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Permalink

<https://escholarship.org/uc/item/9k56b2c7>

Journal

Maternal and Child Nutrition, 19(3)

ISSN

1740-8695

Authors

Marino, Jessica A
Meraz, Kimberly
Dhaliwal, Manuvir
et al.

Publication Date

2023-07-01

DOI

10.1111/mcn.13498

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Impact of the COVID-19 pandemic on infant feeding practices in the United States: Food insecurity, supply shortages and deleterious formula-feeding practices

Jessica A. Marino¹  | Kimberly Meraz¹ | Manuvir Dhaliwal¹ |
Denise D. Payán²  | Tashelle Wright³ | Jennifer Hahn-Holbrook^{1,4} 

¹Department of Psychology, University of California, Merced, California, USA

²Department of Health, Society, and Behavior, University of California, Irvine, California, USA

³Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada

⁴Health Sciences Research Institute, University of California, Merced, USA

Correspondence

Jennifer Hahn-Holbrook, Department of Psychology, University of California, 5200 Lake Rd, Merced, CA 95343, USA.
Email: jhahn-holbrook@ucmerced.edu

Funding information

University of California Merced,
Grant/Award Number: Psychology Department 2021 Research Support Award

Abstract

The coronavirus disease 2019 (COVID-19) pandemic increased food insecurity among US households, however, little is known about how infants, who rely primarily on human milk and/or infant formula, were impacted. We conducted an online survey with US caregivers of infants under 2 years of age ($N = 319$) to assess how the COVID-19 pandemic impacted breastfeeding, formula-feeding and household ability to obtain infant-feeding supplies and lactation support (68% mothers; 66% White; 8% living in poverty). We found that 31% of families who used infant formula indicated that they experienced various challenges in obtaining infant formula, citing the following top three reasons: the formula was sold out (20%), they had to travel to multiple stores (21%) or formula was too expensive (8%). In response, 33% of families who used formula reported resorting to deleterious formula-feeding practices such as diluting formula with extra water (11%) or cereal (10%), preparing smaller bottles (8%) or saving leftover mixed bottles for later (11%). Of the families who fed infants human milk, 53% reported feeding changes directly as a result of the pandemic, for example, 46% increased their provisioning of human milk due to perceived benefits for the infant's immune system (37%), ability to work remotely/stay home (31%), concerns about money (9%) or formula shortages (8%). Fifteen percent of families who fed human milk reported that they did not receive the lactation support they needed and 4.8% stopped breastfeeding. To protect infant food and nutrition security, our results underscore the need for policies to support breastfeeding and ensure equitable and reliable access to infant formula.

KEYWORDS

breastfeeding, COVID-19 pandemic, formula feeding, infant and young child feeding, paediatric nutrition

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1 | INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic increased food insecurity rates worldwide, including in the United States, and especially in families with children. A United States Department of Agriculture (USDA) report found that food insecurity in households with children increased from 6.5% in 2019 to 7.6% in 2020 (Coleman-Jensen et al., 2021). Many households experienced food insecurity for the first time (Morales et al., 2020). Record levels of unemployment, supply shortages, food price increases, hoarding/stockpiling behaviour, income insecurity, overburdened government-funded nutrition programmes and the interplay of these factors, all likely contributed to the rise in household food insecurity during the COVID-19 pandemic (Hernandez & Holtzclaw, 2020). Less is known, however, about the impact of the pandemic on *infant* food insecurity, specifically. This is a critical gap in our knowledge given that infants are an extremely vulnerable population with specialized dietary needs.

The World Health Organization (WHO) and the American Academy of Paediatrics recommend that infants consume only human milk for the first 6 months of life, although formula is an acceptable alternative if an infant is not breastfed (Meek et al., 2022; WHO, 2021). From 6 to 12 months, infant cereals and other soft foods can be gradually introduced, with continued provisioning of human milk or infant formula for at least the first year. Between 1 and 2 years, solid foods should comprise the majority of the diet, although continued human milk supplementation is recommended until the young child's second birthday and beyond. Ensuring infants receive optimal nutrition is critical for long-term health. Disruptions to infant nutrition can lead to malnutrition and have life-long deleterious consequences for cognitive development and growth, leading to a higher risk for chronic illnesses like obesity and cardiovascular disease (Ashabi & O'Neal, 2008; Cook & Frank, 2008; Victora et al., 2016).

Several studies have documented changes in infant feeding behaviour as a result of the COVID-19 pandemic, with most studies focusing on breastfeeding (rather than formula feeding). For example, a study of 1219 mothers in the United Kingdom reported that 41.8% of mothers felt breastfeeding was protected due to COVID-19-related lockdowns, in part, because lactating caregivers could work remotely and engage in direct breastfeeding as opposed to expressing milk with a pump (Brown & Shenker, 2020). In this same study, however, 18.9% of mothers reported that they stopped breastfeeding (largely due to insufficient lactation support), which was more common among mothers with less education and from Black and minority ethnic backgrounds. Similar COVID-19-related breastfeeding changes were reported in Belgium (Ceulemans et al., 2020). In the line with the idea that the pandemic introduced breastfeeding difficulties, Italian mothers who gave birth during COVID-19 quarantine periods had significantly lower exclusive breastfeeding rates at hospital discharge than a group of control mothers who gave birth at the same hospitals the previous year (Zanardo et al., 2021).

Key messages

- One in three families who fed infants formula reported using one or more deleterious formula-feeding practices during the coronavirus disease 2019 pandemic, likely due to formula shortages and financial strain.
- Of the families who fed infants human milk, 15% reported difficulties accessing lactation support directly as a result of the pandemic, although 46% of families reported increased provision of human milk.
- Flexible government programmes and policies are needed to ensure equitable access to lactation support and infant formula during crises.

