



COVID-19 and Food-Related Outcomes in Children with Autism Spectrum Disorder: Disparities by Income and Food Security Status

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ABSTRACT

Background: Limited research suggests increased adverse behavioral outcomes, such as distractibility and hyperactivity, among children with autism spectrum disorder (ASD) as a result of coronavirus 2019 (COVID-19); however, little is known about how the pandemic has impacted food-related behaviors among children with ASD.

Objective: This study characterizes the impact of the pandemic on access to preferred foods and eating behaviors among children with ASD.

Methods: Caregiver proxies ($n = 200$) participated in a cross-sectional, online survey investigating the impact of COVID-19 on reported food and eating behaviors of children, ages 2–17 y. Logistic regression models were used to assess the magnitude of association of a change in the child's eating behaviors and in food availability, overall and by household income and food security status.

Results: A majority of respondents reported a moderate-to-large impact on their child's eating behaviors (57%) since the onset of COVID-19, and 65% reported unavailability of their child's preferred foods. Increased risk of a moderate-to-large impact on children's eating behaviors was associated with shelter regulations compared with no regulations (OR: 2.30; 95% CI: 1.12, 4.72), food insecurity compared with security status (OR: 2.60; 95% CI: 1.45, 4.67), and household income of <\$50,000 compared with \geq \$100,000 (OR: 2.33; 95% CI: 1.02, 5.29). The pandemic also amplified the risk of food unavailability by household food security status (food insecure vs. secure; OR: 4.13; 95% CI: 2.12, 7.69) and across income levels (<\$50,000 vs. \geq \$100,000; OR: 3.48; 95% CI: 1.42, 8.55; and \$50,000 to <\$100,000 vs. \geq \$100,000; OR: 4.00; 95% CI: 1.71, 9.34). Reported frequencies of consumption of meat, seafood, vegetables, and 100% fruit juice significantly decreased among the children post-onset of COVID-19, while frequency of consumption of sweets increased.

Conclusions: A large proportion of caregivers reported substantial COVID-19 impacts on food availability and eating behaviors of children with ASD, especially among low-resource dyads. This study highlights the added burden of existing disparities due to the pandemic on children living with ASD. *Curr Dev Nutr* 2021;5:nzab112.

Keywords: autism spectrum disorder, child, nutrition, feeding behavior, COVID-19, coronavirus, food supply, food security, low income

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Supplemental Tables 1–3 and the Supplemental Appendix are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at <https://academic.oup.com/cdn/>.

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Introduction

The coronavirus disease 2019 (COVID-19) pandemic has given rise to significant burdens on human health as a result of the virus and also of the restrictions put in place by governing bodies to promote reduced risk of transmission. Prior research on worldwide crises has illustrated that, compared with the general population, significantly greater impacts are experienced by people with psychiatric and mental health disorders (1). Those with autism spectrum disorder (ASD) represent a particularly vulnerable population. These individuals often prefer to follow structured routines with specific preferences, especially with foods and eating environments (2, 3). As minor disruptions may lead to increased

stress and anxiety for children with neurodevelopmental disorders (4, 5), it can only be expected that wide-scale shifts brought on by the pandemic will prove to be acutely disrupting (5, 6). However, there is currently a lack of focus on how the changes in food systems and environments are affecting children with ASD, especially in the United States.

ASD affects 1 in 54 children in the United States (7) and is characterized by impairments in social communication and interaction and repetitive behaviors (8). Children with ASD are highly selective in the types of foods they choose, and they consume a less varied diet, in large part due to sensitivities to taste, texture, smell, and appearance of foods (3, 9, 10). Many children also follow specific or restricted diets that further narrow their food options (11). Previous studies have reported a

correlation between limited variety in the diets of children with ASD with nutritional inadequacies (10, 12). Coupled with shortages of certain foods, these conditions can lead to detrimental changes in eating behaviors, such as increased food refusals, and can ultimately lead to poorer health and nutritional status.

Using a nationwide web-based survey, the goals of this study were 2-fold: 1) to describe the impacts of the COVID-19 pandemic on the food environment and eating behaviors of children with ASD and 2) to understand the potential role of sociodemographic, economic, or diet-related factors that may increase the risk of negative outcomes, specifically adverse eating behaviors and difficulty with food availability.

Methods

In this cross-sectional study, parents and caregivers ($n = 200$) across the United States participated in an online survey formulated specifically for understanding the impact of COVID-19 on food environments and eating behaviors of children with ASD. The proxy respondents (≥ 18 y) reported for their children aged 2–17 y with a (self-identified) ASD diagnosis. The survey was conducted during May through June of 2020 when “shelter-in-place” or “stay-at-home” orders were in effect in most states (13).

