

## ORIGINAL ARTICLE

## Gastroenterology: Celiac Disease

# Food insecurity impacts diet quality and adherence to the gluten-free diet in youth with celiac disease

Xinyi Wang<sup>1</sup> | Sven Anders<sup>2</sup> | Zhiqian Jiang<sup>1</sup> | Marcia Bruce<sup>3</sup> |  
Dominica Gidrewicz<sup>4</sup> | Margaret Marcon<sup>5</sup> | Justine M. Turner<sup>1,6</sup> |  
Diana R. Mager<sup>1,6</sup> 

<sup>1</sup>Department of Agricultural, Food and Nutritional Sciences, University of Alberta, Edmonton, Canada

<sup>2</sup>Department of Resource Economics and Environmental Sociology, University of Alberta, Edmonton, Canada

<sup>3</sup>Department of Medicine, University of Calgary, Calgary, Canada

<sup>4</sup>Division of Pediatric Gastroenterology and Nutrition, University of Calgary, Calgary, Canada

<sup>5</sup>Department of Gastroenterology, Hepatology and Nutrition, The Hospital for Sick Children, Toronto, Canada

<sup>6</sup>Department of Pediatrics, University of Alberta, Edmonton, Canada

**Correspondence**

Diana R. Mager, Department of Agricultural, Food & Nutritional Sciences, Clinical Nutrition, 2-021D Li Ka Shing Centre for Research Innovation, Clinical Research Unit, University of Alberta, Edmonton, AB, Canada, T6G 0K2. Email: [mager@ualberta.ca](mailto:mager@ualberta.ca)

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**Abstract**

**Objectives:** Celiac disease (CD) is an autoimmune gastrointestinal disorder that requires a strict lifelong gluten-free diet (GFD). Gluten-free (GF) foods are more expensive and less readily accessible than gluten-containing foods, contributing to an increased risk for food insecurity (FI). The study aimed to determine associations between GF-FI, sociodemographic risk factors and child dietary adherence and diet quality (DQ).

**Methods:** A 26-item, cross-country online survey was administered through social media to parents of children with CD on the GFD. The survey elicited household and CD child sociodemographic and clinical characteristics (e.g., duration of CD), measures of household FI, child DQ and GFD adherence, and parents' concerns related to GF food. Household GF-FI was evaluated using the validated Hunger Vital Sign™ and the US Department of Agriculture Six-Item Short Form Household Food Security Survey Module.

**Results:** GF-FI occurred in 47% of households with children with CD with >30% reporting low to very low food security. Sociodemographic risk factors identified included lower income, renters, rural residency, single-parental households, and having children with additional dietary restrictions ( $p < 0.001$ ). Regardless of FI status, a majority of households reported experiencing significantly higher GF food expenditure. GF-FI was associated with reduced adherence to the GFD, increased consumption of processed GF food, and lower intakes of fresh fruits and vegetables and GF grains among children with CD ( $p < 0.05$ ).

**Conclusions:** GF-FI is prevalent in this multiethnic cohort of households with CD children and is associated with worsening DQ and GFD adherence. Policy interventions are urgently needed to address GF-FI.

**KEYWORDS**

food security, gluten-free food, pediatric

**Abbreviations:** CD, celiac disease; CI, confidence interval; DQ, dietary quality; F/V, fruits and vegetables; FI, food insecurity/food insecure; FS, food secure; GF, gluten-free; GFD, gluten-free diet; GF-FI, gluten-free food insecurity; HFSSM, Household Food Security Survey Module; Low FS, low food security; Marginal FS, marginal food security; OR, odds ratio; US, United States; USDA, United States Department of Agriculture; Very low FS, very low food security.

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## 1 | INTRODUCTION

Celiac disease (CD) is an autoimmune gastrointestinal disease that leads to damage in the small intestine triggered by the ingestion of gluten, a protein found in wheat, rye, and barley.<sup>1</sup> CD is estimated to occur in 1 in 100 people worldwide and its global occurrence has increased dramatically over the past few decades.<sup>2,3</sup> Life-long adherence to a gluten-free diet (GFD) is the mainstay of treatment for CD.<sup>4</sup> A major challenge associated with the GFD is the high cost of gluten-free (GF) foods.<sup>5,6</sup> Before the pandemic, GF foods were known to be on average more than 180% of the cost of gluten-containing foods, a factor that may contribute to increased risk for food insecurity (FI).<sup>6</sup> The interruptions in food supply chains, ongoing climate change, global conflicts, and the COVID-19 pandemic have all contributed to rising food costs (GF and gluten-containing food) over the past 3 years.<sup>7–10</sup>

FI is defined as the inability to access adequate, affordable and nutritious food due to financial constraints.<sup>11</sup> Almost one in five households (18%–20%) across Canada reported experiencing some level of FI in 2022.<sup>11</sup> This represented an increase of 312,000 food-insecure households compared to 2021, with half of them being households including children (<18 years).<sup>11</sup> FI could lead to a significant risk of suboptimal nutrient intake, adverse health consequences (e.g., delayed growth and development) and reduced adherence to the GFD in youth with CD.<sup>12,13</sup>

A recent pediatric study in CD showed that 19%–24% of US households with children with CD experienced FI.<sup>14</sup> Approximately 7.5% of families reported gluten consumption in the affected child caused by the limited availability of GF food.<sup>14</sup> Currently, there is no data available about GF-FI in Canadian households with children with CD, the potential underlying sociodemographic determinants and the potential impact of FI on the affected child's diet quality (DQ) and dietary adherence to the GFD. Identification of the mechanisms contributing to household GF-FI and understanding the impact of GF-FI on child dietary adherence and DQ is important to prevent adverse health sequelae and to inform effective policy interventions to address this serious issue.