Less is known about the effects of the COVID-19 pandemic on families who fed their infants with infant formula, and who face unique challenges. Indeed, anecdotal reports suggest that infant formula and bottled water were limited in availability or sold out in stores in the United States during the COVID-19 pandemic (Guynn, 2020). When infant formula is not accessible, either because it is too expensive or sold out, formula-dependent families have few options and may resort to suboptimal or dangerous infant feeding strategies. For example, caregivers may add extra water to dilute formula (i.e., 'formula thinning'), resulting in a lower calorie and less nutritionally dense food (Burkhardt et al., 2012). Deleterious feeding practices such as formula thinning can lead to malnutrition, growth and cognitive delays, and even infant mortality in extreme cases (Lande et al., 2007; Lucas et al., 1998). Other deleterious feeding practices that may occur in response to formula shortages include inappropriately replacing formula feedings with cow's milk, cereal and juice or mixing these foods with infant formula. Feeding infants age-inappropriate foods can cause nutrient deficiencies, choking-related deaths, allergic reactions and diarrhoea (Lande et al., 2007; Lucas et al., 1998).

How families coped with shortages of formula and other infant supplies in the United States as a result of the COVID-19 pandemic has not been systematically examined. One large study in the United Kingdom reported that 66% of formula-feeding mothers reported no change in feeding behaviour as a result of COVID-19 lockdowns, 18% increased formula feeding, 13% reported a decrease and 3% had stopped formula feeding (Vazquez-Vazquez et al., 2021). Although the reasons for these formula-feeding changes were not explicitly examined, some mothers cited a lack of breastfeeding support, especially face-to-face help, as a reason for introducing formula. In a preprint report on qualitative interviews of mothers conducted during a formula shortage in 2022 in Washington, DC, several mothers reported resorting to deleterious formula-feeding practices such as thinning formula or introducing solids earlier than they had originally intended (Sylvetsky et al., 2022). A study conducted in Brazil reported that infants born postpandemic (compared to prepandemic) had a significantly higher risk of being introduced to complementary foods

before the recommended age (Holand et al., 2022). While these reports are concerning, little is known about how formula shortages reported in the United States due to the COVID-19 pandemic impacted formula-feeding behaviour and infant health.

To address existing knowledge gaps, we conducted an online survey of 319 US families of infants under 2 years of age with four primary aims. First, this study sought to identify challenges encountered in accessing infant formula (and other necessary infant supplies like water) and document how families coped with these difficulties, including the use of deleterious formula-feeding practices (e.g., formula thinning). Second, this study examined the effects of the pandemic on breastfeeding behaviour and willingness and ability to access lactation support. Third, this study explored whether specific brands of infant formula (e.g., those subsidized by the Women, Infants and Children [WIC] nutrition assistance programme for low-income families and specialty soy-based formula for infants with allergies) were more difficult to access during the pandemic, and, if so, how families coped. Finally, we explored the extent to which demographic factors, overall household food insecurity and mixed-feeding status (using human milk and formula) predicted the use of deleterious formula-feeding practices.

2 | MATERIALS AND METHODS

2.1 | Participants and data collection

US caregivers of infants under the age of 2 years were invited to participate in an online survey on the effects of the COVID-19 pandemic on infant feeding practices. Surveys were offered in English and Spanish during the first year and a half of the pandemic (between May 2020 and March 2021), before the widespread availability of vaccines and when government 'shelter in place' orders were common. Participants were recruited from Amazon's Mechanical Turk panels of parents and through social media posts on Facebook and Twitter. Caregivers were eligible to participate if they identified as an adult caregiver of a child under the age of 2 years at the time of survey completion, lived in the United States and spoke English and/or Spanish (IRB # UCM2020-54). Online recruitment continued until study funding (e.g., participant compensation) was exhausted and spanned 10 months due to difficulties in recruiting new families during the pandemic. A total of 550 people took the online survey: 68 caregivers from social media posts and 482 caregivers from MTurk recruitment.

2.2 | Measures

The authors designed this survey to assess infant feeding difficulties families faced as a result of the COVID-19 pandemic, drawing on their survey expertise with guidance from existing resources (Burkhardt et al., 2012; USDA, 2012). All surveys were translated into Spanish by two native Spanish speakers independently, their

translations were compared and inconsistencies were discussed and resolved in consultation with the research team. The instrument was reviewed and revised by coauthors and pilot tested with four caregivers who provided feedback. The full English version of the survey instrument is available in Supporting Information: Materials (the Spanish version is available upon request).

2.2.1 | Formula feeding changes and challenges

Caregivers were asked questions regarding their infant formula use (ever and current). Participants who had ever used formula were asked follow-up questions about whether they had made any changes to the way they fed infants' formula or had problems accessing formula as a result of the COVID-19 pandemic. Participants who answered yes to either question were asked to select the changes and difficulties that applied to them from a list provided (see full survey in Supporting Information: Materials for details). Participants were also given the option to select 'other' and write-in unique challenges or changes they made with regard to formula feeding. We also asked all families who fed formula about the availability of clean water to mix with powdered infant formula and any changes they made to formula feeding as a result. Finally, we asked if their infant had a medical issue that required specialty infant formula (e.g., lactose intolerance or allergies) and, if so, if they had trouble getting specialty formula or made changes to the way they fed their infant.

