Original Article

COVID-19-Related Food Insecurity Among Households with Dietary Restrictions: A National Survey

Jessica D. Guillaume, BS[a], Jyotsna S. Jagai, PhD, MPH, MS[b,c], Jennifer A. Makelarski, PhD, MPH[b],
Emily M. Abramsohn, MPH[b], Stacy Tessler Lindau, MD, MAPP[b,d], Ritu Verma, MD[e], and Christina E. Ciaccio, MD, MSc[f]
Chicago, Ill

> **What is already known about this topic?** A food allergy or celiac disease diagnosis requires dietary elimination of specific foods and creates unique barriers to obtaining adequate nutrition.
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> **What does this article add to our knowledge?** This is the first study to examine patterns of food insecurity by household dietary restriction status in the context of a global pandemic.
>
> **How does this study impact current management guidelines?** Our findings reinforce the importance of routine household food insecurity screening among patients diagnosed with food allergy or celiac disease.

BACKGROUND: Food insecurity dramatically increased because of the COVID-19 pandemic; however, little is known about pandemic-related food insecurity in households with dietary restrictions.

OBJECTIVE: To examine pre-pandemic rates of and pandemic-related change in food insecurity among households with and without dietary restrictions.

METHODS: A cross-sectional, panel-based survey of 3200 U.S. women was conducted in April 2020. Pre-pandemic food insecurity and early pandemic-related change in food insecurity were assessed using the adapted Hunger Vital Sign. Weighted, multivariate logistic regression was used to model the odds of pre-pandemic food insecurity and the odds of incident or worsening pandemic-related food insecurity among households with and without dietary restrictions. In models predicting pandemic-related outcomes, interaction effects between race/ethnicity and dietary restrictions were examined.

RESULTS: Before the COVID-19 pandemic, households with self-reported food allergy (adjusted odds ratio [aOR]: 1.5, 95% confidence interval [CI]: 1.2-1.9), celiac disease (aOR: 2.3, 95% CI: 1.4-3.5), or both (aOR: 2.1, 95% CI: 1.2-3.6) were significantly more likely to be food insecure than households without restrictions. Households with dietary restrictions were also significantly more likely to experience incident or worsening food insecurity during the early pandemic (food allergy: aOR: 1.6, 95% CI: 1.3-2.1) (celiac disease: aOR: 2.3, 95% CI: 1.5-3.5) (both: aOR: 2.0, 95% CI: 1.2-3.4). Race/ethnicity was not a significant moderator of the relationship between dietary restrictions and pandemic-related food insecurity.

CONCLUSION: Households with dietary restrictions were more likely to experience both pre-pandemic and pandemic-related incident or worsening food insecurity than households without restrictions. Clinical care for patients with dietary restrictions

[a]Pritzker School of Medicine, The University of Chicago, Chicago, Ill

[b]Department of Obstetrics and Gynecology, The University of Chicago, Chicago, Ill

[c]School of Public Health, University of Illinois at Chicago, Chicago, Ill

[d]Department of Medicine-Geriatrics, The University of Chicago, Chicago, Ill

[e]Department of Pediatric Gastroenterology, Hepatology, and Nutrition, The University of Chicago, Chicago, Ill

[f]Department of Pediatric Allergy and Immunology, The University of Chicago, Chicago, Ill

Abbreviations used
aOR- Adjusted odds ratio
CeD- Celiac disease
FA- Food allergy
HVS- Hunger Vital Sign
Op4G- Opinions 4 Good

Food insecurity is a prevalent, yet preventable, social determinant of various health outcomes and health care utilization.[1-4] Household food insecurity is defined as an economic and social condition in which households lack adequate or consistent access to food.[5] Before the COVID-19 pandemic, 11.1% of the U.S. population was food insecure[6] and households with food allergies were at higher risk of food insecurity than households without.[7] During the COVID-19 pandemic, early analyses suggest that rates of food insecurity have doubled overall and tripled among households with children.[8] However, little is known about how the COVID-19 pandemic will further impact food insecurity among an already vulnerable population with dietary restrictions.

Individuals with food allergy (FA) or celiac disease (CeD) diagnoses face additional barriers to securing safe and adequate foods.[9-13] FA is a chronic condition affecting 7% of U.S. children[14] and 11% of U.S. adults[15] characterized by an adverse immune-mediated response on exposure to a given food. Dietary elimination of the allergen is essential to prevent life-threatening allergic reactions. CeD is an autoimmune disease affecting 1% of the U.S. population, in which consumption of gluten elicits an inflammatory response that damages the lining of the small intestine.[16] Currently, a gluten-free diet is the only available treatment for patients with CeD. Both FA and CeD require dietary elimination of specific foods and expensive substitutions to maintain healthy nutrition and growth.[9,10] Prior literature suggests that households with FA were more likely to experience food insecurity than households without[7]; however, we find no studies examining the relationship between CeD and household food insecurity.