The study aimed to determine the prevalence and relevant household-level determinants of GF-FI in a multiethnic cohort of Canadian households with children with CD, and the associations with child dietary adherence and changes in DQ on the GFD. We hypothesized that household GF-FI would be highly prevalent and associated with sociodemographic household predictors of FI (e.g., income, homeownership, number of household members with CD). We further hypothesized that GF-FI would be associated with decreased GFD adherence and DQ in affected CD youth living in FI households.

### What Is Known

- Household food insecurity is an important social determinant of health in Canada, contributing to adverse health outcomes and high healthcare expenditure.
- Children with celiac disease have to adopt a strict life-long gluten-free diet.
- Many gluten-free food products are more expensive than their gluten-containing counterparts.

### What Is New

- The prevalence of gluten-free food insecurity in a multiethnic cohort of Canadian households with children with celiac disease is approximately two to three times higher than the national average.
- Gluten-free food insecurity is associated with adverse dietary quality and reduced adherence to gluten-free diets in children and youth with celiac disease.
- Parents of children with celiac disease adopt compensatory strategies to address gluten-free food insecurity.

## 2 | METHODS

A bilingual (English, French) online survey was administered (October 2023–April 2024) via Redcap<sup>®</sup> to Canadian households with youth (2–18 years) with CD on the GFD. Respondents living outside of Canada or parents of children <2 years or not on the GFD were excluded. Participants were recruited with the use of study fliers disseminated through social media platforms (e.g., Instagram and Facebook) run by Celiac Canada (local, national chapters) and celiac community groups (e.g., community CD-focused Facebook pages). Research ethics approval was obtained from the Human Research Ethics Board (Pro00126345) at the University of Alberta before study commencement.

Primary outcomes included the prevalence of GF-FI in a multiethnic cohort and household sociodemographic factors influencing GF-FI prevalence. Secondary outcomes included the associations of household GF-FI with child dietary adherence to the GFD and DQ, as well as parental perceptions regarding the barriers and facilitators of household GF-FI.

### 2.1 | Survey instrument

The 26-item survey contained 25 close-ended questions related to household sociodemographic (province/territory,

geographical residence by population size, self-identified ethnicity, dual vs. single parental household, household annual income, and homeownership), CD children's clinical characteristics (age, duration of CD, other specialized diets in addition to the GFD, and the number of family members in the household who have CD and follow the GFD), household GF-FI, household food expenditures related to the GFD, parental perception of child's GFD adherence, and DQ. One open-ended question was included for respondents to address any concerns related to FI, GFD adherence, and DQ. Survey content was vetted for face and content validity by experts in the field.

Household GF-FI status was assessed through the validated Hunger Vital Sign™ and the United States Department of Agriculture Six-Item Short Form of the Household Food Security Survey Module (HFSSM).<sup>14–16</sup> Both questionnaires were adapted to assess GF-FI risk by incorporating “GF food” in each question. GF-FI was initially determined and classified into food secure (FS) or FI based on the Hunger Vital Sign™.<sup>16</sup> Households were further categorized into four groups by their FI level according to the six-item HFSSM: (i) *High Food Security* (High FS) with no reported indications of GF food-access problems or limitations: households with raw scores of 0; (ii) *Marginal Food Security* (Marginal FS) indicating anxiety over GF food sufficiency or shortage of food in the house: households with raw scores of 1–1.49; (iii) *Low Food Security* (Low FS) indicating reduced quality, variety, or desirability of diet with little or no indication of reduced GF food intake: households with raw scores of 1.5–4.49; and (iv) *Very Low Food Security* (Very low FS) with reports of multiple indications of disrupted eating patterns and reduced GF food intake households with raw scores of 4.5–6.<sup>15,17</sup>

Children's dietary adherence to the GFD was self-reported by parents as dichotomous variables (yes/no) (Supporting Information S1: Tables 1 and 3). In contrast, parents' perceptions regarding their child's DQ were screened for by asking questions about changes in children's consumption of fresh fruits and vegetables (F/V), prepackaged/processed GF foods and GF grains (Supporting Information S1: Tables 1 and 3). These are common nutritional concerns in children with CD consuming the GFD, with reductions of F/V in particular being associated with reduced DQ in children with CD.<sup>18–20</sup>

Open-ended comments were analyzed by manifest content analysis.<sup>21</sup> The 5A's of food security (i.e., availability, accessibility, adequacy, acceptability, and agency) were used to categorize different themes.<sup>22</sup> Accessibility specifically refers to physical access to adequate and acceptable foods. When new themes were identified from the data (e.g., affordability), then a new category was created. Two researchers coded the entire data set independently and a third researcher made the determining decision regarding coding if consensus was not achieved. Data were reviewed until no new themes were identified, indicating thematic saturation.