2.2.2 | Breastfeeding changes and challenges

Caregivers were asked questions regarding their use of human milk to feed their infant (ever and current). Participants whose infants had ever been fed human milk were asked follow-up questions about whether they had made any changes to the way they fed infants' human milk or had problems accessing breastfeeding support as a result of the COVID-19 pandemic. Participants who answered yes to either question were asked to select the changes and difficulties that applied to them from a list provided (see full survey in Supporting Information: Materials for details) or select 'other' and write-in unique challenges or changes. If participants indicated that they were feeding infants more human milk as a result of the pandemic, they were asked follow-up questions about the reasons why.

2.2.3 | Household food insecurity

Household food insecurity during the COVID-19 pandemic was assessed using the three-item screening version of the USDA US Household Food Security Survey Module (USDA, 2012), modified to specify that food insecurity happened during the COVID-19 pandemic. Participants were asked whether, during the COVID-19 pandemic, they could not afford food, ran out of food or cut/skipped meals. Participants responded with 'Never' (coded as 0), and

'Sometimes' or 'Often' (coded as 1). Participants' responses were then summed to create a food insecurity score ranging from 0 to 3, and then the scores were multiplied by two to parallel the scoring of the full 6-item version, with higher scores indicating more food insecurity. A categorical score was also created to denote high/marginal food security (0–1), low food security (2–4) and very low food security (5–6).

2.2.4 | Sociodemographics

Caregivers were also asked to provide the following sociodemographic information: their age, relationship to the infant (e.g., mother, father, etc.), infants' age, race/ethnicity, marital status, employment status, annual income, household size and state of residency. Family poverty status was defined as having an income under the poverty threshold given participants' reported household size (US Department of Health and Human Services, 2017).

2.2.5 | WIC enrolment and eligibility

Caregivers were asked if they or anyone in their household had newly enrolled in a health or public health services programme (e.g., WIC, SNAP, etc.) since the start of the COVID-19 pandemic. If participants had not enrolled in a government-funded nutritional assistance programme, they were asked why not.

2.3 | Data analysis plan

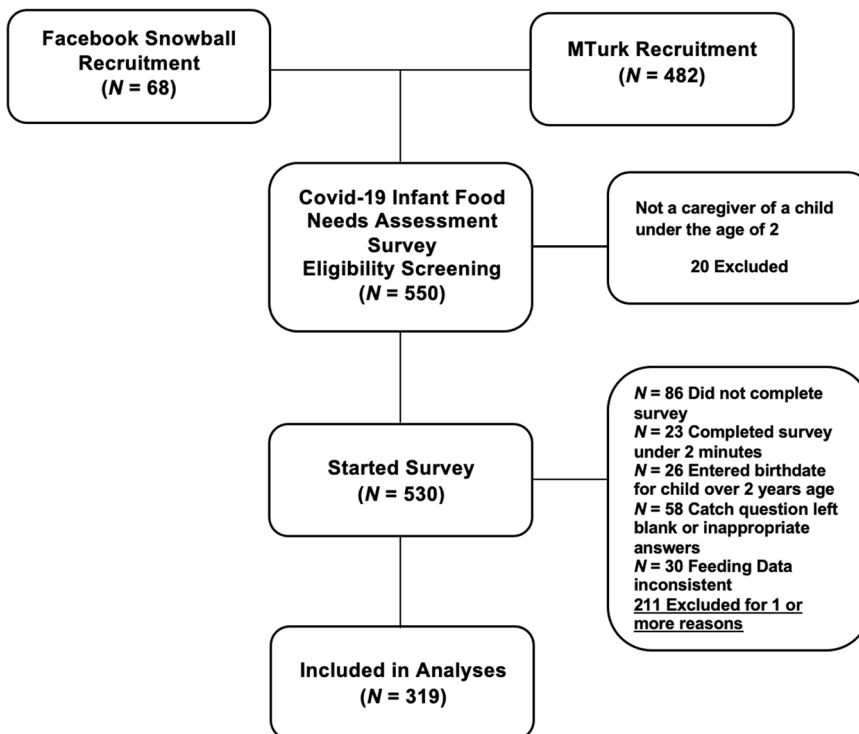
Frequencies and descriptive statistics were used to determine the prevalence rates of all feeding challenges and changes made to infant feeding as a result of the COVID-19 pandemic. To estimate the prevalence of deleterious formula-feeding practices as a result of the COVID-19 pandemic, we coded the changes caregivers made to their formula-feeding practice as harmful (or not) as defined by the Centers for Disease Control and Prevention (CDC) infant feeding guidelines (CDC, 2021). Deleterious formula-feeding practices included skipping infant feedings, adding less formula or more water to bottles (e.g., formula thinning), feeding expired milk or formula, adding infant cereal to bottles, substituting formula feeding with solid food and substituting infant formula feedings for juice or regular milk. Since these deleterious formula-feeding practices are especially harmful to the youngest infants, we also provide prevalence rates of these practices in the subset of the sample with infants under 12 months ($N = 163$) and 5 months ($N = 44$) in Tables 1s and 2s. Finally, in the subsample of formula-feeding families ($N = 210$), we conducted exploratory binomial logistic regressions to examine if deleterious formula-feeding practices due to the pandemic were related to family sociodemographic characteristics, WIC enrolment (0 = not enrolled; 1 = enrolled) or mixed feeding status (0 = exclusively formula feeding;