On March 11, 2020, the World Health Organization declared COVID-19 a global pandemic.[17] As a result of the pandemic and efforts to contain it, the U.S. unemployment rate increased dramatically[18] and negatively impacted people's ability to purchase food.[19] Moreover, both travel and business restrictions disrupted the transport and processing of food, resulting in increased delivery times and reduced global food availability.[20] School closures are also suspected to exacerbate existing inequalities and have detrimental health consequences for children in households that rely on school meals to fill food gaps.[21] Many families have turned to local charitable organizations for assistance, but food banks across the country are experiencing volunteer labor shortages and reduced donations.[22] The COVID-19 crisis has exacerbated rates of food insecurity,[8] but

little is known about how the added restriction of an FA or CeD diagnosis may further impact food access.

Furthermore, it is likely that the burden of pandemic-related food insecurity in households with dietary restrictions is not equally distributed among racial or ethnic groups. Before the pandemic, not only were FA households more likely to be food insecure compared with nonrestricted households, but Black children with FA were significantly more likely to experience low food security compared with White children with FA.[7] There is also growing evidence that the COVID-19 crisis is widening existing racial disparities in food insecurity. Black and Hispanic households with children are nearly twice as likely as White families to struggle with food insecurity during the pandemic (41% and 37% vs 23%).[23] One reason why Black and Hispanic households may be at higher risk of food insecurity than White households is spatial inequality, or the unequal distribution of food stores across communities.[24] With less options for supermarkets and fresh produce in communities of color compared with White neighborhoods,[25-27] we hypothesized that race would moderate the relationship between dietary restrictions and pandemic-related incident or worsening food insecurity. In other words, the relationship between food insecurity and food restriction would be stronger among racial and ethnic minorities due to the compounding effects of structural inequities.

We used data from the National Women's Health COVID-19 Study to examine differences in the pre-pandemic prevalence of food insecurity among households with and without dietary restrictions. We also examined differences in incident or worsening food insecurity during the early phase of the pandemic among households with and without dietary restrictions. We hypothesized that, in the early phase of the pandemic, households with any type of dietary restriction would be more likely to experience incident or worsening food insecurity than households without dietary restrictions. As a secondary hypothesis, we predicted that race/ethnicity would be a significant moderator of the relationship between household dietary restrictions and pandemic-related food insecurity.

METHODS
Study participants

The details of the survey sample for the National Women's Health COVID-19 Study have been previously described.[28] Between April 10 and April 24, 2020, a U.S. national sample of adult women was recruited using the Opinions 4 Good (Op4G) Health Care Panel.[29] Op4G is a philanthropic market research company whose panels of participants have been used in prior peer-reviewed studies.[28,30,31] Op4G maintains sociodemographic and health characteristics for each panelist to facilitate targeted recruitment of eligible individuals for future studies. The Op4G Health Care Panel comprises 350,000+ members recruited pre-pandemic using a combination of methods including nonprofit community partners, web campaigns, and word of mouth. A nested quota sampling strategy was used to ensure that the sample distribution of age and educational attainment matched 2018 population estimates.[32] The objective of the National Women's Health COVID-19 Study was to examine the impact of the pandemic on women's health and health-related socioeconomic risks and if these impacts varied by racial and ethnic groups; to meet these objectives, the quota oversampled East/Southeast Asian women given the risk of potential disproportionate impacts to this particular population.[33,34] Women who did

TABLE I. Weighted sample sociodemographic, household, and self-rated health characteristics