## 2.2 | Statistical analysis

Statistical analysis was performed using Statistical Analysis Software (SAS, Version 9.4; SAS Institute Inc.). Data were expressed as frequencies/proportions unless otherwise specified. Bivariate analysis was conducted to examine unadjusted comparisons of household sociodemographic and clinical characteristics between FS and FI households, with chi-square tests for categorical variables.<sup>23</sup> The Fisher exact test was used if the expected cell frequency was <5. Binary logistic regression was initially used to assess the association between FI levels and GFD adherence/DQ expressed as an unadjusted odds ratio (OR) with a 95% confidence interval (95% CI). Multivariable logistic regression models were then estimated to investigate these associations by separately accounting for potentially confounding covariates (i.e., household annual income, household geographical residence by population size, type of parental household, having other specialized diets in addition to the GFD) due to sample size limitations and the prevalence of zero observations in contingency tables, expressed as adjusted ORs with 95% CI. The multicollinearity of independent variables was evaluated using Spearman correlation coefficients ( $r=0.7$  as the threshold) (Supporting Information S1: Tables 2 and 4).<sup>24,25</sup>

The following thresholds were used to classify the effect size: small (OR: 1.68–3.47), medium (OR: 3.47–6.71), and large (OR > 6.71).<sup>26,27</sup>  $p < 0.05$  was considered as statistically significant. For open-ended questions coded by themes, the chi-square test was performed to determine potential differences by FI, sociodemographic and clinical CD characteristics. Logistic regression was also performed to investigate the associations between thematic content and GFD adherence/DQ.

## 3 | RESULTS

### 3.1 | Survey response rate

One thousand thirty-five individuals opened up the survey. Of these, 612 people gave consent (435 full responses and 177 partial survey responses). No significant differences in household sociodemographic characteristics were found between full survey responders and partial survey responders ( $p > 0.05$ ).

### 3.2 | Clinical and sociodemographic characteristics

Clinical and sociodemographic characteristics of participating Canadian households are presented in Table 1. The majority of households were dual-parental

**TABLE 1** Clinical and sociodemographic characteristics of Canadian households with children and youth with celiac disease by gluten-free food insecurity.<sup>a</sup>

Variable	Category	Total (N = 498) n (%)	Food secure (N = 265) n (%)	Food insecure (N = 233) n (%)	p Value <sup>b</sup>
Clinical characteristics					
Age of child with CD (years) (N = 474)	2–6	93 (19.6)	51 (19.8)	42 (19.4)	0.437
	7–12	215 (45.4)	123 (47.7)	92 (42.6)	
	13–18	166 (35.0)	84 (32.6)	82 (38.0)	
Child's duration of CD (years) (N = 494)	<2	188 (38.1)	106 (40.3)	82 (35.5)	0.272
	>2	306 (61.9)	157 (59.7)	149 (64.5)	
Other specialized diets in addition to the GFD (N = 494)	Yes	104 (21.1)	46 (17.5)	58 (25.1)	<b>0.038</b>
	No	390 (78.9)	217 (82.5)	173 (74.9)	
The specific type of specialized diets (N = 86)	Vegetarian	3 (3.5)	1 (2.8)	2 (4.0)	0.062
	Nut allergies	6 (7.0)	4 (11.1)	2 (4.0)	
	Lactose free	18 (20.9)	4 (11.1)	14 (28.0)	
	Dairy free	29 (33.7)	9 (25.0)	20 (40.0)	
	Other	20 (23.3)	11 (30.6)	9 (18.0)	
	Multiple allergies	10 (11.6)	7 (19.4)	3 (6.0)	
Family members in the household have CD and follow GFD (N = 495)	1–2 members	430 (86.9)	234 (88.6)	196 (84.8)	0.094
	3–4 members	48 (9.7)	19 (7.2)	29 (12.6)	
	Other	17 (3.4)	11 (4.2)	6 (2.6)	
Sociodemographic characteristics					
Province/territory (N = 498)	Alberta	178 (35.7)	94 (35.5)	84 (36.1)	0.976
	Ontario	80 (16.1)	44 (16.6)	36 (15.5)	
	British Columbia	70 (14.1)	38 (14.3)	32 (13.7)	
	Manitoba	44 (8.8)	22 (8.3)	22 (9.4)	
	Saskatchewan	29 (5.8)	17 (6.4)	12 (5.2)	
	New Brunswick	25 (5.0)	11 (4.2)	14 (6.0)	
	Quebec	23 (4.6)	13 (4.9)	10 (4.3)	
	Newfoundland	18 (3.6)	9 (3.4)	9 (3.9)	

TABLE 1 (Continued)

