childhood food insufficiency, 68.7% reported hypertension, 29.6% reported type 2 diabetes, 34.2% reported CVD, and 29.9% were classified with obesity. Over half of the sample (55.4%) had more than one cardiometabolic condition (32.1% had two conditions and 23.3% had three conditions) and 28.0% had one condition. Participants experiencing food insufficiency in childhood were more likely to report a poor household economic condition in childhood, low paternal educational attainment, and bad or average self-rated health as a child (Table 1). Participants experiencing food insufficiency in childhood were also more likely to have a lower current monthly income, experience frequent financial hardship, report no wealth markers, have less than a high school education, have reported manual labor jobs as their primary occupation in adulthood, have been a former smoker, and have two or more cardiometabolic conditions. A higher proportion of participants reporting childhood food insufficiency had hypertension or CVD, but not type 2 diabetes or obesity.

In models stratified by sex and adjusted for age, childhood food insufficiency was associated with higher odds of type 2 diabetes among females and CVD among males (Table 2). Childhood food insufficiency was also associated with higher odds of having two, or three to four, cardiometabolic conditions among males. Among females, childhood food insufficiency was not associated with any individual cardiometabolic condition or total number of cardiometabolic conditions after additional adjustment for childhood socioeconomic conditions and health factors. These non-significant associations remained after adjustment for adulthood socioeconomic conditions and lifestyle behaviors (Figs. 1 and 2). Among males, childhood food insufficiency remained associated with higher odds of CVD and with having two or three to four cardiometabolic conditions, compared to none, in models further adjusted for childhood socioeconomic and health factors and in models further adjusted for adulthood socioeconomic conditions and lifestyle behaviors. The association of childhood food insufficiency with

Table 1
Participant characteristics by childhood food sufficiency status among older adults living in Puerto Rico (n = 2712).