Survey items included caregiver-reported data at the household- or child-level, including demographics, socioeconomic status, impacts on food purchasing and food-preparation methods, height and weight, retrospectively obtained child’s food and diet characteristics, and retrospectively obtained impacts on the child’s physical activity, food intake, and eating behaviors (**Supplemental Appendix 1**). Recruitment was conducted online, mainly via advertising through social media channels, such as Facebook[®]. Participants provided consent prior to the collection of responses, and were not asked any personally identifying information. At the end of the survey, they were given the option to enter a raffle for 1 of 10 \$20 Amazon gift cards and were provided a separate link to enter their e-mail addresses. All materials were approved by the Purdue University Institutional Review Board (IRB-2020–646). No waivers were granted for human subjects and all protocols followed were approved. This study was not part of a larger clinical trial.

Statistical analysis

Descriptive characteristics were analyzed for dichotomous or ordinal-level data for the following: US region (Northeast, Midwest, South, and West); “shelter-in-place” or “stay-at-home” regulation/order at the time of survey response (yes/no); living with a spouse/partner (yes/no); number of children <18 y of age (n); respondent’s level of education and spouse/partner’s level of education (high school graduate or less, some college or associate degree, college degree, graduate degree or above); household income prior to regulations (<\$50,000, \$50,000 to <\$100,000, \geq \$100,000); loss of employment or reduced pay of either (or both) caregiver(s) (yes/no); household food insecurity (yes/no); sex of the child (male/female), age of the child (years), age of ASD diagnosis (years), race/Hispanic origin of the child (non-Hispanic White, non-Hispanic Black, Hispanic or Latino, mixed, or “other” race); child’s weight status (underweight, healthy weight, overweight, or obese); and child’s current educational setting (attending school in person, home-schooled, receiving virtual instruction, or not receiving any instruc-

tion; “not receiving instruction” included children who did have access but were not utilizing or engaging in this method of instruction). For weight status, reporter-estimated weight (pounds) and height (inches) for each child were converted to metric units and used to calculate BMI (kg/m^2). BMI percentiles were then used to categorize weight status as underweight (<5th percentile), healthy weight (5th to <85th percentile), overweight (85th to <95th percentile), or obese (\geq 95th percentile) according to the growth charts developed by the CDC for children 2–18 y of age (14).

Other self-reported descriptive characteristics included the following: food rigidity or specificity in the child’s food choices and patterns (yes, if moderately or very rigid; no, if not or slightly rigid) and special or restricted diets, including restrictions due to allergies (yes/no). Retrospective reports on changes in behavior included the following: level of the child’s physical activity (no change, more, or less), amount of the child’s overall food intake (no change, more, or less), impact on overall eating behaviors (none to small vs. moderate to large), frequency of ordering out for meals (no change, more, or less), frequency of cooking meals at home (no change, more, or less), and difficulty in finding foods the child usually eats (yes/no). We further retrospectively examined changes in frequency of consumption of different food groups prior to and post-COVID-19 regulations [$<1\times/\text{wk}$ (rarely), $\geq 1\times/\text{wk}$, $1\times/\text{d}$, $3\text{--}4\times/\text{d}$, $>4\times/\text{d}$].

Self-reported food security status was assessed based on a validated 2-question method; previous studies have demonstrated a sensitivity of 97% and a specificity of 83% against the USDA’s 18-item Household Food Security Survey (15–17). The 2 questions asked were 1) “Within the past 12 months we worried whether our food would run out before we got money to buy more” and 2) “Within the past 12 months the food we bought just didn’t last and we didn’t have money to get more.” Respondents were asked both questions retrospectively for their status prior to the onset of the pandemic as well as their current status (at the time of the survey) with the following options “never,” “sometimes,” or “often.” The household was considered food insecure if either of the questions were affirmative (“sometimes” or “often” vs. “never”).

Descriptive statistics were analyzed using t tests and chi-square tests, using Fisher’s exact tests where required. Multiple analysis of variance (MANOVA) test for repeated measures was used for comparing the frequency of consumption of different food groups. Logistic regression was used to model changes in eating behaviors and difficulty in finding foods the child usually eats. Models included household income level, food security status, shelter regulations, and loss of employment or reduced pay for the caregiver(s) as predictor variables. A final model included all of these predictors along with sex, age, and minority status of the child, as well as whether the family was receiving any food assistance. To improve the precision of our OR estimates, we used a bootstrap method with 10,000 replications for all models. This replication value was chosen by considering precision and computational demand (18, 19).