Variable	Category	Total (N = 498) n (%)	Food secure (N = 265) n (%)	Food insecure (N = 233) n (%)	p Value <sup>b</sup>
Household geographical residence by population size (N = 486)	Prince Edward Island	16 (3.2)	9 (3.4)	7 (3.0)	
	Nova Scotia	13 (2.6)	7 (2.6)	6 (2.6)	
	Northwest Territories	1 (0.2)	0 (0)	1 (0.4)	
	Nunavut	1 (0.2)	1 (0.4)	0 (0)	
	Yukon	0 (0)	0 (0)	0 (0)	
	<10,000	105 (21.6)	35 (13.4)	70 (31.3)	<0.001
Household annual income (\$CAD) (N = 464)	10,000–49,000	73 (15.0)	40 (15.3)	33 (14.7)	
	50,000–149,000	100 (20.6)	53 (20.2)	47 (21.0)	
	150,000–499,000	70 (14.4)	42 (16.0)	28 (12.5)	
	>500,000	138 (28.4)	92 (35.1)	46 (20.5)	
	Canadian	265 (53.6)	141 (53.4)	124 (53.9)	0.539
Cultural/ethnic ancestry <sup>c</sup> (N = 494)	British	82 (16.6)	41 (15.5)	41 (17.8)	
	European	75 (15.2)	46 (17.4)	29 (12.6)	
	First Nations, Métis and Inuit	29 (5.9)	12 (4.5)	17 (7.4)	
	Other	43 (8.7)	24 (9.1)	19 (8.3)	
	<\$30,000	18 (3.9)	3 (1.2)	15 (7.0)	<0.001
	\$30,000–\$49,999	25 (5.4)	4 (1.6)	21 (9.8)	
Type of parental household (N = 489)	\$50,000–\$99,000	117 (25.2)	24 (9.6)	93 (43.3)	
	\$100,000–\$250,000	279 (60.1)	199 (79.9)	80 (37.2)	
	>\$250,000	25 (5.4)	19 (7.6)	6 (2.8)	
	Dual parents	432 (88.0)	253 (95.8)	179 (78.9)	<0.001
	Single parent	57 (11.6)	10 (3.8)	47 (20.7)	
Homeownership (N = 340)	Other <sup>d</sup>	2 (0.4)	1 (0.4)	1 (0.4)	
	Own home	277 (81.5)	154 (91.1)	123 (71.9)	<0.001

(Continues)

TABLE 1 (Continued)

Variable	Category	Total (N = 498) n (%)	Food secure (N = 265) n (%)	Food insecure (N = 233) n (%)	p Value <sup>b</sup>
	Not own home	63 (18.5)	15 (8.9)	48 (28.1)	

Note: Data are presented as frequency or column percentage.

Abbreviations: CD, celiac disease; GFD, gluten-free diet.

<sup>a</sup>Gluten-free food insecurity was determined based on the responses from the Hunger Vital Sign™.

<sup>b</sup> $p < 0.05$  was considered as statistically significant. All statistically significant numbers are bolded.

<sup>c</sup>Cultural/ethnic ancestry is defined from Stats Canada (<https://www12.statcan.gc.ca/census-recensement/2006/ref/rp-guides/ethnic-ethnique-eng.cfm>). Canadian also includes French Canadian; British includes Irish, British, English, and Scottish; European includes Germany, Northern Europe, French, Dutch, Polish, and Ukrainian; Other includes South Asian, Israeli, Chilean, South American, Chinese, and others.

<sup>d</sup>Other refers to unspecified.

(88%,  $n = 432$ ), homeowners (82%,  $n = 277$ ), with an annual income between \$100,000 CAD and \$250,000 CAD (60%,  $n = 279$ ) and included representation from diverse cultural/ethnic ancestries (e.g., Canadian, First Nations, Indigenous & Metis, European, South Asian). Most children with CD were aged between 7 and 12 years (45%,  $n = 215$ ) with a CD diagnosis more than 2 years (62%,  $n = 306$ ). In addition to the GFD, 21% ( $n = 104$ ) had other specialized dietary restrictions such as dairy-free (34%,  $n = 29$ ). Most households (87%,  $n = 430$ ) had one to two family members with CD consuming the GFD. Household geographical residences were evenly distributed across different population sizes (urban, rural) with representations from all provinces/territories (except for Yukon).

### 3.3 | GF-FI and clinical/sociodemographic characteristics

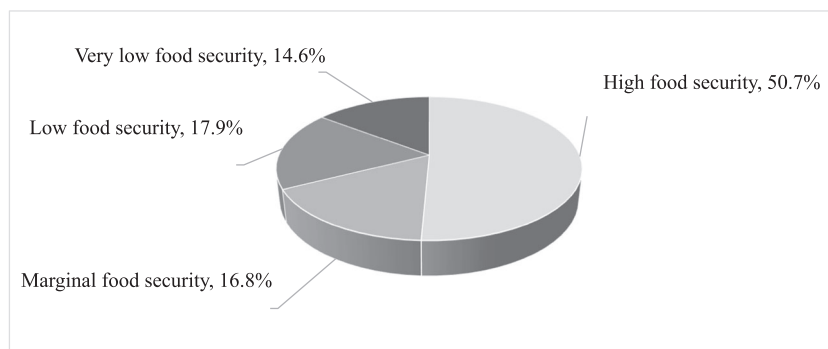
Approximately 47% ( $n = 233$ ) of households were screened positive for GF-FI with the remaining being FS (53%,  $n = 265$ ). Approximately half of the Canadian households with children and youth with CD in this multi-ethnic cohort were categorized as High FS (51%), with 17%, 18%, and 15% identified as Marginal FS, Low FS, and Very low FS, respectively (Figure 1). Regardless of FI status, 92% of households ( $n = 358$ ) reported significantly higher GF food prices over the past 12 months ( $p < 0.05$ ).

GF-FI households were predominantly located in rural areas (population size <10,000), with lower household income (CA\$ <100,000), single-parent households, and a lack of homeownership ( $p < 0.001$ ). Households with GF-FI were more likely to have children who followed other specialized diets (e.g., dairy-free) in addition to the GFD ( $p = 0.038$ ) (Table 1).