Characteristics	Childhood food sufficiency status[a]		
	Food sufficient (n = 1827; %)	Food insufficient (n = 885; %)	p-value
	Mean or % (95% CL)	Mean or % (95% CL)	
Age, y	72.8 (72.3, 73.3)	72.8 (72.2, 73.4)	0.93
Female	56.6 (53.0, 60.2)	56.8 (52.0, 61.7)	0.93
Childhood characteristics			
Household economic conditions in childhood			
Good	38.1 (35.1, 41.1)	5.4 (3.1, 7.7)	<0.0001
Average	48.6 (45.4, 51.9)	33.9 (28.9, 38.8)	
Bad	13.3 (11.2, 15.3)	60.8 (56.0, 65.5)	
Father's level of education			
Did not attend school	33.6 (29.5, 37.7)	50.6 (44.7, 56.5)	<0.0001
<8th grade	45.5 (41.2, 49.9)	40.9 (35.3, 46.6)	
≥8th grade	20.8 (17.7, 24.0)	8.5 (6.2, 10.7)	
Self-rated health as child			
Excellent	32.5 (29.2, 35.8)	21.3 (17.8, 24.9)	<0.0001
Very good	11.2 (9.2, 13.2)	5.3 (3.6, 7.0)	
Good	41.9 (38.6, 45.3)	38.0 (33.9, 42.2)	
Average	13.2 (10.8, 15.6)	28.7 (24.5, 32.9)	
Bad	1.1 (0.6, 1.7)	6.6 (4.6, 8.7)	
Exposure to lean agricultural season during gestation[b]			0.24
Late partial exposure	22.9 (20.5, 25.3)	20.5 (16.5, 24.6)	
Early partial exposure	25.2 (22.5, 27.9)	25.8 (21.6, 30.0)	
Full exposure	26.0 (23.2, 28.8)	23.4 (19.9, 27.0)	
No exposure	25.9 (23.0, 28.7)	30.2 (25.2, 35.2)	
Adulthood characteristics			
Monthly household income in quartiles, U.S. dollars			<0.0001
$0-525	15.8 (12.8, 18.8)	22.3 (17.8, 26.8)	
$526-800	18.6 (15.5, 21.7)	24.5 (19.3, 29.6)	
$801-1380	20.8 (17.7, 24.0)	17.8 (14.2, 21.3)	
>$1380	26.8 (22.8, 30.9)	17.5 (13.2, 21.7)	
Missing	17.9 (14.6, 21.3)	18.0 (13.3, 22.6)	
Receive Nutrition Assistance for Puerto Rico program	29.2 (25.1, 33.4)	41.4 (35.2, 47.6)	<0.0001
Frequency of financial hardship			
Frequently	8.2 (6.4, 10.1)	15.8 (11.5, 20.0)	<0.0001
Sometimes	32.1 (29.3, 35.0)	37.5 (32.9, 42.1)	
Never	59.6 (56.6, 62.6)	46.7 (41.2, 52.2)	
Number of wealth markers[c]			
None	28.7 (25.0, 32.4)	43.8 (38.1, 49.5)	<0.0001
One	32.9 (29.9, 36.0)	29.8 (25.1, 34.5)	
Two or more	38.4 (34.3, 42.4)	26.4 (21.9, 30.9)	
Less than high school educational attainment	56.0 (51.2, 60.9)	80.3 (76.3, 84.4)	<0.0001
Current employment			0.07
Never worked for pay	3.8 (2.5, 5.1)	4.4 (2.8, 6.1)	
Homemaker	9.5 (7.6, 11.3)	12.1 (8.7, 15.4)	
Retired	65.4 (62.1, 68.7)	61.4 (55.9, 66.9)	
Currently working	8.4 (6.1, 10.6)	5.7 (3.4, 7.9)	
Currently not working	12.9 (10.4, 15.4)	16.5 (12.0, 20.9)	
Primary occupation during adulthood			<0.0001
Never worked for pay or homemaker	13.3 (11.0, 15.6)	16.5 (12.9, 20.1)	
Management, professional, office and administrative support	27.4 (23.9, 30.8)	13.7 (10.7, 16.7)	
Services, sales, military	23.3 (20.3, 26.3)	25.1 (20.8, 29.3)	
Manual labor[d]	36.1 (32.4, 39.7)	44.8 (39.1, 50.4)	
Consume alcohol	19.4 (16.8, 22.1)	18.1 (14.1, 22.1)	0.58
Smoking status			
Never	64.1 (61.0, 67.2)	58.4 (52.8, 63.9)	0.03
Current	7.4 (5.7, 9.0)	6.2 (4.2, 8.2)	
Former	28.5 (25.4, 31.7)	35.4 (30.1, 40.8)	
Engage in physical exercise	78.1 (75.3, 80.9)	76.9 (72.9, 80.9)	0.59
Hypertension	68.4 (65.5, 71.3)	76.3 (71.8, 80.7)	0.01
Early onset[e]	13.1 (11.3, 15.0)	5.6 (4.5, 6.8)	0.006
Type 2 diabetes[f]	30.6 (27.3, 34.0)	35.7 (31.4, 39.9)	0.06
Early onset[e]	2.0 (1.3, 2.7)	0.90 (0.4, 1.4)	0.10
Cardiovascular disease	32.0 (28.6, 35.4)	39.0 (33.9, 44.1)	0.01
Early onset[e]	6.7 (5.1, 8.3)	5.0 (3.5, 6.6)	0.01
Obesity	29.7 (26.9, 32.6)	30.1 (25.5, 34.7)	0.89
Total number of cardiometabolic conditions[g]			0.01
0	18.5 (15.9, 21.1)	12.5 (9.5, 15.5)	
1	28.4 (25.7, 31.1)	27.2 (23.2, 31.1)	
2	31.5 (28.4, 34.6)	33.5 (29.1, 38.0)	
3-4	21.6 (19.1, 24.1)	26.8 (23.0, 30.6)	

[a] Childhood food sufficiency status was assessed with the question, "did you suffer economic hardships [in childhood] that prevented you from eating regularly?' Affirmative responses were categorized as food insufficient.

[b] Partial late exposure refers to third trimester gestational exposure late in a lean agricultural season. Partial early exposure refers to third trimester gestational exposure early in a lean agricultural season. Full exposure refers to third trimester gestational exposure for an entire lean agricultural season. No exposure refers to no third trimester gestational exposure to a lean agricultural season.

[c] A cumulative score capturing accumulated economic resources over time, including checking account, savings account, stocks, own a car, and own property (range: 0–5).