1 = mixed feeding). We report both unadjusted and adjusted models. In unadjusted models, we report the association between each potential risk factor for deleterious formula-feeding practices on its own (in separate binomial regression models). In adjusted models, we entered predictors simultaneously to examine the unique variance associated with each predictor. To do this, first we examined potential collinearity associated with our predictors and found that the collinearity of all potential predictors was within acceptable limits (i.e., variance inflation factor were all ≤ 1.34 ; eigenvalues were all ≤ 9.080 ; tolerance values were all < 0.25). Next, we sought to find the most parsimonious model in which the fewest number of variables predicts the most variance. The goodness of model fit was assessed with log-likelihood, χ^2 , and the pseudo- R^2 value proved in binomial logistic regression analysis (i.e., Nagelkerke R). The least predictive variable (defined as the variable with the largest p value) was removed using step-wise deletion. We retained any variable with a p value under 0.10 or whose inclusion in the model increased the pseudo- R^2 value by more than 1%. A fully adjusted model with all the variables examined was included together, regardless of significance or model fit is included in Table 3s. All statistical analyses were performed in SPSS version 21. p values under 0.05 were considered statistically significant. The data and syntax are publicly available (<https://osf.io/rwfyt/>).

3 | RESULTS

See Figure 1 for a flowchart outlining study recruitment and reasons for participant exclusion. Our target sample size was 300 families and was dictated by the amount of the small research grant awarded to J. M. to support online research during the COVID-19 pandemic from the University of California, Merced. Consistent with the recommended filters for online surveys, participants were excluded for not completing the survey ($n = 86$), completing the survey in less than 2 min ($n = 23$; pilot testing indicated the average time to complete the survey was at least 6 min), having a child above the age of 2 years ($n = 26$) or entering an irrelevant answer in response to a catch question to identify bots (i.e., 'write one complete sentence regarding what you think this study was about') ($n = 58$). Lastly, participants were excluded from the analysis if the feeding data they entered was internally contradictory ($n = 30$). For example, people who marked that they were currently exclusively breastfeeding their infant and then marked they were exclusively formula feeding in a separate question. After exclusions, a final sample of $N = 319$ caregivers was included in the analyses. Four participants took the survey in Spanish; the rest took the survey in English. The majority of our sample ($N = 264$) completed the survey in March of 2021 when we posted the link to the survey on Mechanical Turk; thus, only one person in the sample did not have a child under the age of 12 months at some point during the COVID-19 pandemic lockdowns.

Sociodemographic characteristics of the 319 families who completed this survey are presented in Table 1. Overall, 68% of

FIGURE 1 Prisma flow diagram.

survey respondents were mothers, 29% were fathers, 1.6% were grandparents and 1.2% were other types of caregivers. Our sample primarily comprised married, middle-class families with some racial/ethnic diversity (i.e., 66.3% White, 11.7% African American/Black, 10.8% Hispanic/Latino; 6.5% Asian, 5.8% multiracial/multiethnic). The average age of infants at the time caregivers completed the survey was 11.9 months (SD = 5.8; range: 0–24 months). Of the 35.9% of respondents enrolled in food some kind of assistance programmes—16% were newly enrolled since the onset of the COVID-19 pandemic. In terms of food insecurity rates, 60% of the sample was high or marginally food secure, 21.8% had low food security and 17.9% had very low food security.

3.1 | Formula-feeding practices during COVID-19

Responses to the formula-feeding questions are summarized in Table 2. Of the participants, 65.8% were currently or had previously used a formula to feed their infant. Among families who fed formula, 30.5% reported having trouble accessing formula because of the COVID-19 pandemic. The most common challenges to accessing infant formula were: it was completely sold out, participants had to travel to multiple stores or lack of affordability. Notably, 4.3% of families who fed formula reported that they had government benefits, but eligible formula brands were sold out. 39.5% of families who fed formula reported making changes to the way they fed their infant as a result of the COVID-19 pandemic. The three most common changes made were: switching infant formula brands, diluting the formula with extra water and saving leftover mixed formula bottles for later use.

After categorizing the changes that families who fed with formula made as either deleterious versus not necessarily deleterious, we found that one out of every three (33%) families who fed with formula reported making at least one deleterious modification to the way they formula fed their infant as a result of the COVID-19 pandemic. Of the 16.7% of families whose infants relied on specialty formula, two-thirds reported difficulties accessing specialty formula during the COVID-19 pandemic, most commonly because it was sold out at stores. And, 13.3% of families who fed with formula reported trouble accessing clean water during the pandemic, mostly due to water filters being sold out at stores, with some families reporting sanitizing water in other ways (i.e., boiling, filtering) or inappropriately using water substitutes like cow's milk or juice.

3.1.1 | Formula feeding practices in the subsample of families with children under 12 and 5 months during COVID-19

Responses to the formula-feeding questions in the subset of the sample with infants under 12 months (Table 1s) and 5 months (Table 2s) are presented in Supporting Information: Materials. Among formula-feeding families with children under 12 months, we found that 30% reported making at least one deleterious modification to the way they formula fed their infant as a result of the COVID-19 pandemic. Among formula-feeding families with children under 5 months, 27% reported making at least one deleterious modification to the way they fed their infant as a result of the COVID-19 pandemic.

TABLE 1 Demographics of the sample.