Characteristic	No restriction N = 2577 (82.0%)	FA N = 522 (17.0%)	P	CeD N = 140 (5.4%)	P	Both FA and CeD N = 97 (3.9%)	P
Race/ethnicity, n (%)							
White	1622 (67.6)	274 (55.0)	<.01	68 (51.5)	<.01	50 (55.5)	<.01
Black	309 (9.9)	81 (14.0)		15 (9.6)		7 (6.6)	
Hispanic	290 (12.6)	92 (19.5)		37 (26.0)		25 (27.4)	
Other	356 (9.9)	75 (11.5)		20 (12.9)		15 (10.5)	
Education level, n (%)							
High school or less	986 (37.1)	185 (37.0)	.93	56 (45.1)	.10	39 (43.9)	.25
More than high school	1591 (62.9)	337 (63.0)		84 (54.9)		58 (56.2)	
Household income, n (%)							
<25K	597 (19.1)	136 (21.7)	.69	35 (21.7)	.68	23 (20.1)	.54
25K-49K	839 (21.4)	154 (20.6)		43 (20.0)		26 (17.1)	
50K-99K	789 (30.2)	160 (29.3)		41 (26.1)		31 (27.3)	
≥100K	352 (29.3)	72 (28.4)		21 (32.5)		17 (35.5)	
Marital status, n (%)							
Married/partnered	1512 (62.9)	292 (58.9)	.15	78 (58.5)	.48	55 (59.6)	.69
Single	1063 (37.1)	229 (41.1)		62 (41.5)		42 (40.4)	
Household size, n (%)							
Lives alone	468 (16.2)	69 (12.4)	<.01	24 (16.1)	<.10	16 (17.7)	<.01
Self + 1	886 (36.1)	138 (15.9)		35 (24.1)		20 (15.6)	
Self + 2 or more	1214 (47.8)	313 (61.7)		80 (59.8)		60 (66.8)	
No. of household children, n (%)							
0 children	1152 (57.9)	200 (45.5)	<.01	45 (38.8)	<.01	30 (36.2)	<.01
1 child	437 (19.1)	120 (25.0)		34 (27.2)		21 (23.6)	
2 or more children	496 (23.1)	127 (29.5)		36 (34.0)		29 (40.2)	
Region, n (%)							
Midwest	587 (21.2)	103 (18.7)	.70	26 (14.3)	.45	17 (13.3)	.42
Northeast	514 (17.3)	107 (16.8)		25 (17.7)		20 (21.2)	
South	1024 (38.0)	214 (39.1)		57 (41.5)		37 (39.4)	
West	452 (23.6)	98 (25.4)		32 (46.5)		23 (26.1)	
Self-rated general health, n (%)							
Excellent or very good	1078 (45.1)	185 (34.3)	<.01	55 (37.5)	.24	24 (33.3)	<.10
Good	999 (37.1)	202 (39.3)		54 (39.3)		37 (40.7)	
Fair or poor	494 (17.8)	132 (26.4)		31 (23.2)		36 (26.0)	
Self-rated mental health, n (%)							
Excellent or very good	1246 (52.7)	227 (43.4)	<.01	60 (43.2)	.12	43 (44.9)	.25
Good	841 (30.3)	149 (28.6)		45 (32.3)		29 (30.0)	
Fair or poor	480 (17.1)	145 (28.0)		35 (24.5)		25 (25.1)	

Percentages were calculated using calibration weights generated based on the following variables: age, race, education, income, and region.
CeD, Celiac disease; *FA*, food allergy.

not speak English or were <18 years old were excluded from the study. Of the 3634 eligible persons contacted, the online survey was completed by 3200 respondents (an 88% cooperation rate).[35] Using a research panel rather than other available survey methods allowed us to recruit a diverse sample, yield high participation rates and quickly assess early pandemic-related changes. This study was approved by the University of Chicago Institutional Review Board (IRB20-0489). Informed consent was documented electronically using the online survey form, and respondents received $4 in compensation.

Survey design and measures

The self-administered, web-based survey collected basic sociodemographic and household characteristics. FA status was determined using the question: "Does anyone in your household have a physician-diagnosed food allergy?" Similarly, CeD status was determined using the question: "Has a doctor or other health professional ever told anyone in your household that they have celiac (sele-ak) disease, also called sprue (sproo)?" For both questions, respondents could choose from the options: yes, no, don't know, or refuse. Race/ethnicity was determined using 2 questions: "What race do you consider yourself to be? Please select 1 or more." (White, Black or African American, American Indian or Alaskan Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Pacific Islander, or other) and "Do you consider yourself to be Hispanic, Latino/a/x or of Spanish origin" (yes or no). Women who selected American Indian or Alaskan Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Pacific Islander, other, or multiple races were categorized as "Other." Additional measures were included to assess respondent general and mental health.[36,37]