[d] Manual labor jobs include those in farming, fishing, forestry, construction, extraction, maintenance, production, transportation, and material moving.

[e] The following cutoffs were used to define early onset status for each disease: hypertension (<55 years old), type 2 diabetes (<45 years old), and cardiovascular disease (males: <55 years old; females: <65 years old).

[f] Participants reporting a diabetes diagnosis before age 30y were excluded (n = 19) to eliminate possible type 1 diabetes cases.

[g] Includes hypertension, type 2 diabetes, any cardiovascular disease, and obesity.

Table 2
Association of childhood food insufficiency[a] with odds (95% CI) of adulthood cardiometabolic conditions among older adults in Puerto Rico, stratified by sex.

Females				
Cardiometabolic outcome	Model 1	Model 2	Model 3	Model 4
Hypertension	1.5 (0.95, 2.3)	1.3 (0.8, 2.1)	1.3 (0.7, 2.1)	1.2 (0.7, 2.1)
Type 2 diabetes	1.4 (1.0, 1.8)*	1.1 (0.8, 1.6)	1.2 (0.8, 1.6)	1.2 (0.8, 1.6)
Cardiovascular disease	1.0 (0.7, 1.4)	1.0 (0.6, 1.4)	0.9 (0.6, 1.3)	0.9 (0.6, 1.3)
Obesity	1.0 (0.7, 1.4)	0.9 (0.6, 1.2)	0.9 (0.6, 1.2)	0.9 (0.6, 1.2)
Number of conditions[b]				
0	ref	ref	ref	ref
1	1.2 (0.8, 2.2)	0.9 (0.5, 1.8)	0.9 (0.4, 1.6)	0.8 (0.4, 1.6)
2	1.4 (0.8, 2.6)	1.1 (0.5, 2.3)	1.0 (0.5, 2.1)	1.0 (0.5, 2.1)
3-4	1.6 (0.9, 2.9)	1.0 (0.5, 2.1)	0.9 (0.4, 2.0)	0.9 (0.4, 2.0)
Males				
Cardiometabolic outcome	Model 1	Model 2	Model 3	Model 4
Hypertension	1.5 (0.99, 2.3)	1.5 (0.9, 2.4)	1.7 (1.1, 2.6)*	1.7 (1.1, 2.7)*
Type 2 diabetes	1.1 (0.7, 1.7)	1.1 (0.7, 1.7)	1.0 (0.6, 1.7)	1.1 (0.7, 1.8)
Cardiovascular disease	2.0 (1.4, 3.0)***	1.8 (1.1, 2.8)*	1.7 (1.1, 2.6)*	1.7 (1.1, 2.6)*
Obesity	1.0 (0.6, 1.6)	1.1 (0.6, 1.9)	1.2 (0.7, 2.0)	1.2 (0.7, 2.2)
Number of conditions[b]				
0	ref	ref	ref	Ref
1	1.6 (0.9, 2.9)	1.8 (0.9, 3.7)	1.8 (0.9, 3.7)	1.8 (0.9, 3.5)
2	1.8 (1.1, 3.0)*	1.9 (1.0, 3.4)*	1.9 (1.0, 3.4)*	1.9 (1.0, 3.4)*
3-4	2.2 (1.3, 3.7)**	2.0 (1.0, 3.9)*	2.2 (1.2, 4.2)*	2.3 (1.2, 4.4)*

Model 1: adjusted for age.
Model 2: adjusted for Model 1 + childhood household economic conditions, self-rated health as child, father's educational attainment.
Model 3: adjusted for Model 2 + participation in Nutrition Assistance for Puerto Rico program, educational attainment, wealth markers, and primary occupation during adulthood.
Model 4: adjusted for Model 3 + smoking and physical exercise.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

[a] Being food sufficient in childhood was the comparison group. Childhood food sufficiency status was assessed with the question, "did you suffer economic hardships [in childhood] that prevented you from eating regularly?' Affirmative responses were categorized as food insufficient.

[b] Includes hypertension, type 2 diabetes, any cardiovascular disease, and obesity.

hypertension was stronger among males after adjusting for adulthood socioeconomic factors and lifestyle behaviors.