Results

Altogether, the survey was completed by 200 parents and caregivers across the United States (**Table 1**). Among the children, close to 76% were male, the mean age was 7.7 y (range: 2–18 y), and the majority were non-Hispanic White (62%). Just over half of respondents disclosed

TABLE 1 Parent and child characteristics by impact of COVID-19 regulations on the eating behaviors of children with ASD in the United States¹

	Total (n = 200)		Impact on eating behaviors		P
	Total n	n (%)	None to small (n = 84), n (%)	Moderate to large (n = 114), n (%)	
Parent characteristics					
US region	198				
Midwest		55 (27.8)	23 (27.4)	32 (28.1)	
Northeast		44 (22.2)	19 (22.6)	25 (21.9)	
South		54 (27.3)	24 (28.6)	30 (26.9)	
West		45 (22.7)	18 (21.4)	27 (23.7)	0.98
Shelter regulations ²	195				
Yes		151 (77.0)	58 (69.9)	112 (82.3)	
No		39 (19.9)	23 (27.7)	16 (14.2)	
Don't know		6 (3.1)	2 (2.4)	4 (3.5)	0.03
Respondent living with spouse/partner	199				
Yes		149 (74.9)	66 (77.7)	83 (72.8)	
No		50 (25.1)	19 (23.4)	31 (27.2)	0.44
Number of children <18 y living at home, mean (SD)	192	2.1 (1.0)	2.0 (0.9)	2.2 (1.0)	0.19
Respondent education ³	183				
High school graduate or less		17 (9.3)	8 (10)	9 (8.7)	
Some college/associate degree		70 (38.3)	25 (31.3)	45 (43.7)	
College degree		45 (24.6)	25 (31.3)	20 (19.4)	
Graduate degree or above		51 (27.9)	22 (27.5)	29 (28.2)	0.22
Spouse/partner education ³	133				
High school graduate or less		19 (14.3)	11 (18.6)	8 (10.8)	
Some college/associate degree		50 (37.6)	22 (37.3)	28 (37.8)	
College degree		30 (22.6)	10 (17.0)	20 (27.0)	
Graduate degree or above		34 (25.6)	16 (27.1)	18 (24.3)	0.39
Household income (pre-COVID)	163				
<\$50,000		74 (45.4)	25 (36.8)	49 (51.6)	
\$50,000 to <\$100,000		54 (33.1)	24 (35.3)	30 (31.6)	
≥\$100,000		35 (21.5)	19 (27.9)	16 (16.8)	0.11
Loss of employment/reduced pay of either caregiver (post-COVID) ⁴	144				
Yes		53 (36.8)	19 (30.7)	34 (41.5)	
No		91 (63.2)	43 (69.4)	48 (58.5)	0.18
Food insecurity (pre-COVID)	198				
Yes		108 (54.6)	40 (47.1)	68 (60.2)	
No		90 (45.4)	45 (52.9)	45 (39.8)	0.07
Food insecurity (post-COVID)	198				
Yes		118 (59.6)	39 (46.4)	79 (69.3)	
No		80 (40.4)	45 (53.6)	35 (30.7)	0.001
Child characteristics					
Sex	197				
Male		149 (75.6)	67 (78.8)	82 (73.2)	
Female		48 (24.4)	18 (21.2)	30 (26.8)	0.36
Age (y), mean (SD)	198	7.7 (4.1)	7.4 (4.1)	7.9 (4.1)	0.46
Age of diagnosis (y), mean (SD)	193	3.7 (2.4)	3.3 (2.2)	4.0 (2.5)	0.05
Race	195				
Non-Hispanic White		121 (62.5)	54 (65.9)	67 (59.3)	
Non-Hispanic Black		14 (7.2)	6 (7.3)	8 (7.1)	
Hispanic or Latino		27 (13.9)	11 (13.4)	16 (14.2)	
Mixed		19 (9.7)	6 (7.3)	13 (11.5)	
Other		14 (7.1)	5 (6.1)	9 (8.0)	0.84
Weight status	102				
Underweight		16 (15.7)	6 (13.3)	10 (17.5)	
Normal weight		43 (42.2)	19 (42.2)	24 (42.1)	
Overweight		16 (15.7)	7 (15.6)	9 (15.8)	
Obese		27 (26.5)	13 (28.9)	14 (24.6)	0.93

(Continued)

TABLE 1 (Continued)

	Total (n = 200)		Impact on eating behaviors		P
			None to small (n = 84), n (%)	Moderate to large (n = 114), n (%)	
	Total n	n (%)	n (%)	n (%)	
Educational setting ⁵	165				
Attending school in person		1 (0.6)	0 (0.0)	1 (1.0)	
Home-schooled		12 (7.3)	5 (7.5)	7 (7.1)	
Receiving virtual instruction		104 (63.0)	41 (61.2)	78 (64.3)	
Not receiving any instruction		48 (29.1)	11 (31.3)	38 (27.6)	0.91

¹ASD, autism spectrum disorder; COVID-19/COVID, coronavirus disease 2019; GED, general educational development. *P* values derived using chi-square or *t* tests, as appropriate, comparing impact on eating habits, none to small vs. moderate to large; Fisher's exact *P* value was used in place of chi-square for characteristics with cells ≤ 5 .

²*P* value for this variable excluded the "Don't know" category.

³High school graduate including GED or other equivalent.