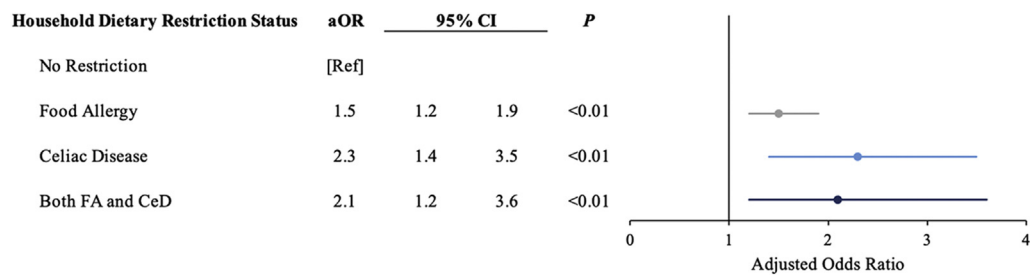| Household Dietary Restriction Status	aOR	95% CI		P
No Restriction	[Ref]			
Food Allergy	1.5	1.2	1.9	<0.01
Celiac Disease	2.3	1.4	3.5	<0.01
Both FA and CeD	2.1	1.2	3.6	<0.01

FIGURE 1. Odds of pre-pandemic food insecurity. Analyses are adjusted for race/ethnicity, education, household income, marital status, household size, number of household children, region, and respondent self-rated general and mental health. *aOR*, Adjusted odds ratio; *CeD*, celiac disease; *CI*, confidence interval; *FA*, food allergy.

Pre-pandemic food insecurity was assessed using 2 items adapted from the validated Hunger Vital Sign (HVS) screener.[38] The measures were preceded by the statement: "Some people have made the following statements about their food situation. Please answer whether the statements were often, sometimes, or never true for you and your household in the **12 months before the coronavirus pandemic.**" Earlier in the survey, the start of the coronavirus pandemic was defined according to the World Health Organization declaration on March 12, 2020. HVS measures were individually modified (notated in bold) to probe specifically for pre-pandemic food insecurity: "In the **12 months before the coronavirus pandemic,** you worried that your food would run out before you got money to buy more" and "In the **12 months before the coronavirus pandemic**, the food you bought just didn't last and you didn't have money to get more." A response of "often true" or "sometimes true" to either item was considered a positive screen. Change in food insecurity was determined using a single question adapted (in bold) from the HVS: "How has your worry about food running out before you got money to buy more changed **since the start of the coronavirus pandemic**?" Responses were collected using a 5-point Likert scale (much more to much less worried) and dichotomized into more versus same or less. Responses were dichotomized to ensure adequate sample size and to specifically highlight worsening pandemic-related change in household food insecurity status. Nonresponse rates for individual measures ranged from 0% to 2.5% (median, 0.2%).

Statistical analysis

We adjusted sample weights using the raking-ratio method[39] to correct for any imbalances in the marginal distributions of age group (18-24 years, 25-44 years, 45-64 years, ≥65 years), race (Asian, Black, Other, White), education (high school or less, more than high school), income category (<$25,000, $25,000-$49,000, $50,000-$99,999, ≥$100,000), and region (Midwest, Northeast, South, West) using 2018 U.S. population data for adult women.[32] All analyses were performed using survey weights. Of the 3200 survey respondents, 54 responses were excluded from analyses (24 respondents did not answer the income measure used to calculate survey weights and 30 respondents did not answer one or both of the FA/CeD measures). Respondents who answered yes to both the FA and CeD measures (n = 97) were included in all 3 dietary restriction groups: FA, CeD, and both CeD and FA. Each dietary restriction group was compared with households with no dietary restrictions.

We described respondent sociodemographic, household, and health characteristics stratified by household dietary restriction status and used χ^2 tests to examine bivariate associations between these characteristics and each type of household dietary restriction. Next, we used multivariate logistic regression to model: (1) the odds of pre-pandemic food insecurity, (2) the odds of early pandemic-related incident or worsening food insecurity, and (3) the odds of early pandemic-related incident or worsening food insecurity with race/ethnicity included as an interaction variable. In all models, the primary predictor of interest was household dietary restriction status, with no restrictions as the reference group. Models controlled for the following sociodemographic, household, and health characteristics: race/ethnicity, education, income, marital status, region, self-rated general health and mental health (categorical variables), and household size and number of children (continuous variables). Model results are presented as adjusted odds ratios (aOR) with 95% confidence intervals (CI). All analyses were performed using Stata software, version 16.1 (StataCorp, College Station, TX).

RESULTS
Sample characteristics

Table I summarizes the weighted individual- and household-level characteristics of survey respondents by self-reported household dietary restriction status (see Table E1 in this article's Online Repository at www.jaci-inpractice.org to compare weighted and unweighted demographic data). Of 3146 respondents, 17% of women indicated that someone in their household had a physician-diagnosed FA, 5% of women indicated that someone in the household had a diagnosis of CeD, and 4% of women indicated that both were true. In bivariate analyses, race/ethnicity, household size, number of household children, and respondent self-rated general and mental health were significantly associated with at least one of the household dietary restrictions (P < .10).

