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ORIGINAL ARTICLE

Prolonged breastfeeding, sugar consumption and dental caries at 2 years of age: A birth cohort study

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Abstract

Objectives: Previous cohort studies have found a positive association between prolonged breastfeeding (≥12 months) on dental caries, but few of them analysed the mediated effect of sugar consumption on this association. This study investigated whether prolonged breastfeeding is a risk factor for caries at 2-year follow-up assessment (21–27 months of age) and whether this effect is mediated by sugar consumption.

Methods: A birth cohort study was performed in the Brazilian Amazon (n = 800). Dental caries was assessed using the dmf-t index. Prolonged breastfeeding was the main exposure. Data on baseline covariables and sugar consumption at follow-up visits were analysed. We estimated the OR for total causal effect (TCE) and natural indirect effect (NIE) of prolonged breastfeeding on dental caries using the G-formula.

Results: The prevalence of caries was 22.8% (95% CI: 19.8%–25.8%). Children who were breastfed for 12–23 months (TCE = 1.13, 95% CI: 1.05–1.20) and for ≥24 months (TCE = 1.27, 95% CI: 1.14–1.40) presented a higher risk of caries at age of 2 years than those breastfed <12 months. However, this risk was slightly mediated by a decreased frequency of sugar consumption at age of 2 years only for breastfeeding from 12 to 23 months (NIE; OR = 0.95, 95% CI: 0.91–0.97).

Conclusions: In this study, the effect of prolonged breastfeeding on the increased risk of dental caries was slightly mediated by sugar consumption. Early feeding practices for caries prevention and promoting breastfeeding while avoiding sugar consumption should be targeted in the first 2 years of life.

KEYWORDS
birth cohort, dental caries, infant sugar consumption, prolonged breastfeeding

1 | INTRODUCTION

Dental caries is the most common noncommunicable disease.[1] Data from 72 worldwide studies have estimated the mean caries prevalence in young children to range from 17% among infants to 36% at 2 years of age, showing that its prevalence increases with age.[2] Moreover, dental caries consistently has a negative impact on the oral health-related quality of life of preschool children and their families.[3]

Dental caries affects very young children and lasts through adolescence and adulthood into later life.[4] A dose-dependent association

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among free-sugar consumption, dental caries development and other noncommunicable chronic diseases (NCDs) has been previously recognized.[5,6] According to the World Health Organization (WHO),[1] free-sugar intake is an essential dietary factor in dental caries development, as the disease does not occur in the absence of dietary sugars.

On the other hand, there is evidence indicating that prolonged breastfeeding after 12 months is associated with an increased risk of dental caries. The results were found in two systematic reviews regarding prolonged breastfeeding and dental caries risk.[7,8] However, while a systematic review and meta-analysis has shown an increased risk of caries in children breastfed after 12 months,[7] another systematic review has indicated that only breastfeeding beyond 24 months leads to an increased risk of caries.[8] Nonetheless, the quality of evidence from both reviews was low due to the limited number of included cohort studies at that time. The prolonged breastfeeding and dental caries results vary due to differences in study designs, different cut-off points for breastfeeding duration, different statistical analyses and differences in adjustment for potential confounders and/or mediating factors.

To date, most birth cohort studies have found positive associations between prolonged breastfeeding beyond 12 months of age and dental caries,[9–13] although a recent study has reported contradictory results, as prolonged breastfeeding practices were not associated with dental caries,[14] even after statistical adjustment for socioeconomic factors and sugar intake.

In addition, few of the published birth cohort studies[12,13] performed data analysis using marginal structural models (MSMs), which has been recommended for studies on breastfeeding and dental caries,[15] as they are useful to address intermediate confounders affected by the exposure. The MSMs are a class of causal models that estimates the causal effect of the exposure in the presence of time-dependent covariates that can act simultaneously as confounders and intermediate variables, from observational data.[16–18]

Therefore, the aim of this population-based birth cohort study was to investigate whether prolonged breastfeeding is a risk factor for dental caries at age of 2 years and whether this effect is mediated by sugar consumption using MSMs.

2 | METHODS

2.1 | Data setting and sample selection

This population-based birth cohort, the Maternal and Child Health and Nutrition in Acre (MINA-Brazil Study), started in 2015 in Cruzeiro do Sul, Acre State, Western Brazilian Amazon. The public water supply in this region is not fluoridated. The MINA-Brazil cohort profile has been published in detail elsewhere.[19] Briefly, baseline data collection for the entire birth cohort included 1881 children who were born from July 2015 to June 2016 at the Women's and Children's Hospital of Juruá Valley, the only maternity hospital in the region, where 96% of the deliveries take place. After delivery, upon the acceptance of the invitation to participate in the study, 1246 live babies from families living in the urban area were eligible for follow-up visits at 6, 12 and 24 months of age. At the 2-year follow-up visit, when the study children had 21 to 27 months of age, two research paediatric dentists (JA and EP) performed dental caries examinations.