### 3.4 | Associations of GF-FI with adherence to the GFD and DQ

The associations between GF-FI status and GFD adherence/DQ in children and youth with CD are summarized in Table 2. As the severity of household GF-FI increased from Marginal FS to Very low FS, the odds of children with CD not adhering to the GFD increased substantially in comparison to those with High FS. This association remained the same for households with different severity of GF-FI when confounding variables were considered individually (i.e., household annual income, geographical residence by population size, single vs. dual parental household, and additional dietary restrictions).

The odds of altering the type of GF food (e.g., processed vs. unprocessed) was small for the Marginal FS group (OR 2.79, 95% CI 1.52, 5.10), but large for both Low FS (OR 4.34, 95% CI 2.39, 7.89) and Very low FS (OR 4.75, 95% CI 2.33, 9.67) groups. The odds



**FIGURE 1** The spectrum of gluten-free food security in a multiethnic cohort of Canadian households with children with celiac disease. Four categories were developed based on the Six-Item Short Form of the Household Food Security Survey Module (a) *High Food Security*: with no reported indications of food-access problems; (b) *Marginal Food Security*: indicating anxiety over food sufficiency in the house; (c) *Low Food Security*: indicating reduced quality, variety, or desirability of diet with little or no indication of reduced food intake; (d) *Very Low Food Security*: with reports of multiple indications of disrupted eating patterns and reduced food intake.<sup>15,17</sup>

of consuming fewer fresh fruits and vegetables were small, medium, and high for Marginal FS (OR 2.87, 95% CI 1.44, 5.73), Low FS (OR 4.38, 95% CI 2.33, 8.23), and Very low FS (OR 8.61, 95% CI 4.41, 16.81) groups, respectively. The odds of consuming fewer GF grains were small for both Marginal FS (OR 2.39, 95% CI 1.05, 5.46) and Low FS (OR 2.89, 1.35, 6.19) groups, but medium for the Very low FS group (OR 4.48, 95% CI 2.07, 9.66).

Considering confounding variables individually (household income, geographical residence by population size, single vs. dual parental and/or additional therapeutic dietary restrictions) did not change the associations of GF-FI status with the change in the type of GF food or increased consumption of processed GF food. However, its association with reduced consumption of GF grains was no longer significant for the Marginal FS group ( $p > 0.05$ ). By adjusting for household income only, the odds of reduced consumption of fresh fruits/vegetables and GF grains for the Very low FS group decreased, shifting from large (OR 8.61, 95% CI 4.41, 16.81) to medium (OR 5.97, 95% CI 2.77, 12.85) and from medium (OR 4.48, 95% CI 2.07, 9.66) to small (OR 2.48, 95% CI 1.04, 5.91), respectively.

### 3.5 | Parental concerns about GFD and compensatory strategies utilized

Seven categories were identified from parents of children and youth with CD (Table 3). GF food affordability (40%,  $n = 86$ ) and availability (19%,  $n = 43$ ) were two major concerns expressed by the parents regardless of GF-FI status. Both FS and FI households had challenges with GF accessibility, with more families living in remote or rural communities (69%) than urban communities (31%) ( $p = 0.046$ ). Parents who expressed concerns about GF availability (OR 3.36, 95% CI 1.51, 7.45) and GF accessibility (OR 4.50, 95% CI 1.42,

14.23) were more likely to have children who did not adhere to the GFD than parents who did not have these concerns ( $p < 0.05$ ). Approximately 12% of parents ( $n = 28$ ) also highlighted the types of compensatory strategies that parents utilized to address their primary concerns related to the high costs of GF foods. Strategies endorsed by parents included sacrificing their own food intake (3%,  $n = 6$ ) and budget adjustments, such as reduced funds allocated to entertainment and family activities (7%,  $n = 16$ ). These strategies were independent of household income, place of residency, single versus dual parent households or homeownership ( $p > 0.05$ ).

## 4 | DISCUSSION

This is the first study to determine the socio-demographic determinants of GF-FI among a multiethnic cohort of Canadian households with children with CD. Similar to other pediatric clinical populations,<sup>28,29</sup> the prevalence of GF-FI was 47% in this population, which was roughly two times greater than the reported national prevalence of household FI (18%–20%) with 33% experiencing low to very low FS.<sup>11</sup> Irrespective of GF-FI status, most households expressed their concerns about the high cost of GF food. Households with low annual income, rural residency, single-parental households, rental tenure, and children managing additional dietary restrictions alongside GFD were more likely to be GF-FI. Despite the majority of households with incomes well above the poverty level, approximately 43% of these households experienced GF-FI. GF-FI was approximately two times higher (84%) in households below the poverty line.<sup>30</sup> GF-FI was related to poor child DQ and decreased GFD adherence. To address challenges associated with GF food, parents developed compensatory strategies, including cutting back on their own dietary

intake, and/or reducing their DQ by consuming less nutritious and less expensive foods, and adjusting their budget in other areas of life such as reducing social activities and purchasing used clothes.

A recent study conducted in US households with children with CD has shown that 27% of households screened positive for GF-FI during the COVID-19 pandemic and roughly 5% of households who were

**TABLE 2** Unadjusted and adjusted associations between gluten-free food security status and dietary adherence to the gluten-free diet/diet quality<sup>a</sup> in children and youth with celiac disease.