⁴Loss of employment or reduced pay for the caregiver and/or their partner post-COVID-19; includes 1 respondent reporting postponement of job and 1 respondent reporting expiring work visa due to delays.

⁵Not receiving any instruction included children who did have access to virtual instruction but were not utilizing or engaging in this method of instruction. *P* value for this variable excluded the "attending school in person" category.

information on their child's height and weight: 16% fell into the underweight category while another 16% were classified as overweight, and 26% were classified as obese. Approximately 57% of participants reported a moderate-to-large impact of the pandemic and its associated regulations on the overall eating behaviors of their child. Over 82% reported having shelter regulations at the time of survey response compared with 70% who reported none to a small impact on their child's eating behaviors ($P = 0.03$). The mean age of ASD diagnosis was 3.7 y.

Over half the caregivers reported having an associate's or college degree or higher, and 45% reported a household income of <\$50,000 (Table 1). The median household income of the study population was in the range of \$50,000–\$60,000 (data not shown). Loss of employment was significantly associated with household income level ($P < 0.01$; Supplemental Table 1).

An increase of 9% in food insecurity was observed among the study population as a whole (Table 1). Moderate-to-large impacts on eating behaviors were significantly higher among food-insecure households upon the onset of COVID-19; however, this difference was marginal prior to COVID-19. Household food security status was also positively associated with household income level (Supplemental Table 1).

Almost all respondents reported some level of rigidity or specificity in their child's food choices or preferences, and greater levels of rigidity were significantly associated with a greater impact on eating behaviors (Table 2). While close to 80% of children were following a special or restricted diet, this characteristic was not associated with the pandemic's impact on eating behaviors. Retrospectively reported, the amount of overall food intake, frequency of consumption of various food groups, and energy expenditure were all impacted for most children upon the onset of COVID-19. A large majority of respondents reported either increased or decreased overall food intake. When compared with those who reported no change in overall food intake, a greater percentage of those reporting an altered amount reported moderate-to-large impacts on their child's eating behaviors. While a large percentage of caregivers reported decreased or increased levels of physical activity among their children as a result of the pandemic, alterations in the

level of physical activity were not associated with impact on eating behaviors.

Reported frequencies of consumption of meat, seafood, vegetables, and 100% fruit juice significantly decreased among the children, while the frequency of consumption significantly increased for sweets (Figure 1). We further examined changes in frequency of consumption of different food groups by overall amount of food intake and food security status (Supplemental Tables 2 and 3). There were significant differences in several groups by change in overall food intake, with frequency of meat, vegetable, and fruit consumption each showing a greater decrease among children who decreased overall intake compared with the percentages of increased intake among those with increased overall intake. In contrast, the percentage of those reporting an increase in the frequency of grain consumption among those with increased overall intake was similar to those who reported a decrease in both. Percentages for an increase in the frequency of consumption of grains were also similar across food security status, although the percentage for a decrease in frequency was greater among those in food-insecure households. Fat consumption frequency also increased among those in food-insecure households and a greater percentage of respondents reported both increased and decreased consumption of meat and sugar-sweetened beverages among food-insecure households compared with food-secure households. We analyzed consumption of the food groups by rigidity and special diet and the only significant difference was for the frequency of egg consumption by rigidity; a greater percentage of children whose caregivers reported as moderate to very rigid exhibited a decrease in the frequency of consumption of eggs (15.5%) compared with those who were not rigid (4.4%) and the opposite was true for an increase in frequency (6.5% vs. 17.8%, respectively; $P = 0.03$).

Methods for acquisition of foods for these families were also altered after COVID-19 regulations (Table 3). Difficulty finding preferred foods (65%) was positively associated with the magnitude of impact on eating behaviors (Table 3) and inversely associated with household income level (Supplemental Table 1). Among those reporting a moderate-to-large impact, a greater percentage of caregivers reported a decrease

TABLE 2 Food characteristics of children with ASD and change in food behaviors after the onset of COVID-19 regulations¹

	Total (n = 200)		Impact on eating behaviors		P
	Total n	n (%)	None to small (n = 84), n (%)	Moderate to large (n = 114), n (%)	
Food characteristics					
Food rigidity or specificity ²	198				
Very		79 (39.9)	28 (32.9)	51 (45.1)	
Moderately		63 (31.8)	23 (27.1)	40 (35.4)	
Slightly		45 (22.7)	26 (30.6)	19 (16.8)	
Not at all		11 (5.6)	8 (9.4)	3 (2.7)	0.013
Special or restricted diet ³	195				
Yes		153 (78.5)	65 (78.3)	88 (78.6)	
No		42 (21.5)	18 (21.7)	24 (21.4)	0.965
Changes post-onset of COVID-19					
Overall food intake	193				
Increased		81 (42.0)	30 (36.6)	51 (46.0)	
Decreased		70 (36.3)	17 (20.7)	53 (47.8)	
No change		42 (21.8)	35 (42.7)	7 (6.3)	<0.001
Level of physical activity	182				
Increased		38 (20.9)	15 (19.2)	23 (22.1)	
Decreased		99 (54.4)	38 (48.7)	61 (58.7)	
No change		45 (24.7)	25 (32.1)	20 (19.2)	0.139

¹Food characteristics and changes in outcomes were obtained retrospectively; P values derived using chi-square or t tests, as appropriate, comparing impact on eating habits, none to small vs. moderate to large; Fisher's exact P value was used in place of chi-square for characteristics with cells ≤5. ASD, autism spectrum disorder; COVID-19, coronavirus disease 2019.