For our secondary aim, childhood food insufficiency was significantly associated with typical onset of hypertension among women (Odds Ratio (OR) (95% Confidence Intervals (CI)): 2.9 (1.6, 5.5)) and marginally significantly associated with early onset of CVD among men (2.2 (1.0, 4.7) after controlling for all childhood and adulthood covariates (Supplemental Table 1). No other associations between childhood food insufficiency and onset of cardiometabolic conditions were statistically significant for males or females.

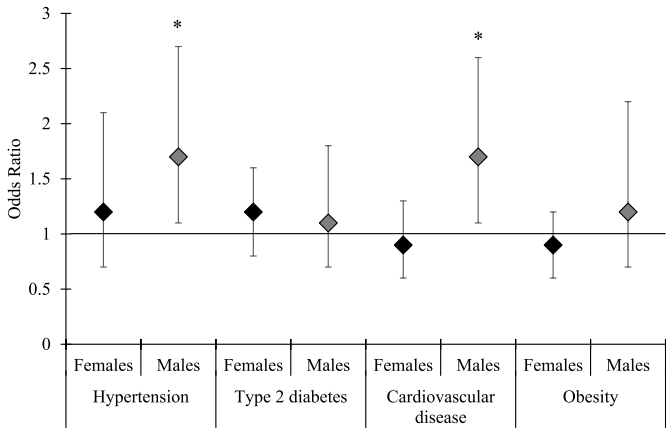

Fig. 1. Multivariate-adjusted association of childhood food insufficiency with odds (95% CI) of individual adulthood cardiometabolic conditions stratified by sex
*$P < 0.05$.

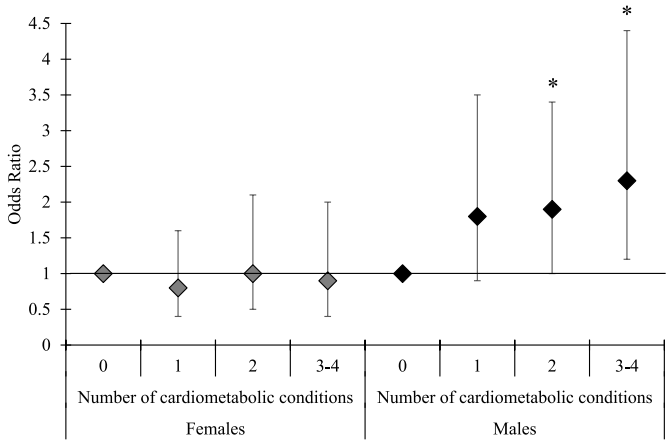

Fig. 2. Multivariate-adjusted association of childhood food insufficiency with odds (95% CI) of total number of adulthood cardiometabolic conditions stratified by sex
*$P < 0.05$.

4. Discussion

In this sample of older adults in Puerto Rico, childhood food insufficiency remained significantly associated with higher odds of CVD in adulthood for males, but not females, after adjusting for each set of life course confounders. A similar pattern was seen among males for odds of hypertension and odds having three or more cardiometabolic conditions. Childhood food insufficiency was only marginally related to early onset CVD among males.

Our findings align with cumulative inequality theory, which views childhood as the most crucial stage of the life course in establishing a trajectory towards social inequality that eventually shapes adult health (Ferraro et al., 2016). Specifically, cumulative inequality theory posits that the childhood environment (e.g., socioeconomic status) both directly (e.g., "sensitive period") and indirectly (e.g., future resources) shapes an individual's future health. Simultaneously, stressors related to the childhood environment can change how an individual functions in society and develops at a personal level, which may also impact an individual's future health (Ferraro et al., 2016). Thus, when investigating the relationship between childhood exposures and adult health, analyses must account for both early exposures and midlife risks and resources accumulated over the life course (Ferraro et al., 2016). Our study applied this approach by adjusting our regression models for childhood

socioeconomic and health factors, adulthood socioeconomic factors, and adulthood lifestyle behaviors.