	Marginal food security		Low food security		Very low food security	
	OR <sup>b</sup> (95% CI)	p Value	OR <sup>b</sup> (95% CI)	p Value	OR <sup>b</sup> (95% CI)	p Value
Dietary nonadherence to the gluten-free diet						
Crude model <sup>c</sup>	3.11 (1.39, 6.92)	<b>0.006</b>	5.38 (2.63, 11.00)	<b>&lt;0.0001</b>	11.69 (5.45, 25.08)	<b>&lt;0.0001</b>
Adjusted models						
Household income <sup>d</sup>	3.32 (1.45, 7.59)	<b>0.004</b>	5.17 (2.37, 11.27)	<b>&lt;0.0001</b>	8.23 (3.51, 19.30)	<b>&lt;0.0001</b>
Geographical residence <sup>e</sup>	3.31 (1.49, 7.36)	<b>0.003</b>	5.17 (2.52, 10.64)	<b>&lt;0.0001</b>	11.74 (5.43, 25.40)	<b>&lt;0.0001</b>
Dual/single parent <sup>f</sup>	2.97 (1.33, 6.62)	<b>0.008</b>	5.16 (2.51, 10.59)	<b>&lt;0.0001</b>	10.17 (4.67, 22.16)	<b>&lt;0.0001</b>
Additional dietary restriction <sup>g</sup>	3.18 (1.43, 7.06)	<b>0.004</b>	5.35 (2.62, 10.92)	<b>&lt;0.0001</b>	10.96 (5.12, 23.45)	<b>&lt;0.0001</b>
Change in the type of gluten-free food						
Crude model <sup>c</sup>	2.79 (1.52, 5.10)	<b>0.001</b>	4.34 (2.39, 7.89)	<b>&lt;0.0001</b>	4.75 (2.33, 9.67)	<b>&lt;0.0001</b>
Adjusted models						
Household income <sup>d</sup>	2.70 (1.44, 5.06)	<b>0.002</b>	3.53 (1.87, 6.66)	<b>&lt;0.0001</b>	3.41 (1.58, 7.38)	<b>0.002</b>
Geographical residence <sup>e</sup>	2.84 (1.53, 5.27)	<b>0.001</b>	4.24 (2.31, 7.78)	<b>&lt;0.0001</b>	5.29 (2.53, 11.05)	<b>&lt;0.0001</b>
Dual/single parent <sup>f</sup>	2.60 (1.41, 4.78)	<b>0.002</b>	4.28 (2.33, 7.86)	<b>&lt;0.0001</b>	4.23 (2.01, 8.88)	<b>0.0001</b>
Additional dietary restriction <sup>g</sup>	2.85 (1.55, 5.24)	<b>0.001</b>	4.28 (2.36, 7.78)	<b>&lt;0.0001</b>	4.47 (2.20, 9.08)	<b>&lt;0.0001</b>
More processed gluten-free food						
Crude model <sup>c</sup>	2.99 (1.67, 5.34)	<b>0.0002</b>	4.47 (2.56, 7.81)	<b>&lt;0.0001</b>	4.36 (2.37, 8.05)	<b>&lt;0.0001</b>
Adjusted models						
Household income <sup>d</sup>	3.23 (1.75, 5.95)	<b>0.0002</b>	5.14 (2.74, 9.67)	<b>&lt;0.0001</b>	4.35 (2.12, 8.90)	<b>&lt;0.0001</b>
Geographical residence <sup>e</sup>	3.05 (1.69, 5.52)	<b>0.0002</b>	4.36 (2.46, 7.72)	<b>&lt;0.0001</b>	4.28 (2.30, 7.99)	<b>&lt;0.0001</b>
Dual/single parent <sup>f</sup>	2.95 (1.64, 5.31)	<b>0.0003</b>	4.58 (2.60, 8.07)	<b>&lt;0.0001</b>	4.24 (2.23, 8.07)	<b>&lt;0.0001</b>
Additional dietary restriction <sup>g</sup>	3.01 (1.68, 5.39)	<b>0.0002</b>	4.40 (2.52, 7.69)	<b>&lt;0.0001</b>	4.22 (2.29, 7.79)	<b>&lt;0.0001</b>
Fewer fresh fruits and vegetables						
Crude model <sup>c</sup>	2.87 (1.44, 5.73)	<b>0.003</b>	4.38 (2.33, 8.23)	<b>&lt;0.0001</b>	8.61 (4.41, 16.81)	<b>&lt;0.0001</b>
Adjusted models						
Household income <sup>d</sup>	2.91 (1.41, 6.02)	<b>0.004</b>	3.61 (1.79, 7.32)	<b>0.0004</b>	5.97 (2.77, 12.85)	<b>&lt;0.0001</b>
Geographical residence <sup>e</sup>	2.93 (1.45, 5.93)	<b>0.003</b>	4.94 (2.59, 9.43)	<b>&lt;0.0001</b>	8.65 (4.36, 17.16)	<b>&lt;0.0001</b>
Dual/single parent <sup>f</sup>	2.56 (1.27, 5.16)	<b>0.009</b>	4.25 (2.25, 8.03)	<b>&lt;0.0001</b>	6.92 (3.45, 13.87)	<b>&lt;0.0001</b>
Additional dietary restriction <sup>g</sup>	2.91 (1.46, 5.78)	<b>0.002</b>	4.31 (2.30, 8.08)	<b>&lt;0.0001</b>	8.25 (4.23, 16.10)	<b>&lt;0.0001</b>
Fewer gluten-free grains						
Crude model <sup>c</sup>	2.39 (1.05, 5.46)	<b>0.038</b>	2.89 (1.35, 6.19)	<b>0.006</b>	4.48 (2.07, 9.66)	<b>0.0001</b>
Adjusted models						
Household income <sup>d</sup>	2.09 (0.91, 4.79)	0.083	1.87 (0.82, 4.24)	0.136	2.48 (1.04, 5.91)	<b>0.041</b>
Geographical residence <sup>e</sup>	1.99 (0.85, 4.72)	0.114	2.93 (1.37, 6.27)	<b>0.005</b>	4.28 (1.99, 9.24)	<b>0.0002</b>