Pre-pandemic food insecurity

Overall, 37% of households in our sample were food insecure. Households with dietary restrictions reported higher rates of pre-pandemic food insecurity (47% FA, 56% CeD, and 53% both) than households with no dietary restrictions (35%), and these differences were significant in bivariate analyses (P < .01). Figure 1 illustrates the adjusted odds of experiencing food insecurity before the COVID-19 pandemic for households with FA, CeD, and both compared with households without dietary restrictions (see Table E2 in this article's Online Repository at www.jaci-inpractice.org for the full model). Overall, all 3 dietary restriction groups were significantly more likely to experience pre-pandemic food insecurity compared with households with no restriction (FA: aOR: 1.5, 95% CI: 1.2-1.9; CeD: aOR: 2.3, 95% CI: 1.4-3.5; both: aOR: 2.1, 95% CI: 1.2-3.6).
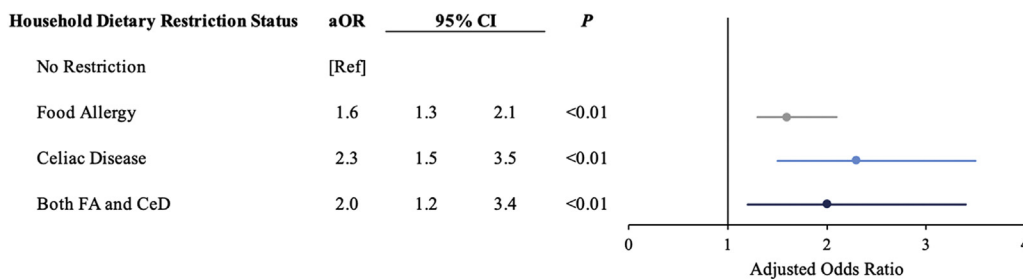
Household Dietary Restriction Status	aOR	95% CI		P
No Restriction	[Ref]			
Food Allergy	1.6	1.3	2.1	<0.01
Celiac Disease	2.3	1.5	3.5	<0.01
Both FA and CeD	2.0	1.2	3.4	<0.01

FIGURE 2. Odds of pandemic-related incident or worsening food insecurity. Analyses are adjusted for race/ethnicity, education, household income, marital status, household size, number of household children, region, and respondent self-rated general and mental health. *aOR*, Adjusted odds ratio; *CeD*, celiac disease; *CI*, confidence interval; *FA*, food allergy.

TABLE II. Interaction effects between race/ethnicity and household dietary restriction status in models predicting pandemic-related incident or worsening food insecurity

	Household dietary restriction					
	FA		**CeD**		**Both FA and CeD**	
Race/ethnicity	aOR (95% CI)	P	aOR (95% CI)	P	aOR (95% CI)	P
White	[Ref]		[Ref]		[Ref]	
Black	1.1 (0.6-2.3)	.72	1.1 (0.3-4.1)	.91	1.2 (0.2-10.3)	.84
Hispanic	1.8 (0.9-3.5)	.11	0.9 (0.3-2.8)	.88	0.6 (0.2-2.4)	.50
Other	1.3 (0.6-2.7)	.45	3.6 (1.0-13.6)	.06	2.3 (0.5-9.7)	.26

Analyses are adjusted for race/ethnicity, education, household income, marital status, household size, number of household children, region, and respondent self-rated general and mental health.
aOR, Adjusted odds ratio; *CeD*, celiac disease; *CI*, confidence interval; *FA*, food allergy.

Pandemic-related food insecurity

Figure 2 depicts the likelihood of experiencing new or worsening food insecurity after the start of the COVID-19 pandemic by household dietary restriction type (see Table E3 in this article's Online Repository at www.jaci-inpractice.org for the full model). Households with FA (aOR: 1.6, 95% CI: 1.3-2.1), CeD (aOR: 2.3, 95% CI: 1.5-3.5), or diagnoses of both (aOR: 2.0, 95% CI: 1.2-3.4) were all significantly more likely to experience incident or worsening food insecurity when compared with households without restrictions. Race/ethnicity was not found to have a significant interaction effect with any of the 3 dietary restriction types (Table II).

DISCUSSION

These national data show that in the early phase of the COVID-19 pandemic, households with each type of dietary restriction (FA, CeD, and both) were significantly more likely than households without dietary restrictions to experience pandemic-related incident or worsening food insecurity. Race/ethnicity was not found to be a significant moderator of this relationship. Our study provides an early look at the impact of COVID-19 on households with food restrictions, while also filling important knowledge gaps about the pre-pandemic prevalence of food insecurity in households with restrictions. We found that before the pandemic, households with FA, CeD, or both were all more likely to be food insecure than households without restrictions.