Many studies have demonstrated a relationship between childhood socioeconomic status and development of CVD in adulthood (Kelishadi & Poursafa, 2014), and our findings add to this literature by demonstrating a specific aspect of low socioeconomic status, food insufficiency, that may impact adult cardiovascular health. Donnan et al. (1994) found that in a case-control study of older adults in China, inadequate food intake in childhood was associated with higher odds of acute myocardial infarction for men aged <65y and for both men and women aged ≥65 years (Donnan et al., 1994), further supporting our findings. To the best of our knowledge, this study in China and our findings are the only investigations on the potential role of childhood experiences of food insufficiency in development of cardiovascular risk in adulthood. Less consistent evidence exhibits an association between early life socioeconomic status and metabolic risk in adulthood, which may explain why we did not find a relationship between childhood food insufficiency and obesity or diabetes in our study. Household income in the prenatal period but not periods of childhood may be more influential to adulthood BMI (Ziol-Guest et al., 2009), and food insufficiency in adulthood has been consistently associated with adult obesity in women in cross-sectional analyses (Larson & Story, 2011). Pathway (Insaf et al., 2014) or accumulation of risk (Friedman et al., 2015; Insaf et al., 2014) models may also more accurately capture the development of metabolic risk in adulthood.

The significant relationship of childhood food insufficiency with adulthood cardiometabolic health among men compared to women in our study counters most existing evidence, which suggests that the relationships of early life socioeconomic conditions and risk of cardiometabolic conditions are stronger for women (Friedman et al., 2015). The unique sex differences we documented may be related to gender differences in the childhood psychosocial environment; child psychosocial stress can often coexist with experiences of food insufficiency and other tradeoffs made by low-income households (Knowles et al., 2016). Previous work has found that hostile maternal child-rearing and low parental socioeconomic status were independently associated with higher cardiometabolic risk in boys, but not girls. For girls, hostile maternal child-rearing attitudes were associated with higher cardiometabolic risk for those in low socioeconomic status families but lower cardiometabolic risk for those in higher socioeconomic status families (Pulkki et al., 2003). Although definitive data are limited, girls in Puerto Rico during the mid-twentieth century may have been more involved with family meal preparation, protecting them from severe food insecurity by increasing their direct access to food. However, a recent study of children in Canada demonstrated that while girls were more likely to assist with choosing and preparing family meals compared to boys, household food security status moderated these roles differently for girls and boys. Girls in food-insecure, versus food-secure, households were less likely to assist with choosing family meals while boys in food-insecure, versus food-secure, households more likely to assist with preparing family meals (Blanchet et al., 2020). Furthermore, a meta-analysis found that boys, compared to girls, aged 0–59 months in low-and-middle-income countries were more likely to be undernourished (e.g., wasted, stunted, underweight) (Thurstans et al., 2020), a risk factor for development of cardiometabolic diseases (Grey et al., 2021). The authors summarized that both social and biological factors may explain these disparities, including parental caretaking behaviors in the first years of life, girl-focused nutrition programming, and sex hormones (Thurstans et al., 2020), which are protective against cardiovascular risk in females during the reproductive age (Mercuro et al., 2011). Thus, our non-significant findings for the relationship between childhood food insufficiency and cardiometabolic health conditions among Puerto Rican females may be explained by biological-, family-, and policy-level factors protecting girls from potential long-term consequences of childhood food insufficiency. These differences for males versus females may also be due to distinct trajectories in the relationship of early-life disadvantage with diet and physical activity behaviors in adulthood which can shape cardiometabolic risk. Although sparse, some research suggests that early-life disadvantage may lead to both poor diet and leisure-time physical activity behaviors in U.S. males, but only to poor leisure-time physical activity behaviors in U.S. females (Lee et al., 2018).