For the present analysis, we excluded twins ($n = 20$), children with special needs such as cognitive and/or motor disability ($n = 6$), and craniofacial malformations ($n = 1$), resulting in 800 children (92.2% of the participants) with complete dental caries risk (Figure 1).

2.2 | Outcome

Dental caries was assessed according to the WHO criteria[20] and calculated in terms of decayed, missing and filled primary teeth (dmft). Decayed teeth were assessed as lesions extending into dentin. Then, the following categories were defined as outcome: absence of dental caries (dmft equals zero) and presence of dental caries (dmft equals at least one), as previously described.[21] Children were examined in dental offices in a knee-to-knee position under artificial light using a flat mouth mirror, WHO probes (blunt-tip probe) and sterile gauze to clean and dry the teeth.

2.3 | Main explanatory variable

Breastfeeding duration was the main explanatory variable, and information was collected at 6-month, 1- and 2-year follow-up visits by using the following questions: 'Is the child being currently breastfed? If "No", at what age did the child stop being breastfed?'. Breastfeeding duration was categorized as follows: <12 months (reference category for comparison), 12–23 and ≥24 months.

2.4 | Covariates

Socioeconomic status (SES) baseline confounders were obtained through face-to-face interviews and included the family wealth index, estimated based on household assets using principal component analysis,[22] maternal education (years of schooling), maternal age at delivery (years) and self-reported skin colour (defined by the Demographic Census of the Brazilian Institute of Geography and Statistics as white, mulatto, black and indigenous).

At the 2-year follow-up visit, information on sugar consumption was obtained. The mother/guardian was asked to record each food/drink item or food group consumed in the 24 h before the interview. The 24-h food record was adapted from a previous study,[23] grouping the food items as follows: (1) breast milk, (2) water, (3) tea, (4) cow milk, (5) milk powder, (6) powdered chocolate milk drinks, (7) yogurt, (8) coffee, (9) porridge, (10) fruits, (11) natural juice, (12) industrialized juice, (13) soft drinks, (14) cookies, (15) candies, (16) lollipops, (17) chocolate, (18) sweet and salty snacks, (19) meat, (20) eggs, (21) beans, (22) rice, (23) bread, (24) vegetables/green leaves, (25) potatoes, (26) instant noodles, (27)

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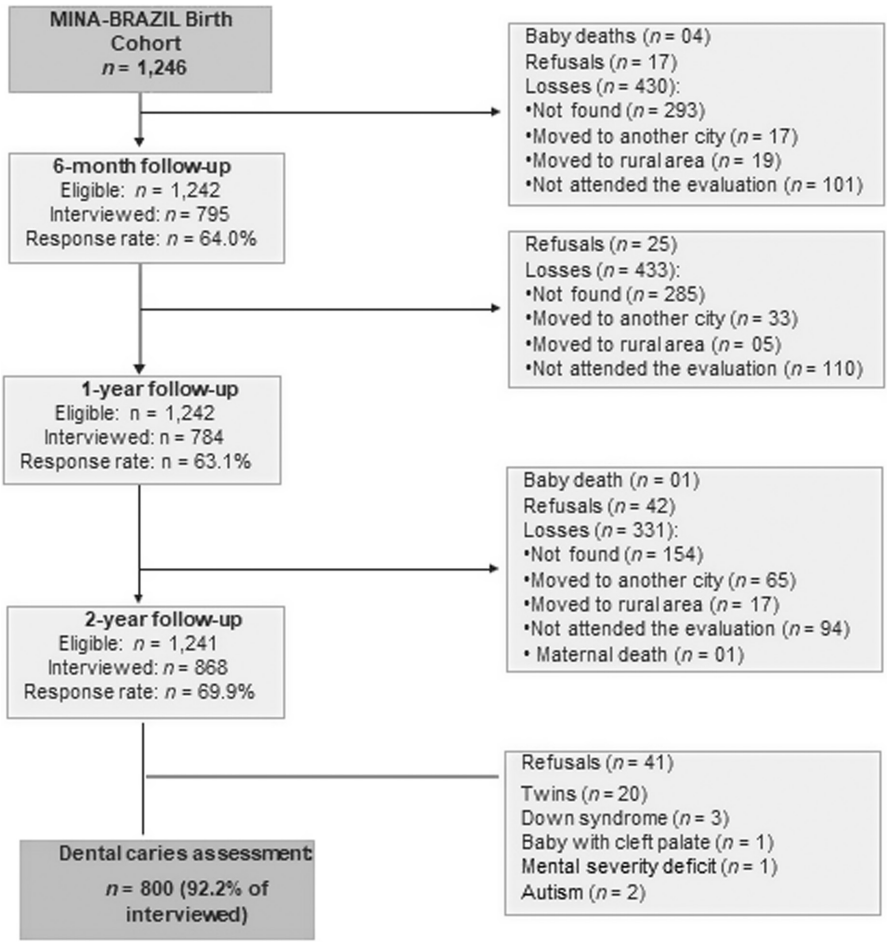