	N	Mean (SD) or n (%)	Range
Infant age (months)	319	11.9 (5.8)	0–24
Caregiver age (years)	311	34 (7.1)	18–63
Mother		217 (68.0)	
Father		93 (29.2)	
Grandparent		5 (1.6)	
Other		4 (1.2)	
Infant feeding behaviour	313		
Used exclusively human milk		103 (32)	
Used exclusively formula		65 (20)	
Used both human milk and formula		145 (47)	
Caregiver race/ethnicity	309		
White/Caucasian		205 (66.3)	
Black/African American		36 (11.7)	
Hispanic/Latino		25 (10.8)	
Asian		20 (6.5)	
Multiracial/Multiethnic		18 (5.8)	
Other		5 (1.7)	
Marital status	309		
Married		273 (88.3)	
Single		32 (10.4)	
Widowed		4 (1.3)	
Adults in household	309	2.23 (0.8)	1–7
Children in household	309	1.70 (0.8)	1–5
Employment status	310		
Full-time		215 (69.1)	
Homemaker		41 (13.2)	
Part-time		32 (10.3)	
Annual income	308	75,000 (25,000)	<10K–>400K
Poverty	308	24 (7.8)	
COVID-19 enrolment in government programmes	313		
No		198 (63.3)	
WIC		50 (16.0)	
SNAP/food stamp benefits		42 (13.4)	
Food bank/pantry or soup kitchens		37 (11.8)	
No enrolled before the pandemic		37 (11.8)	
Free/reduced school lunch		24 (7.7)	
Other		1 (0.3)	

Note: The N values vary by the question because the question did not apply to all participants or participants left questions blank. Further, participants were allowed to select multiple answers, which is why n (%) can equal more than 100%. Participants selected all options who applied.

Abbreviations: COVID-19, coronavirus disease 2019; WIC, Women, Infants and Children.

TABLE 2 Formula-feeding changes and difficulties due to the COVID-19 pandemic.

Question	N total respondents	% of formula users, N = 210	% of total sample, N = 319
Have you ever or are you currently using infant formula to feed your baby?			
No	109	-	34.2
Yes	210	100.0	65.8
If formula feeding, have you (or your partner) had trouble accessing formula due to the COVID-19 pandemic?			
No	145	69.0	45.5
Yes	64	30.5	20.1
Reasons for difficulties accessing formula ^a			
Had to go to two or more stores to find formula	43	20.5	13.5
Formula at the grocery store was completely sold out	42	20.0	13.2
Had to switch formula brands	25	11.9	7.8
Could not afford to buy formula	16	7.6	5.0
Have government benefits but formula allowed to buy was sold out	9	4.3	2.8
Had no transportation to buy formula	9	4.3	2.8
Other	2	1.0	0.6
Have you (or your partner) made changes to the way you feed formula due to COVID-19?			
No	127	60.5	39.8
Yes	83	39.5	26.0
Changes made in formula feeding ^a		39.5	26.0
Engaged in at least one deleterious feeding practice	70	33.3	21.9
Had to switch brands	26	12.4	8.2
Added extra water ^b	24	11.4	7.5
Saved leftover formula for later ^b	24	11.4	7.5
Feeding formula more often	22	10.5	6.9
Added cereal to formula ^b	21	10.0	6.6
Made smaller bottles ^b	17	8.1	5.3
Fed baby solid foods instead ^b	15	7.1	4.7
Skipped formula feedings ^b	14	6.0	4.0
Substituted with other milk/juice ^b	9	4.3	2.8
Fed baby expired formula ^b	4	1.9	1.3
Other	2	1.0	0.6
Does your baby have a medical issue that requires them to eat a specialty infant formula?			
No	174	82.9	54.5
Yes	35	16.7	11.0

(Continues)

TABLE 2 (Continued)

Question	N total respondents	% of formula users, N = 210	% of total sample, N = 319
Have you (or your partner) had trouble obtaining specialty formula in COVID-19?			
No	12	5.7	3.8
Yes	23	11.0	7.2
Difficulties obtaining specialty formula ^a	23	11.5	7.2
Formula at the grocery store was completely sold out	14	6.7	4.4
Had to go to two or more stores to find formula	12	5.7	3.8
Had to switch formula brands	10	4.8	3.1
Could not afford to buy formula	5	2.4	1.6
Had no transportation	4	1.9	1.3
Had government benefits (e.g., WIC), but formula allowed to buy was sold out	4	1.9	1.3
Have you experienced any difficulties in getting clean water during the pandemic?			
No	182	86.7	57.1
Yes	28	13.3	8.8
Difficulties getting clean water for formula ^a		13.3	8.8
Bottled water sold out at store	21	10.0	6.6
Contaminated water supply	12	5.7	3.8
Water filters sold out at store	11	5.2	3.4
Cannot afford to buy water	4	1.9	1.3
Had no transportation to store	1	0.5	0.3
Other	1	0.5	0.3
Changes have been made to the way you give formula to your baby due to water access ^a			
Sanitizing water (i.e., boiling, filtering)	18	8.6	5.6
Substitute with cow's milk, soymilk or juice	8	3.8	2.5
Feeding formula less often	8	3.8	2.5
Switched from bottled water to tap water	6	2.9	1.9
Switched from tap water to bottled water	3	1.4	0.9
Other	1		0.5

Note: Only families who answered yes to the question regarding using infant formula (N = 210) were asked follow-up questions about formula changes and access. The N values vary by the question because the question did not apply to all participants or participants left questions blank.

Abbreviations: COVID-19, coronavirus disease 2019; WIC, Women, Infants and Children.

^aDenotes a question in which participants selected all options that applied, which is why n (%) can equal more than 100% or the total number of people who responded to a question.

^bDenotes a potentially deleterious formula-feeding practice.

3.2 | Predictors of deleterious formula-feeding practices

See Table 3 for a summary of sociodemographic predictors of using deleterious formula-feeding practices as a result of the

pandemic in the subsample of families who used infant formula. In unadjusted analyses, we found that households below the poverty line were slightly more likely to engage in deleterious formula-feeding practices, although this difference was only a trend and did not reach statistical significance. However, families

TABLE 3 Sociodemographic predictors of using deleterious formula-feeding practices as a result of the COVID-19 pandemic.