²In food preferences or choices.

³Includes restrictions due to allergies.

in cooking frequency as well as an increase in the frequency of ordering out compared with those reporting no impact to a small impact.

When examining the impact of COVID-19 on children's eating behaviors using logistic regression, shelter regulations, household food security status, and household income were all significant predictors. Shelter regulations significantly contributed to adverse eating behaviors (OR: 2.30; 95% CI: 1.12, 4.72). Caregivers living in food-insecure households were more likely to report moderate-to-large changes in their child's eating behaviors when compared with families living in food-secure homes; however, this was only significant for food security status after the onset of the pandemic (OR_{pre}: 1.70; 95% CI: 0.96, 3.00; OR_{post}: 2.60; 95% CI: 1.45, 4.67; **Table 4**). Similarly, respondents living in households with incomes <\$50,000 were more likely to report a moderate-to-large impact on eating behaviors when compared with those with household incomes ≥\$100,000 (OR: 2.33; 95% CI: 1.02, 5.29). No predictors remained significant upon adjustment for potential confounders, although food insecurity displayed marginal significance (P = 0.06).

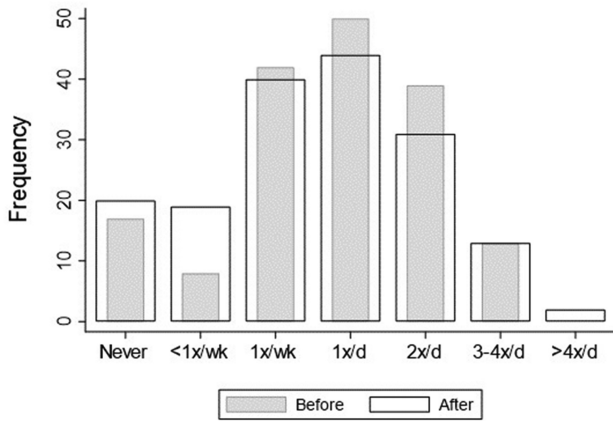
Analogously, families living in food-insecure households were significantly more likely to report having difficulty with food availability when compared with children living in food-secure homes; however, compared with pre-COVID-19, the effect was greater post-onset of COVID-19 (OR_{pre}: 2.27; 95% CI: 1.25, 4.13 vs. OR_{post}: 4.13; 95% CI: 2.12, 7.69). Similarly, families with household income levels of both <\$50,000 and \$50,000 to <\$100,000 were more likely to report having difficulty with food availability post-COVID-19 regulations when compared with those reporting a household income level ≥\$100,000 (OR: 3.48; 95% CI: 1.42, 8.55; and OR: 4.00; 95% CI: 1.71, 9.34, respectively). Food insecurity (post-onset) remained significant after adjusting for several covariates (OR: 7.19; 95% CI: 1.20, 42.98).

Discussion

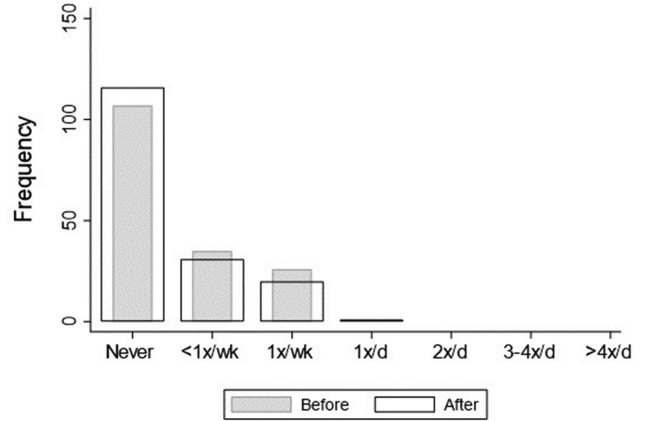
There is a lack of studies characterizing the needs of ASD families in the United States during COVID-19 specific to food environments and eating behaviors. Our survey findings shed light on the adverse effects of the current crisis on these outcomes. Prior to COVID-19, individuals with ASD were already at risk for inadequate nutritional intake and health outcomes, mainly due to greater food selectivity, lack of a diverse diet, and poor gut health (20). Our results suggest that COVID-19 has amplified these challenges, particularly among families with low household income and/or household food insecurity status. These findings, coupled with the known nutritional deficiencies present in some children with ASD prior to the pandemic, highlight the importance of monitoring the unique needs of this high-risk population and tailoring public health responses to lower-resource ASD families.