Alternatively, the sex differences we documented may underscore a unique context for some children living in households at risk of food insufficiency, like our sample of adults born in Puerto Rico in the 1930s and 1940s, a period marked by the Depression, World War II, and great geopolitical, economic, public health, and biomedical shifts in the country (Gonzalez, 2016). For the poorest households during the 1930s, diets were deficient in high-quality protein, vitamins, and minerals, which persisted into the 1940s; only 7–8% of households approached meeting dietary requirements and rat studies demonstrated that this diet resulted in subnormal growth (Fernandez, 1975). Simultaneously, more mothers and their children were working outside the home to supplement the household economy (PuertoRican Studies Center, 2002), which may have impacted boys differently than girls due to distinct cultural expectations for parenting boys and girls (Lucca-Irizarry & Pacheco, 1989). Likewise, circular migration patterns between the island and the mainland U.S. are common for Puerto Ricans (Acevedo, 2004; Duany, 2002), and may have moderated the relationship between childhood food insufficiency and cardiometabolic disease development through differential exposure to food environments during adulthood. Overall, Puerto Ricans living in the mainland U.S. seem to have stable dietary quality over time, compared to other Hispanic/Latino heritages, but also appear to begin their time in the mainland U.S. with lower quality diets (Tucker, 2021). Research in the mid-1980s showed that mothers in Puerto Rico had lower prevalence of obesity, but higher intake of sugar and soft drinks and lower intake of fruits, vegetables, white bread, eggs, and beef, compared to Puerto Rican mothers in the South Bronx of New York City (Sanjur et al., 1986). Additional binational research in the mid-1990s confirmed similar patterns among a sample of Puerto Rican women permanently living in the mainland U.S. and Puerto Rican women living in the island, some of whom had lived in the U.S. for a period of time and then returned to live in Puerto Rico (Rodriguez, 1997). Yet, all of these women retained a high intake of traditional Puerto Rican foods, particularly rice and beans (Rodriguez, 1997), which have been found to relate to higher adherence to the cardiometabolic-protective Mediterranean Diet Score among Puerto Rican older adults living in Boston (Mattei et al., 2017). However, number of years living in the U.S. was inversely associated with consuming a traditional dietary pattern in the same cohort of Puerto Rican adults (Mattei et al., 2018). In addition, among a multi-site, heritage-diverse cohort of U.S. Hispanics/Latinos, fewer years living in the mainland U.S. was associated with lower consumption of a Burgers, Fries, and Soft Drinks dietary pattern and an Egg and Cheese dietary pattern among Puerto Ricans (Maldonado et al., 2021). These findings underscore the potential influence of exposure to U.S. mainland food environments over the life course on eventual cardiometabolic disease development among Puerto Ricans. The adherence to health-promoting aspects of the Puerto Rican diet, even for those adults who lived for a portion of time in the mainland U.S., may help explain why we did not observe a relationship between childhood food insufficiency and cardiometabolic health conditions in adulthood among females. However, the limited binational research on dietary intake among Puerto Rican men restricts our understanding of the possible contribution of diet during adulthood to the relationships we documented in our study. Future research is needed to elucidate gender-specific aspects of diet with circular migration among Puerto Ricans, particularly in the context of early-life disadvantage, such as childhood food insufficiency.

Understanding the distinct features of the stressful context of socioeconomic adversity is instrumental to informing programming to protect children and families. High levels of stress related to socioeconomic adversity have been associated with elevated levels of circulating

cortisol in children (Barr, 2017), and children are cognitively, emotionally, and physically aware of household food insecurity (Fram et al., 2011). Children in food-insecure households may also experience greater exposure to violence (Jackson et al., 2018) and trauma (Becker et al., 2018), which may indicate that childhood food insecurity under these circumstances is more memorable and, thus, more stressful. Food insufficiency has been associated with greater odds of having post-traumatic stress disorder symptoms among a sample of Hispanic/Latina women in high-poverty, urban areas of the U.S. (Golin et al., 2016). We also previously documented in a cohort of Puerto Rican adults in the U.S. mainland that food insecurity was associated with 5-year odds of dysregulated primary allostatic load markers (neuroendocrine and inflammation markers) (McClain et al., 2018), mediators to downstream cardiometabolic disruption. The level to which their own childhood food insecurity experiences modify this relationship in adulthood is unclear, but may be a valuable approach for future investigations given that food insecurity in childhood may be a memorable event. Furthermore, future studies should explore sex differences in these relationships, as Puerto Rican boys on the island of Puerto Rico and in South Bronx, New York previously reported higher exposure to cumulative adverse childhood experiences compared to girls. Boys were more likely to experience neglect, physical abuse, and exposure to violence (Polanco-Roman et al., 2021), which may co-exist with household food insecurity and place boys at a higher risk of developing cardiometabolic diseases (Suglia et al., 2018).