Variable	Unadjusted coefficients			Adjusted multivariate model		
	Odds ratio	p value	95% Confidence interval	Odds ratio	p value	95% Confidence interval
Child's age at survey	1.121	0.444	0.837–1.502	1.323	0.130	0.921–1.900
Marital status	1.026	0.952	0.452–2.330			
Unemployment status	1.325	0.529	0.552–3.181	2.264	0.116	0.817–6.270
Poverty status	2.933	0.075	0.896–9.606			
Household income	0.528	0.000	0.373–0.747			
Enrolled in food assistance programme	6.502	0.000	3.450–12.255	5.177	0.000	2.449–10.941
Food insecurity status	6.986	0.000	3.658–13.339	3.829	0.000	1.854–7.905
Mixed feeding status	1.504	0.211	0.793–2.852			

Note: Binomial logistic regression was used for all analyses to predict engaging in deleterious formula-feeding practices (0 = no deleterious formula-feeding practice; 1 = at least one deleterious formula-feeding practice) during the COVID-19 pandemic. Only families that fed with infant formula were included in these analyses ($N = 210$), given that families that had never fed with formula could not have used deleterious formula-feeding practices. In the unadjusted models, variables were entered one at a time so that the unique contribution of each predictor could be estimated. In adjusted multivariate models, all variables were entered simultaneously, with variables removed one at a time until the most parsimonious model (the model that predicted the most variance with the fewest predictors) was found. A model with all predictors included is presented in Table 3s. Variables were coded as follows: infant age at the time of survey (in months, z-scored), marital status (0 = not married; 1 = married), caregiver unemployment status (0 = employed vs. 1 = unemployed), household poverty status (0 = not in poverty; 1 = poverty), household income (z-scored), enrolment in government food assistance programme (0 = not enrolled; 1 = enrolled), food insecurity status (0 = food secure, 1 = food insecure), mixed feeding status (0 = exclusively formula-feeding; 1 = fed with formula and human milk). Odds ratios are reported in terms of $\text{Exp}(B)$, because odds ratios can be easier to interpret than the standard binomial logistic regression coefficient, which is in log-odds units.

Abbreviation: COVID-19, coronavirus disease 2019.

with lower incomes were significantly more likely to engage in deleterious formula-feeding practices compared to families with higher incomes. In addition, families enrolled in food assistance programmes (compared to nonenrolled families) and food (compared to food secure) insecure families were also significantly more likely to engage in deleterious infant feeding practices. In unadjusted analyses, the following variables had no relationship with deleterious infant feeding: infant age, mixed feeding status, caregiver marital status, caregiver age, and caregiver employment status.

In adjusted analyses designed to identify the most parsimonious model predicting deleterious formula-feeding practices, four variables emerged as unique and meaningful predictors: enrolment in food assistance programmes, household food insecurity, infant age at the time of the survey and unemployment status. Specifically, families who were enrolled in food assistance programmes were 5.18 times more likely to have used a deleterious formula-feeding practice compared to families who were not enrolled in a food assistance programme. Likewise, families who were food insecure were 3.83 times more likely to have used a deleterious formula-feeding practice compared to families who were food secure. Employment status and age of the infant both predicted more than 1% of the variance in deleterious formula-feeding practices and so were retained in the model; however, neither factor reached statistical significance in the adjusted model. Together, these variables accounted for approximately 35% of the variance in deleterious formula-feeding

practices (estimate derived from Nagelkerke pseudo- R^2). A very similar pattern of results was observed in the full, nonparsimonious model when all variables were included, regardless of model fit (see Table 3s).

3.3 | Breastfeeding practices during COVID-19

Responses to the breastfeeding questions are summarized in Table 4. Of the participants, 77.7% were currently or had previously used human milk to feed their infants. Of these families who fed human milk, 53.2% reported making changes to the way they fed human milk to their infants as a result of the COVID-19 pandemic. The most common changes made by families who fed with human milk were: putting the infant to the breast more often and expressing milk more often to increase the human milk supply or so that other caregivers could feed the infant. Among families who fed human milk, 46.6% indicated they were feeding their infant human milk *more* often as a result of the pandemic (e.g., those putting baby to breast more often, pumping to increase supply and pumping so that other caregivers can feed the baby), while only 6% were breastfeeding *less* often. The most frequently mentioned reasons for feeding human milk *more* often included: the benefits of human milk consumption for the infant's immune system (37.1%), being at home more often facilitated putting the baby to breast (31.0%) and concerns about obtaining formula because of finances (8.9%) or formula shortages (8.1%).

TABLE 4 Breastfeeding changes during the COVID-19 pandemic.