We previously published on the impacts of the pandemic on overall and specific behaviors of children with ASD (21). Here we present initial evidence of food-related challenges encountered by ASD families due to COVID-19 in the United States. About half of our US sample reported a moderate-to-large impact on the eating behaviors displayed by their child. Comparatively, a recent survey conducted in Italy revealed an estimate of 28% of ASD families reporting greater difficulty in managing meals compared with before the pandemic (6). Differences in the wording of survey questions may be, in part, responsible for this incongruity. However, this may suggest harsher impacts of the pandemic on meal-time patterns and behaviors among ASD families in the United States when compared with those in Italy.

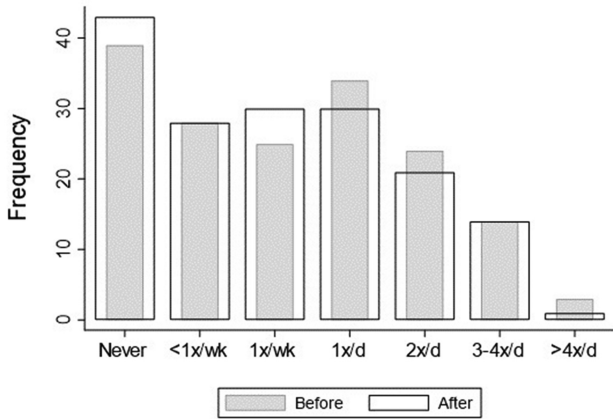
In terms of food availability, a recent summary on the potential impacts of COVID-19 suggests that long-term exposure to reduced access coupled with increased consumption of less expensive, less nutritious



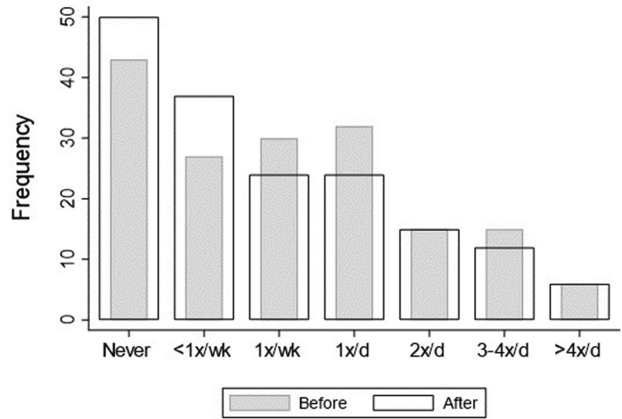
(A) Meat, $P=0.02$



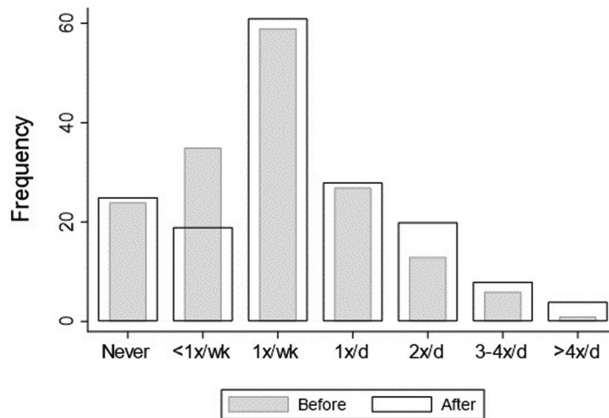
(B) Seafood, $P=0.03$



(C) Vegetables, $P=0.01$



(D) 100% fruit juice, $P<0.01$



(E) Sweets, $P<0.001$

FIGURE 1 (A–E) Change in frequency of consumption of food groups before and after the onset of COVID-19 regulations ($n = 200$). Note: Only those that were significant are shown. P values were calculated using MANOVA test for repeated measures. COVID-19, coronavirus disease 2019; MANOVA, multiple analysis of variance.

TABLE 3 Changes in acquisition and preparation of foods after the onset of COVID-19 regulations among ASD families by impact on eating behaviors¹

Food environment characteristics	Total (n = 200)		Impact on eating behaviors		P
	Total n	n (%)	None to small (n = 84), n (%)	Moderate to large (n = 114), n (%)	
Difficulty in finding foods	196				
Yes		127 (64.8)	40 (47.1)	87 (78.4)	
No		69 (35.2)	45 (52.9)	24 (21.6)	<0.001
Frequency of ordering out	196				
Increased		37 (18.9)	11 (13.1)	26 (23.2)	
Decreased		128 (65.3)	54 (64.3)	74 (66.1)	
No change		31 (15.8)	19 (22.6)	12 (10.7)	0.031
Frequency of cooking	199				
Increased		138 (69.4)	58 (68.2)	80 (70.2)	
Decreased		22 (11.1)	3 (3.5)	19 (16.7)	
No change		39 (19.6)	24 (28.2)	15 (13.2)	<0.001

¹ P values derived using chi-square test; Fisher's exact P value was used for characteristics with cells ≤5. ASD, autism spectrum disorder; COVID-19, coronavirus disease 2019.

foods could lead to detrimental effects on nutrition status (22). Given that this research was aimed at the general population, these adverse effects are likely to be augmented in individuals with ASD. In addition to poorer nutrition status, it is likely that unavailability of preferred foods would lead to emotional distress for all involved, adding to the burden of caregivers and families (23, 24).