**TABLE 2** (Continued)

	Marginal food security		Low food security		Very low food security	
	OR <sup>b</sup> (95% CI)	<i>p</i> Value	OR <sup>b</sup> (95% CI)	<i>p</i> Value	OR <sup>b</sup> (95% CI)	<i>p</i> Value
Dual/single parent <sup>f</sup>	2.27 (1.00, 5.18)	0.051	2.50 (1.15, 5.43)	<b>0.021</b>	3.48 (1.55, 7.80)	<b>0.003</b>
Additional dietary restriction <sup>g</sup>	2.50 (1.10, 5.67)	<b>0.028</b>	2.87 (1.35, 6.11)	<b>0.006</b>	4.26 (1.98, 9.16)	<b>0.0002</b>

Note:  $p < 0.05$  was considered as statistically significant, which are bolded.

Abbreviations: 95% CI, 95% confidence interval; GF, gluten-free; OR, odds ratio.

<sup>a</sup>Diet quality was screened by changes in the type of GF food and the consumption of processed GF food, fresh fruits and vegetables, and GF grains.

<sup>b</sup>All ORs are in reference to the "High Food Security" group. Households were categorized into four groups based on the Six-Item Household Food Security Survey Module: *High Food Security*, *Marginal Food Security*, *Low Food Security*, and *Very Low Food Security*.

<sup>c</sup>No adjustments.

<sup>d</sup>Adjusted for income.

<sup>e</sup>Adjusted for geographical residence by population size.

<sup>f</sup>Adjusted for type of parental household.

<sup>g</sup>Adjusted for additional dietary restrictions.

**TABLE 3** Thematic analysis of parental perceptions of characteristics contributing to gluten-free food insecurity.

Themes	Quotes from parents of children with celiac disease
Affordability <sup>a</sup> ( $n = 86$ , 37.6%)	The cost is just outrageous to allow the kids to enjoy what they should be able to. It's hard just to keep fresh fruit/veggies as that cost has also skyrocketed.
Availability <sup>b</sup> ( $n = 43$ , 18.8%)	The lack of products has been our biggest issue. Many products that we considered staples are no longer available.
Adequacy <sup>c</sup> ( $n = 25$ , 10.9%)	... and staff at these places are not knowledgeable about Celiac or cross-contamination. This has resulted in accidental ingestion of gluten ...
Accessibility <sup>d</sup> ( $n = 17$ , 7.4%)	There are fewer GF options in our community (Inuvik) and because we are a remote community, we wait 3-plus weeks for food to be mailed to us and/or the shipping costs are prohibitive.
Agency <sup>e</sup> ( $n = 17$ , 7.4%)	CD NEEDS to be recognized by the Canadian government as a disability AND there need to be caps on what can be charged for the special diet ... It is nearly impossible to calculate the difference on income taxes and Canada needs to follow suit and make it an easier process like other countries in Europe for example.
Variety ( $n = 13$ , 5.7%)	Not enough GF food choices. It's harder to find some GF products like flour. I wish there were more options for GF food.
Compensatory strategy ( $n = 28$ , 12.2%)	We always made GF food a priority. Other areas of our lives, we went without or decreased our usage so we could buy the food (e.g., drove less, less travel, fewer activities/lessons, used clothing, etc). I (as a parent) have often skipped meals or eaten less healthy/filling meals to ensure my children can eat what they need.

Note: Data are presented as frequency ( $n$ ) or percentage (%). The following definition was employed (<https://www.torontomu.ca/foodsecurity/unlesspecified>): One hundred thirty-four participants left open-ended comments.

Abbreviations: CD, celiac disease; GF, gluten-free.

<sup>a</sup>Affordability: The ability to afford food at all times.

<sup>b</sup>Availability: Sufficient supply of food for all people at all times.

<sup>c</sup>Adequacy: Access to food that is nutritious and safe, and produced in an environmentally sustainable way.

<sup>d</sup>Accessibility: Physical and social access to food for all people at all times.

<sup>e</sup>Agency: The policies and processes that enable the achievement of food security.