Brown et al[40] outline important shortcomings in federal and state nutrition policy that help explain our key pandemic-related findings. Despite efforts made through the Families First

Coronavirus Response Act to expand nutrition benefits offered by the Supplemental Nutrition Assistance Program and the Special Supplemental Nutrition Program for Women, Infants and Children, this policy failed to address the increased cost and decreased availability of allergen/gluten-free products.[9,11,12] On a local level, families relying on emergency assistance programs, such as food pantries or soup kitchens, were limited by temporary location closures and lack of allergen/gluten-free options. Brown et al[40] noted that of the 60,000 food pantries and soup kitchens around the country, only 4 consistently stock allergen-free foods and only 2 were operational during the early months of the pandemic. Many organizations are also implementing boxed food distribution protocols,[40] further limiting options for families and resulting in unnecessary food waste in resource-limited setting. Many families with restrictions also rely on online shopping and delivery to purchase necessary specialty items. Early in the pandemic, postal package delivery and grocery delivery services were inundated with orders; this resulted in increased shipping delays and further restricted access to food.[41,42] The COVID-19 pandemic compromised our national food system in ways that uniquely disadvantaged families with dietary restrictions.

We hypothesized that, given structural inequities such as the limited distribution of supermarkets in communities of color compared with White neighborhoods,[25-27] race and ethnicity would moderate the relationship between household food restriction and pandemic-related food insecurity. However, we were surprised to find that the relationship between household dietary restrictions and pandemic-related food insecurity was similar across all racial and ethnic subgroups. One possible explanation is that households who are food insecure have

similarly limited access to food in their communities, regardless of race or ethnicity. It is also possible that our secondary analyses had insufficient power to detect small, but important moderation effects. Despite our findings, we argue that race and ethnicity should be considered when addressing food insecurity among those with food restrictions. After controlling for other social and economic factors, people identifying with minority racial and ethnic groups are still at higher risk of experiencing food insecurity compared with Whites.[43] Prior studies have outlined the ways in which race- and ethnicity-based discrimination and racism within our systems of housing, criminal justice, and employment contribute to disparities in rates of food insecurity.[44,45] Although our data did not demonstrate a moderating effect by race, these structural factors cannot be overlooked in the treatment of patients with dietary restrictions.

In addition to describing pandemic-related changes in food insecurity, our findings support prior pre-pandemic studies of FA[7] and uncover a similar trend in CeD households. To our knowledge, no other studies have examined the relationship between CeD and food insecurity. In fact, a number of studies suggest that CeD diagnoses are more common in high socioeconomic households.[46,47] However, the data regarding socioeconomic status and formal CeD diagnosis are conflicting.[48,49] Our study showed no significant bivariate relationship between household income, educational attainment, or marital status with any of the household dietary restriction types. Studies analyzing administrative claims data have documented that families accrue significant costs associated with diagnosis, treatment, and follow-up for CeD when compared with matched controls.[50-52] These costs are in addition to those acquired from adhering to a gluten-free diet.[13] It is possible that the added financial strain associated with CeD diagnosis and treatment makes it harder for households to afford food.

Further research is needed to understand the unique barriers FA and CeD households encounter in accessing safe foods. Many studies evaluating food insecurity intervention outcomes fail to collect data from their sample regarding dietary restrictions.[53-55] Without data, it becomes impossible to evaluate whether food insecurity interventions are equally as effective for food-restricted households as they are for households without restrictions. Moreover, some studies exclude patients with FA entirely from their intervention.[56] Our data suggest that excluding food-restricted patients from intervention studies may disadvantage people who are at highest risk of food insecurity.