Question	N total respondents	% of human milk users, N = 248	% of total sample, N = 319
Have you ever or are you currently using breast milk to feed your baby?			
No	71	-	22.3
Yes	248	100.0	77.7
Have you made any changes to the way you (or your partner) breastfeed your baby due to COVID-19?			
No	116	46.8	36.4
Yes	132	53.2	41.4
Changes made in breastfeeding ^a			
Made at least one change to increase human milk feeding	113	45.6	35.4
Putting the baby to breast more often ^b	70	28.2	21.9
Pumping breast milk to increase my milk supply ^b	63	25.4	19.7
Pumping so other caregivers can feed the baby ^b	26	10.5	8.2
Breastfeeding less often	15	6.0	4.7
Stopped breastfeeding	12	4.8	3.8
Other	3	1.2	0.9
If using breast milk more often, reasons given ^a			
Breast milk benefits the baby's immune system	92	37.1	28.8
I am at home and able to breast feed more often	77	31.0	24.1
Concerns about having money to buy formula	22	8.	6.9
Concerns about formula shortages	20	8.1	6.3
Concerns about going to the store to buy formula	16	6.5	5.0
I was running out of formula	13	5.2	4.1
Other	4	1.6	1.3
Have you (or your partner) been able to access all of the breastfeeding support that you need during COVID-19?			
No	37	14.9	11.6
Yes	210	84.7	65.8
Difficulties in obtaining breastfeeding support ^a			
I do not want to take my baby to get support in person	13	5.2	4.1
Money is too tight right now	13	5.2	4.1
I am too busy managing other things to get help	11	4.4	3.4
I do not know where to find breastfeeding help	8	3.2	2.5
Lack of transportation	6	2.4	1.9
I have reached out for professional help but never heard back	6	2.4	1.9
I do not have insurance that covers this	6	2.4	1.9
Other	5	2.0	1.6
I am caring for someone who is sick	3	1.2	0.9

TABLE 4 (Continued)

Question	N total respondents	% of human milk users, N = 248	% of total sample, N = 319
Due to COVID-19 quarantine	3	1.2	0.9
My partner does not support breastfeeding	2	0.8	0.6

Note: Only families who answered yes to the question regarding using human milk (N = 248) were asked follow-up questions about changes to human milk feeding or lactation support access. The N values vary by the question because some questions did not apply to all participants or participants left questions blank.

Abbreviation: COVID-19, coronavirus disease 2019.

^aDenotes a question in which participants selected all options that applied, which is why n (%) can equal more than 100% or the total number of people who responded to a question.

^bDenotes behaviours categorized as increasing human milk feedings.

4 | DISCUSSION

Many US families in our study reported making changes to the way they fed their infants as a direct result of the COVID-19 pandemic. The most common challenge for families who fed with formula was obtaining infant formula, with 30.5% reporting difficulty. Given this, it is not surprising, though still concerning, that 33% of families who fed with formula reported resorting to deleterious formula-feeding practices during the pandemic such as adding extra water or cereal to make formula last longer, making smaller bottles or feeding leftover/expired formula. Our deleterious formula-feeding prevalence rate of 33% for families who fed with formula (22% of the total sample) is higher than the previously reported rate of 15% found in an urban sample collected before the pandemic (Burkhardt et al., 2012). Our study may have underestimated the total prevalence rate of deleterious formula-feeding practices given that our measure only captured changes in infant feeding practices as a direct result of the COVID-19 pandemic (and did not include deleterious formula feeding practices that were already occurring). Nationally representative studies are urgently needed to determine the true prevalence rate of deleterious formula-feeding behaviour in the United States and its consequences for infant health. We recommend the development and inclusion of infant food security indicators (e.g., the use of deleterious formula-feeding practices) into existing/planned infant feeding studies and national assessments of household food security. Likewise, clearer guidance is needed for parents on how to properly mix powdered infant formula (Wilkinson et al., 2019), where to get emergency formula if supplies are running low and the health consequences of improper formula feeding.

The most common change made by families who fed human milk during the COVID-19 pandemic was feeding infants more human milk because of its benefits for the infant's immune system. This increase may have been due, in part, to the increase in remote work opportunities for mothers due to lockdowns, institutional closures and social distancing policies, which may have provided mothers more time to focus, fewer visitors, more privacy, increased responsive feeding, greater partner/family support and delayed their return to work (Brown & Shenker, 2020). This boost, however, most likely inequitably benefited white, higher resourced women compared to

non-White racialized minorities (Brown & Shenker, 2020). In line with this view, a 2020 survey of 2426 low-income families enrolled in WIC in Southern California found that the percentage of infants who received any human milk at 6 months significantly decreased from 48.7% before March 2020 to 38.6% after March 2020 (Koleilat et al., 2022). Further research is needed to examine factors contributing to the infant feeding experiences of racial/ethnic and low-income mothers in the United States during the pandemic.

Given the 2022 national formula shortage crisis in the United States, where nationwide out-of-stock percentage for United States retailers reached a high of 74% (Kaiser Family Foundation, 2022), it is important to seek comprehensive policy solutions to prevent and address acute formula shortages and to increase breastfeeding rates. Evidence-based interventions that promote breastfeeding include: providing breastfeeding support, particularly offered by trained personnel and at scheduled times (Renfrew et al., 2012), community/social support groups (Pérez-Escamilla et al., 2016; Thomson et al., 2012), increasing mother–infant physical contact (Little et al., 2021) and remote (i.e., online) breastfeeding support and education (Gavine et al., 2022). At the policy level, recommendations to increase breastfeeding rates include the adoption of paid maternity leave to increase exclusive breastfeeding, breastfeeding duration, infant health and maternal health (Chai et al., 2018; Jou et al., 2018). Public and private sector industries can also adopt family-friendly policies with scheduling flexibilities and remote work opportunities (i.e., telecommuting), particularly as employees transition back to work after an extended leave (e.g., maternity leave).