Changes in energy intake and expenditure were also observed among our study population. For example, a decrease in physical activity of the child was reported by 55% of our survey respondents, and children were consuming fewer vegetables and meat while consuming more sweets. A recent study among adults found that self-quarantining during COVID-19 led to stress eating and reduced physical activity, both risk factors for weight gain (25). Our findings show >26% of children in the study were reported as obese; comparatively, in 2017–2018, the prevalence of obesity among US children aged 2–19 y was 19.3% (26). Thus, due to this predisposition for weight gain, conditions imposed by COVID-19, such as self-quarantine and food unavailability, may disproportionately affect the weight status of individuals with ASD. Of note, over one-third of respondents reported decreased food intake, which may have been due to unavailability of preferred foods or changes in the environment that may have led to food refusals or lack of resources to purchase foods (5). As evidenced, caregivers reported shifts in both directions for food intake amount and physical activity, which was anticipated given the heterogeneity of ASD phenotypes.

Our findings further inform how the overall impacts of COVID-19 trickle down to shape food acquisition, preparation, and consumption patterns of families with ASD. Many families from our study reported an increase in cooking at home and in relying on take-out post-onset of COVID-19. With regard to ASD, these changes may have either positive or negative consequences. Cooking at home is considered healthier than consuming food prepared outside the home, as meals are likely to be prepared fresh, include a greater variety of food groups, and made with less salt and unhealthy fats (27). Consequently, poor nutrition is linked to negative effects on the immune system and inflammatory pathways, which may exacerbate ASD symptoms and co-occurring conditions, including gastrointestinal distress and hyperactivity (28, 29). At the same time, drastic changes to food patterns and routines, such as a shift to

home-cooked meals, may lead to high levels of anxiety for the child and behaviors leading to unfavorable outcomes (5). However, our findings showcase a greater distinction on the impact on children's eating behaviors among families reporting a decrease in cooking frequency compared with those who reported an increase.

The disparities by household income level and food security status on the impacts of the pandemic among the families are revealing. Health disparities have been previously reported in the literature stemming from both of these predictors (30, 31). However, the COVID-19 pandemic has intensified existing struggles faced by these families. This is showcased by the greater magnitude of effect of food insecurity post-onset of the pandemic on the outcomes examined in this study compared with food insecurity pre-pandemic. Food insecurity is a risk factor for delayed development of growth and cognition and can further impede the development of children with ASD and other developmental disorders (30). Those experiencing food insecurity are also more likely to be chronically malnourished (22). The specific nutrient deficiencies in these cases overlap with those experienced by many children with ASD—namely, vitamins A and D, iron, zinc, and selenium (32–34). Many of these nutrients act as or act in conjunction with antioxidants (32). Consequently, a chronically unhealthy diet may lead to obesity, diabetes, and other chronic and inflammatory metabolic conditions, for which individuals with ASD are at higher risk (35). We also observed greater volatility in the change in frequency of consumption of meat, grains, fats, and sugar-sweetened beverages among children living in food-insecure households. Diets of children with ASD are already limited, with many preferring a higher consumption of grains and a lower consumption of protein (3, 36). These data suggest that the pandemic is exacerbating the quality of their diets and living in households with low resources may have compounding effects on the nutritional status of these vulnerable populations.

Finally, we report a significantly greater percentage of respondents affirming loss of employment or reduced pay among those living in lower-income households compared with those living in higher-income households, which has held true among the whole US population for decades (37). This unfortunate circumstance perpetuates already existing disparities, with greater burdens likely falling on children with ASD

TABLE 4 Impact of before (pre) and after (post) the onset of COVID-19 regulations on children's eating behaviors and food availability among ASD families accounting for shelter regulations, household food security status, and household income¹