We acknowledge limitations to these findings. Although our dataset closely resembles U.S. population data for women,[28] our findings are limited in generalizability by the use of a panel-based quota sample rather than a probability sample. Our use of an online survey may underestimate food insecurity by excluding a small subset of households with limited internet access—a more prevalent condition among Black and Hispanic households than in White and Asian households.[57] At the same time, our findings may overestimate the prevalence of food insecurity in the general population as single woman-headed households have higher rates of food insecurity than their male counterparts.[6] To mitigate this limitation, we accounted for marital status, household size, and number of children in all multivariate analyses. The timing of the survey, which was relatively early in the pandemic, April 2020, may be a limitation in this study as an increasing number of households may experience food insecurity as the pandemic continues. In addition, dietary restriction status was determined by respondent self-reporting a medical diagnosis. Self-report of a medical diagnosis may over- or underestimate the true prevalence of these conditions.[58] Because we are considering household-level estimates rather than individual-level estimates, we anticipated that our estimates would be higher than previously reported individual-level estimates for the average U.S. adult.[15,16,59] Our study may be limited by sample size, in particular for analyses with smaller subgroups; the overall study was designed to ensure reasonably precise estimates in subgroups of interest for the primary objectives of the National Women's COVID Health Study (ie, racial/ethnic groups).[28] However, in a *post hoc* analysis calculating the minimally detectable difference between those with no food restriction and those with both FA and CeD (our smallest comparison group), given that 35% of the sample with no food restrictions were food insecure, we were powered to detect a difference in proportion of food insecurity between groups of 14% (power = 0.80, alpha = 0.05). Similarly, for the subgroup of the sample with CeD (5.4%), we calculate a minimally detectable difference between households with no food restrictions and those with CeD of 12%. All analyses are weighted based on age, race, education, income, and region to reduce the effects of selection bias in the sample. We also did not collect data on the type or number of household food allergies, which might modulate food accessibility or financial burden of the restriction.[60]

In summary, we have demonstrated that households with dietary restrictions were more susceptible to both pre-pandemic food insecurity and pandemic-related new or worsening food insecurity when compared with households without restrictions. This study has important policy implications regarding how best to minimize the impact of the COVID-19 pandemic and create equitable food assistance programs. Our study also underscores the importance of addressing food insecurity among patients with FA and CeD, as the economic burden of an allergen/gluten-free diet may be underestimated.

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TABLE E1. Sociodemographic, household, and self-rated health characteristics for the unweighted and weighted samples

Characteristic	Unweighted sample N = 2577		Weighted sample N = 2577
	N	**%**	**%**
Race/ethnicity			
White	1914	60.9	62.3
Black	398	12.7	10.6
Hispanic	394	12.5	13.9
Other	436	13.9	10.3
Education level			
High school or less	1188	37.8	37.2
More than high school	1954	62.2	62.8
Household income			
<25K	745	23.7	19.6
25K-49K	1010	32.2	21.3
50K-99K	959	30.5	30.0
≥100K	428	13.6	29.1
Marital status			
Married/partnered	1827	58.2	62.2
Single	1312	41.8	37.8
Household size			
Lives alone	545	17.4	15.5
Self + 1	1039	33.2	34.5
Self + 2 or more	1547	49.4	50.0
No. of household children			
0 children	1367	53.3	55.6
1 child	570	22.2	20.3
2 or more children	630	24.5	24.1
Region			
Midwest	699	22.3	20.7
Northeast	626	19.9	17.1
South	1258	40.0	38.3
West	559	17.8	23.9
Self-rated general health			
Excellent or very good	1282	40.9	43.3
Good	1218	38.9	37.5
Fair or poor	635	20.3	19.3
Self-rated mental health			
Excellent or very good	1490	47.6	50.9
Good	1006	32.1	30.1
Fair or poor	635	20.3	19.0