Food availability and affordability are key dimensions of the food environment, which influences dietary behaviour and nutrition (Herforth & Ahmed, 2015). Our work emphasizes the importance of investigating infant food insecurity, particularly during times of crises or when supply shortages occur. Twenty percent of families in our study reported that formula was completely sold out and that they had to travel to multiple stores. Poverty is the primary cause of food insecurity, and poverty can make it more difficult for families to cope with crises like the COVID-19 pandemic (Laborde et al., 2020), particularly for people of colour whose health and economic well-being were disproportionately impacted (Kim et al., 2020; Payán et al., 2021). In line with this view, poverty and economic hardship

made it difficult for families to buy formula, and families eligible for government nutrition assistance programmes reported WIC benefit-eligible formula brands sold out. These challenges undermine the intent of programmes like WIC to safeguard the health of low-income women, infants and children and can lead to harmful changes to how infants are fed and deleterious feeding practices. We found food insecure families and low-income families were much more likely to engage in deleterious formula-feeding practices, which is consistent with previous research (Burkhardt et al., 2012). Specific to the WIC programme, documented barriers to food shopping during the COVID-19 pandemic included a limited stock of WIC items, reduced store hours and vendor restrictions (e.g., social distancing, limits on the number of individuals in a store) (Zimmer et al., 2021). Adopting and implementing policy flexibilities, such as allowing online transactions for WIC recipients, can help to address some of these barriers by reducing the need for multiple store trips, facilitating the selection of eligible items, providing convenience and reducing the transportation burden placed on families to redeem their WIC benefits (Zimmer, et al., 2021). Companies can also limit the number of formula products purchased by households to safeguard inventory during periods of high demand and supply shortages.

4.1 | Strengths and limitations

Study strengths include the use of an online survey to remotely collect data during the pandemic when in-person data collection was not feasible, recruitment of newly food insecure households and implementation of relatively strict exclusion criteria to ensure the accuracy of the data collected online (i.e., to screen out internet bots). Our study also included detailed questions about formula feeding challenges, which are aspects of food insecurity that are not captured in the USDA Food Insecurity Measure. Thus, our study was able to look at a largely unstudied feature of food insecurity in households with young children.

Our results should be considered in the context of several important limitations. First, given the retrospective nature of this study, we could not ascertain how old the infant was when the feeding practice/challenge occurred. This limitation is especially relevant when considering deleterious formula-feeding practices. For example, while some formula-feeding practices are always potentially harmful regardless of infant age (e.g., feeding expired or leftover mixed formula), others are more harmful to infants under 12 months (e.g., feeding juice or cow's milk instead of formula, skipping formula feedings) and still others are especially harmful to infants under 5 months (e.g., feeding solid food instead of formula, formula thinning). To help address this limitation, we have included tables in the Supporting Information: Materials that give the prevalence of pandemic-related formula feeding changes reported in the subset of the sample with infants under 12 months (Table 1s) and 5 months (Table 2s). It is notable that the prevalence of COVID-19-related deleterious formula-feeding practices among families who fed formula was similar between the full sample (33.3%) and

families with children under 12 months (30.3%), although rates were slightly lower in families with children under 5 months (26.9%). Second, our sample was not nationally representative and our findings are not likely to be generalizable to all US families and contexts. For instance, self-selection into this online study may have led families that experienced a greater number of formula-feeding challenges to be more likely to participate. Given potential bias in recruitment, it is important to note that results from our study should not be used to state that overall trends in breastfeeding and breastfeeding experiences were positive during the pandemic. Third, it was notable that more households in our sample were extremely food insecure than in a nationally representative US sample. Thus, our study may be overestimating how common infant feeding challenges were in the United States during the pandemic and the resulting use of deleterious formula-feeding practices. Finally, we did not have a sufficiently large sample size to examine racial/ethnic disparities in food insecurity. Larger population-level survey research is needed to closely examine infant food insecurity specifically in racial/ethnic minorities and among extremely marginalized populations (i.e., low-income, very food-insecure households).

5 | CONCLUSION

The use of deleterious formula-feeding practices as a result of supply and income disruptions born from the COVID-19 pandemic was fairly common in our US sample. We hope this study will increase awareness about food insecurity issues unique to infants and help persuade researchers designing future studies, especially national assessments of household food insecurity, to include infant food security indicators. Only then can we gauge the prevalence of infant food insecurity and deleterious infant feeding practices in the United States and design flexible government programmes and policies to ensure equitable access to lactation support and infant formula.

AUTHOR CONTRIBUTIONS

All authors helped to conceptualize and develop the study design. Jessica A. Marino, Kimberly Meraz and Manuvir Dhaliwal oversaw subject recruitment. Kimberly Meraz, Manuvir Dhaliwal and Jennifer Hahn-Holbrook carried out the data analysis. Jessica A. Marino, Manuvir Dhaliwal and Jennifer Hahn-Holbrook wrote the initial draft of the paper. Denise D. Payán and Tashelle Wright provided a critical review and additional content for the discussion. All authors reviewed and approved this manuscript for publication.

ACKNOWLEDGEMENTS

We would like to thank research assistants Esther Lapite and Alejandra Cornejo who contributed to the development of the study. This work was funded by an internal grant, the Research Support Award, from the Psychology Department at the University of California, Merced.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

All data produced in the present study are available at: <https://osf.io/rwfyf/>.

ORCID

Jessica A. Marino  <http://orcid.org/0000-0003-0454-5502>

Denise D. Payán  <http://orcid.org/0000-0003-3236-862X>

Jennifer Hahn-Holbrook  <http://orcid.org/0000-0002-8899-8869>

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SUPPORTING INFORMATION

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

How to cite this article: Marino, J. A., Meraz, K., Dhaliwal, M., Payán, D. D., Wright, T., & Hahn-Holbrook, J. (2023). Impact of the COVID-19 pandemic on infant feeding practices in the United States: Food insecurity, supply shortages and deleterious formula-feeding practices. *Maternal & Child Nutrition*, *19*, e13498. <https://doi.org/10.1111/mcn.13498>