FS reported GF-FI.<sup>14</sup> Another panel-based survey focusing on US women with dietary restrictions and/or CD has indicated that 56% of households with CD had FI.<sup>31</sup> Risk factors for FI in these studies included household poverty, rural residency, younger population, non-White, and poorly educated.<sup>14,31,32</sup>

Household income is a robust predictor of FI.<sup>11</sup> The risk of experiencing FI declines as household income

increases. A national sample of US households with food allergies has shown that households with higher household income (USD \$65,000) were less likely to experience FI ( $p < 0.0001$ ). This income level was comparable to the median household income in our study (CAD\$89,000). Although the cost of GF food products declined from 240% to 183% over the past 10 years, it was still significantly higher than the gluten-

containing counterparts which added an extra layer of financial hardship for households with CD, especially for those with lower income.<sup>6</sup>

Housing status is another critical determinant of FI among households with children, including children with CD.<sup>11,33</sup> Owning a house is an important financial asset and source of debts in Canada, particularly amid the prevailing housing crisis, precipitated by surging house prices and decreased government subsidies for the construction of affordable rental housing.<sup>34–36</sup> Homeownership confers some protection against FI which is consistent with our study findings.<sup>33</sup> This study confirmed that single-parent households were more likely to experience FI compared to dual-parent households.<sup>37</sup> This finding was also supported by the analysis of adolescents who completed the 2017–2018 Canadian Community Health Survey reporting that the high rate of FI occurred more frequently among adolescents who were not living with two parents.<sup>38</sup> Rural residency was also an important sociodemographic risk factor for GF-FI potentially related to the relatively higher GF food costs and lower availability of GF food staples in rural compared to urban areas.<sup>39</sup>

Consistent with previous studies, children living in GF-FI households had higher odds of nonadherence to GFD (i.e., gluten ingestion) compared to those with GF-FS.<sup>14,32,40</sup> The DQ of children with CD deteriorated as the severity of household GF-FI increased as indicated by increased consumption of processed GF food and decreased consumption of fresh fruits and vegetables and GF grains. Similarly, Ma et al. have shown that people living in FI households have poor dietary consumption of macronutrients and micronutrients and reduced caloric intake.<sup>32</sup> Many parents of children with CD developed compensatory strategies and behaviors to combat GF-FI related to the high cost and low availability of GF food, poor dietary quality, and unsafe consumption of gluten-containing food. Adherence to the GFD is essential not only for promoting the repair of intestinal damage and mitigating symptoms but also for preventing clinical complications. It was alarming that parents advocating for their children to adhere to GFD were limiting their own food consumption and utilizing entire household financial resources to pay for GFD.

While a tax reduction for GF products has been implemented in Canada and the United States,<sup>41</sup> the prevalence of GF-FI among households with children with CD is still substantial. Existing tax credits may not provide sufficient financial relief on GF food expenditures to individuals with CD, especially those with lower incomes below the taxable threshold in Canada who are at higher risk of GF-FI.<sup>41</sup> This tax rebate only offers retroactive refunds of the previous year's incremental household expenditures in the form of reimbursement rather than assisting with the direct, high cost of GF foods in a timely manner.<sup>41</sup> The parental

burden associated with the calculation of incremental cost differences of GF foods in the marketplace needed to obtain any reimbursement, was a major barrier cited by parents. The current Canadian regulation around GF foods is viewed to pose a substantial financial hurdle for CD households, especially for those who experience financial difficulties affording the GFD overall. While federal nutrition programs in the United States such as the Supplemental Nutrition Assistance Program, the Special Supplemental Nutrition Program for Women, Infants, and Children, and the National School Lunch Program provide direct dietary assistance for eligible individuals, the financial needs associated with GF foods are not explicitly addressed in these programs.<sup>42</sup> Strengthening current federal nutrition programs, extending disability benefits and broadening health insurance coverage (e.g., GF food as prescribed drugs) for individuals with CD is warranted.<sup>32,41</sup>

Study limitations inherent in survey design included the potential for recall and selection bias related to convenience sampling. This was mitigated by using multiple social media channels to disseminate the survey in both national languages (English and French) to all regions in Canada, which resulted in responses from a multiethnic cohort of parents with children with CD. While sociodemographic and clinical factors such as the current age of the affected child, other dietary restrictions, and the number of household members with CD are known to influence child adherence to the GFD, the survey did not address other potential influencing factors (e.g., GI symptoms). This was done to minimize respondent burden. Absolute changes in DQ were not included in the survey design, but rather screening questions related to major determinants of DQ in children with CD (e.g., fresh fruit and vegetable and process/prepackaged GF-food intake) were included.<sup>18–20</sup> Hence, the potential for parental misclassification of processed GF foods may have influenced study findings, but this risk might be low due to high parental nutrition literacy in this population.<sup>18</sup> Although not powered to determine parental perspectives and compensatory strategies used to combat household GF-FI, the higher response rate for open-ended questions enabled a comprehensive evaluation of parental perspectives regarding the challenges associated with the GFD.

While causality between household GF-FI status, and GFD adherence and DQ cannot be established, findings support that the high prevalence of GF-FI in households with children with CD in this multiethnic cohort may negatively impact overall DQ and adherence to the GFD. Ongoing evaluation of the GF-food environment and other factors influencing accessibility, affordability, and adequacy of the GFD is critical to the formation of effective policies to address these important issues. These findings highlight the pressing need

for policy generation to address the affordability and availability of GF food to support this vulnerable population in achieving optimal health outcomes as the GFD is the only treatment for CD.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

## ORCID

Diana R. Mager  <http://orcid.org/0000-0002-5558-8783>

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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