TABLE E2. Full models predicting odds of pre-pandemic food insecurity

Characteristic	Household dietary restriction		
	FA aOR (95% CI)	**CeD** aOR (95% CI)	**Both FA and CeD** aOR (95% CI)
Household dietary restriction status			
No restriction	[Ref]	[Ref]	[Ref]
Restriction	1.5 (1.2-1.9)	2.3 (1.4-3.5)	2.1 (1.2-3.6)
Race/ethnicity			
White	[Ref]	[Ref]	[Ref]
Black	1.6 (1.2-2.2)	1.7 (1.3-2.3)	1.6 (1.2-2.2)
Hispanic	1.6 (1.2-2.1)	1.4 (1.0-1.9)	1.3 (1.0-1.8)
Other	1.5 (1.1-2.0)	1.6 (1.1-2.2)	1.5 (1.1-2.1)
Education level			
High school or less	[Ref]	[Ref]	[Ref]
More than high school	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.8 (0.7-0.9)
Household income			
<25K	6.6 (4.6-9.3)	7.1 (4.9-10.5)	7.2 (4.9-10.6)
25K-49K	3.4 (2.5-4.7)	3.6 (2.5-5.0)	3.4 (2.4-4.9)
50K-99K	2.4 (1.7-3.3)	2.5 (1.8-3.6)	2.5 (1.8-3.5)
≥100K	[Ref]	[Ref]	[Ref]
Marital status			
Married/partnered	[Ref]	[Ref]	[Ref]
Single	1.0 (0.8-1.2)	1.0 (0.8-1.2)	1.0 (0.8-1.2)
Household size	1.1 (1.0-1.2)	1.1 (1.0-1.2)	1.1 (1.0-1.2)
No. of household children	1.2 (1.0-1.3)	1.2 (1.0-1.4)	1.2 (1.0-1.4)
Region			
Midwest	[Ref]	[Ref]	[Ref]
Northeast	1.4 (1.0-1.8)	1.3 (1.0-1.7)	1.3 (1.0-1.7)
South	1.4 (1.1-1.8)	1.5 (1.2-1.9)	1.5 (1.2-1.9)
West	1.7 (1.3-2.3)	1.9 (1.4-2.6)	1.9 (1.4-2.6)
Self-rated general health			
Excellent or very good	[Ref]	[Ref]	[Ref]
Good	1.1 (0.9-1.4)	1.1 (0.8-1.3)	1.1 (0.8-1.3)
Fair or poor	1.3 (1.0-1.8)	1.2 (0.9-1.6)	1.2 (0.9-1.6)
Self-rated mental health			
Excellent or very good	[Ref]	[Ref]	[Ref]
Good	1.1 (0.9-1.4)	1.1 (0.9-1.4)	1.1 (0.9-1.4)
Fair or poor	1.6 (1.3-2.2)	1.7 (1.3-2.3)	1.7 (1.2-2.2)

aOR, Adjusted odds ratio; *CeD*, celiac disease; *CI*, confidence interval; *FA*, food allergy.

TABLE E3. Full models predicting odds of pandemic-related incident or worsening food insecurity

	Household dietary restriction		
	FA	CeD	Both FA and CeD
Characteristic	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Household dietary restriction status			
No restriction	[Ref]	[Ref]	[Ref]
Restriction	1.6 (1.3-2.1)	2.3 (1.5-3.5)	2.0 (1.2-3.4)
Race/ethnicity			
White	[Ref]	[Ref]	[Ref]
Black	1.1 (0.8-1.5)	1.1 (0.8-1.5)	1.1 (0.8-1.5)
Hispanic	1.4 (1.1-1.8)	1.2 (0.9-1.6)	1.2 (0.9-1.6)
Other	1.4 (1.1-1.9)	1.4 (1.0-1.9)	1.3 (1.0-1.8)
Education level			
High school or less	[Ref]	[Ref]	[Ref]
More than high school	0.9 (0.8-1.0)	0.9 (0.8-1.0)	1.0 (0.9-1.1)
Household income			
<25K	1.8 (1.3-2.5)	2.0 (1.5-2.9)	2.1 (1.4-2.9)
25K-49K	1.8 (1.4-2.4)	2.1 (1.5-2.8)	2.0 (1.5-2.8)
50K-99K	1.2 (0.9-1.5)	1.3 (1.0-1.7)	1.3 (0.9-1.7)
≥100K	[Ref]	[Ref]	[Ref]
Marital status			
Married/partnered	[Ref]	[Ref]	[Ref]
Single	1.0 (0.9-1.3)	1.0 (0.8-1.2)	1.0 (0.8-1.2)
Household size	1.0 (0.9-1.1)	1.1 (1.0-1.2)	1.1 (1.0-1.2)
No. of household children	1.2 (1.0-1.3)	1.2 (1.0-1.3)	1.2 (1.0-1.3)
Region			
Midwest	[Ref]	[Ref]	[Ref]
Northeast	1.4 (1.1-1.9)	1.4 (1.1-1.9)	1.5 (1.1-2.0)
South	1.3 (1.0-1.6)	1.4 (1.1-1.7)	1.3 (1.0-1.7)
West	1.2 (0.9-1.6)	1.3 (1.0-1.8)	1.3 (1.0-1.8)
Self-rated general health			
Excellent or very good	[Ref]	[Ref]	[Ref]
Good	1.1 (0.9-1.4)	1.1 (0.9-1.4)	1.1 (0.9-1.4)
Fair or poor	1.4 (1.0-1.8)	1.5 (1.1-1.9)	1.5 (1.1-2.0)
Self-rated mental health			
Excellent or very good	[Ref]	[Ref]	[Ref]
Good	1.1 (1.0-1.5)	1.2 (0.9-1.5)	1.2 (0.9-1.5)
Fair or poor	2.0 (1.5-2.5)	2.0 (1.5-2.7)	2.0 (1.5-2.7)

aOR, Adjusted odds ratio; *CeD*, celiac disease; *CI*, confidence interval; *FA*, food allergy.