The mechanisms linking food insufficiency to cardiometabolic diseases and their onset are not entirely understood, but it is theorized that food insufficiency, may both lower the quality of foods consumed (Hanson & Connor, 2014) and cause binge-scarcity cycles which have potential physiologic consequences (Laraia, 2013), including through physiological stress-response pathways (McClain et al., 2018) that may directly and indirectly increase cardiometabolic risk. Emerging literature also ties food insecurity with disordered eating (Becker et al., 2017), and with an increase in fat stores (Laraia, 2013), which can also increase risk of cardiometabolic diseases. Our findings underscore the need to better understand the relationships between food insecurity, disordered eating, and cardiometabolic diseases, in that intermittent drastic changes in food and nutrient intake may have physiologic consequences that impact timing of development of cardiometabolic diseases later in life.

This study has several notable strengths. First, we investigated the association of a specific experience of early child socioeconomic adversity, food insufficiency, on adult cardiometabolic health, which adds to a limited evidence base. In particular, our study contributes to a large gap in studies examining how the relationship between childhood adversity and cardiometabolic outcomes differ by sex (Suglia et al., 2018). Identifying specific, modifiable attributes of socioeconomic adversity can inform programming to prevent and reduce risk of later disease. We also carefully considered life course factors that would potentially confound the food insufficiency-cardiometabolic health relationship by controlling for multiple childhood and adulthood factors. Lastly, our sample was representative of the non-institutionalized older adult population of Puerto Rico, increasing generalizability and providing much-needed evidence of the role of socioeconomic factors in development of CVD in a low-to-middle income country.

This study has several limitations. First, the analyses were cross-sectional, demonstrating a significant but not causal relationship. The analyses also may have over or underestimated the potential effect on health in adulthood; we captured exposure to a specific childhood adversity, though we attempted to control for other confounding adversities, and we were not able to account for deceased participants with cardiometabolic conditions. We also were unable to control for other potential confounders (e.g., childhood exposure to violence, racism, discrimination, dietary quality in adulthood). We controlled for socioeconomic factors using the available indicators of economic resources, which may have not been sufficient. For example, racism has been linked to health disparities in Puerto Rico (Caraballo-Cueto & Godreau, 2021). Previous research demonstrated that women on the island of Puerto Rico mostly identified their race as Puerto Rican or White, and this occurred even if they had darker skin tones (Landale & Oropesa, 2002). In fact, skin color appears to be a more adequate predictor of health outcomes for Puerto Ricans compared to standard race categories (Caraballo-Cueto & Godreau, 2021), but these data were not available in the cohort. Similarly, we adjusted for exposure to the lean agricultural season during gestation, but this exposure may have been more applicable to those living in the countryside during childhood. Individuals living in urban or suburban areas during childhood may have had different influential exposures that are possible confounders. We also controlled for smoking in our models, as individuals reporting childhood food insufficiency were more likely to be former smokers. However, residual confounding may still be possible. Last, assessing childhood experiences of food insecurity may have introduced recall bias, though recall of childhood socioeconomic position among adult women has been found to be valid for use in epidemiological studies (Krieger et al., 1998).

5. Conclusions

Our findings linking childhood food insufficiency to higher odds of cardiometabolic conditions in adulthood among Puerto Ricans, notably men, underscore the importance of using an ecobiodevelopmental approach to promote healthy child development (Shonkoff et al., 2012) which tracks throughout the life course. Future research should test these relationships among other at-risk populations, as well as employing a validated and reliable food insecurity assessment tool. Because food insecurity is episodic, including multiple measurement time points across childhood and adulthood will shed more light on the role of transient versus persistent food insecurity in contributing to cardiometabolic risk. These findings also inform the programmatic work of public health stakeholders to improve access to sufficient, healthy food in childhood to help prevent eventual cardiovascular-related diseases among marginalized populations.

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Data sharing

Data described in the manuscript are publicly and freely available without restriction at https://www.icpsr.umich.edu/web/DSDR/studies/34596.

Ethical statement

The institutional review boards at the University of Wisconsin-Madison and the University of Puerto Rico approved the study.

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ACM, HC, and JM designed the research questions. ACM analyzed the data and wrote the manuscript. HC analyzed the data for the exploratory analyses and wrote the related aspects of the manuscript. All authors reviewed and revised the manuscript, and approved the final version. All authors have access to the data presented in this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2022.101066.

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