	Overall eating behaviors		Food availability ²	
	OR (95% CI)	P	OR (95% CI)	P
Model 1 (n = 190)				
Shelter regulations				
No	(Ref)	—	(Ref)	—
Yes	2.30 (1.12, 4.72)	0.02	0.84 (0.39, 1.81)	0.66
Model 2 (n = 198)				
Food insecurity (pre)				
No	(Ref)	—	(Ref)	—
Yes	1.70 (0.96, 3.00)	0.07	2.27 (1.25, 4.13)	0.01
Model 3 (n = 198)				
Food insecurity (post)				
No	(Ref)	—	(Ref)	—
Yes	2.60 (1.45, 4.67)	0.001	4.13 (2.12, 7.69)	<0.001
Model 4 (n = 163)				
Household income (pre)				
≥\$100,000	(Ref)	—	(Ref)	—
\$50,000 to <\$100,000	1.48 (0.63, 3.49)	0.37	3.48 (1.42, 8.55)	0.01
<\$50,000	2.33 (1.02, 5.29)	0.04	4.00 (1.71, 9.34)	0.001
Model 5 (n = 198)				
Loss of employment (post) ³				
No	(Ref)	—	(Ref)	—
Yes	1.60 (0.80, 3.22)	0.18	1.15 (0.44, 3.00)	0.78
Model 6 (n = 120)				
Sex				
Female	(Ref)	—	(Ref)	—
Male	1.18 (0.37, 3.76)	0.78	1.62 (0.34, 7.78)	0.55
Age	1.03 (0.91, 1.17)	0.63	1.01 (0.88, 1.16)	0.88
Minority race	0.88 (0.31, 2.50)	0.81	1.00 (0.33, 3.06)	0.99
Shelter regulations	2.20 (0.66, 7.36)	0.20	0.99 (0.26, 3.80)	0.99
Loss of employment ³	1.17 (0.40, 3.43)	0.77	0.94 (0.31, 2.85)	0.91
Food resources ⁴	0.24 (0.03, 2.01)	0.19	0.49 (0.12, 1.98)	0.32
Household income (pre)				
≥\$100,000	(Ref)	—	(Ref)	—
\$50,000 to >\$100,000	2.13 (0.62, 7.27)	0.23	3.25 (0.81, 13.08)	0.10
<\$50,000	4.25 (0.48, 37.33)	0.19	1.76 (0.27, 11.54)	0.56
Food insecurity (post)				
No	(Ref)	—	(Ref)	—
Yes	3.02 (0.98, 9.36)	0.06	7.19 (1.20, 42.98)	0.03

¹Child overall and eating behaviors defined as none to small (Ref) vs. moderate to large; food availability defined as (difficulty vs. no difficulty finding the child's usual or preferred foods). ASD, autism spectrum disorder; COVID-19, coronavirus disease 2019; Ref, reference; SNAP, Supplemental Nutrition Assistance Program; WIC, USDA Special Supplemental Nutrition Program for Women, Infants, and Children.

²Missing 2 subjects across all food availability models.

³Loss of employment or reduced pay for the caregiver and/or their partner post-COVID-19; includes 1 respondent reporting postponement of job and 1 respondent reporting expiring work visa due to delays.

⁴Receiving food resources including, SNAP, WIC, food stamps, mobile meals, food pantry, school meals, meals for elderly, etc.

and their families (38). These findings emphasize a need for a focus on wider systems-based approaches and policies to resolve issues such as accessibility and affordability of nutritious food, proper health care, and autism-specific services.

To date, there are no reports on the impacts of the pandemic on food and eating behaviors among children with ASD in the United States. We further examined these findings by household income and food security status. Due to the nature of events occurring as a result of the novel pandemic, there were limited prior resources with validated questionnaires for our specific questions. Expediency was a priority in gathering data during the quarantine periods to report preliminary findings and generate further hypotheses. For these reasons, our study did not de-

mand the computation of a sample size. In addition, we were limited to conducting a single survey cross-sectional study design, and thus were subject to recall and information bias for several of the before and after comparisons. These included questions on food security status, our main outcome of overall change in eating behaviors, and our secondary outcomes of frequency of consumption of different food groups. The online nature of the survey may have introduced selection bias, given that our sample was more affluent and highly educated than the average American household based on US Census data. To limit participant burden, we did not ask about respondent sex, race/ethnicity, or whether they prepared the child's meals or ate with them. We also did not itemize income by federal unemployment or stimulus income. Last, we at-

tempted to include the date of the surveys into our regression models as the timing of deployment of resources is crucial in the face of a disaster such as the pandemic. However, the variance inflation factor (VIF) for the date variable was very high (>20), and thus we decided to remove it. In the model with the survey date variable, there was a <10% difference in the OR for food insecurity.

In conclusion, the COVID-19 pandemic has presented major challenges to all aspects of health. Disruptions in the food supply and job losses have resulted in increased household food insecurity. However, vulnerable populations, including those with ASD and other neurodevelopmental disorders, are disproportionately at risk for adverse outcomes. Our findings illustrate a majority of caregivers facing moderate-to-large impacts on their children's eating behaviors alongside unavailability of preferred foods, and the effects are greater among low-income households and those experiencing food insecurity. These findings suggest an amplified effect of the pandemic on disadvantaged ASD families and bring forth several hypotheses that require further exploration for potentially tailoring future public health policies and interventions.

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