FIGURE 1 Flowchart of participants in the MINA-Brazil birth cohort study for analysis of breastfeeding duration and dental caries

hamburger, (28) nuggets and (29) sausage. Information on sugar added by the family to items 2 to 11 from this food list was also collected. Food items 2–11 with added sugars and items 12–18 were combined in a new variable and categorized into two different approaches for analyses: (a) the number of times per day that the child consumed sugar as a continuous variable (mean = 4.67, SE = 2.82), and (b) sugar consumption frequency, categorized as 0–5 times/day or ≥6 times/day.[24] Information on oral hygiene practices (frequency of tooth brushing and use of fluoride toothpaste) and the use of bottle feeding (no/yes) was also collected.

2.5 | Data quality control

Follow-up interviews were repeated in a random sample of 10% of study participants for quality control checks. The two research paediatric dentists (JA and EP), with previous experiences in oral health surveys, underwent two training and calibration exercise sessions for a 5-h period with pictures of 20 clinical cases and 20 extracted human primary teeth for the studied clinical conditions, with an interval of 1 week between sessions to obtain intra- and interexaminer reliability kappa values ($k > 0.94$). All data were entered into tables using the Census and Survey Processing System (CSPro, U.S. Census Bureau, ICF International).

2.6 | Statistical analyses

Study participant baseline characteristics were analysed using proportions (%) for categorical variables according to the prevalence of caries with 95% confidence intervals (CIs). Poisson regression models with robust variance were used to estimate the prevalence ratios (PRs) with 95% CIs. Participants with few missing values in some covariates were maintained in adjusted models by creating a missing-value category.

A directed acyclic graph (DAG) for the effects of breastfeeding duration on dental caries at 2 years is shown in Figure 2. We assumed that breastfeeding duration has a direct effect (DE) on the probability of having caries at age of 2 years and an indirect effect (IE) mediated through sugar consumption. In the DAG, we used breastfeeding duration as the exposure and sugar consumption as the mediator. Although oral hygiene variables have been reported to be highly correlated to SES,[13,15] they were not included in the mediation analysis due to their high frequencies in our study population. Thus, the wealth index, maternal education, age and skin colour were considered baseline confounders (variables for SES) in this analysis. Bottle-feeding at age of 2 years was classified as an intermediate confounder, that is a confounder of the mediator-outcome association that is on the causal pathway between the exposure and outcome, as the use of bottle-feeding comes after the initiation of breastfeeding and can contribute to sugar intake.

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To estimate the DE of breastfeeding duration on dental caries at age of 2 years and the IE mediated through sugar consumption, we used parametric g-computation using Monte Carlo simulations performed by the Stata G-formula command. In this study, we considered that the use of bottle-feeding at the 2-year follow-up is an intermediate confounder as it is affected by the exposure (breastfeeding duration) and acts as a confounder for the association between the mediator (sugar consumption) and the outcome (caries) at 2 years. In this case, the standard methods are not appropriated, as conditioning on the bottle-feeding would bias the natural direct effect of breastfeeding duration on caries occurrence, as part of the mediating effects through bottle-feeding would be blocked. Similarly, not conditioning on the bottle-feeding would also introduce bias on the mediator-outcome association.[16–18] The g-computation procedure is part of the MSM and it was suggested as an alternative to overcome the limitations of the traditional methods in estimating the causal effects of an exposure on the outcome while dealing with the presence of time-varying confounders.[25] The G-formula approach has several advantages compared to the traditional mediation methods, as it handles intermediate confounders (in our case, bottle feeding at 2 years) and allows the inclusion of exposure–mediator interaction.[26,27] We calculated the (i) natural DE (NDE), characterized by the effect of breastfeeding duration on caries that is not explained by sugar consumption (mediator); (ii) natural IE (NIE), which represents the effect of breastfeeding duration on dental caries through sugar consumption frequency and (iii) controlled DE (CDE), corresponding to the DE of the exposure on the outcome when the categorized mediator (ie 0–5 times/day and ≥6 times/day) is maintained constant at a level of interest. In this study, we examined the effect of breastfeeding duration on dental caries if all children had low frequencies of sugar consumption (ie 0–5 times/day). The total causal effect (TCE) was calculated by the sum of the NDE and the NIE. We included exposure–mediator interaction terms in the analysis. Bootstrapping with 1000 replications was used to calculate the 95% bootstrap-corrected CI (95% BC-CI). As the Stata G-formula command implements logistic regression for binary outcomes with estimates corresponding to the log of the odds ratio (OR), we exponentiated the results to present ORs. All analyses were performed in Stata version 14.0 (StataCorp).

3 | RESULTS

The overall prevalence of caries at age of 2 years was 22.8% (95% CI: 19.8%–25.8%). Almost half of the study sample (49.3%) had an ideal brushing frequency (≥2 times a day) at age of 2 years, while 81.2% used toothpaste with ≥1000 ppm fluoride (results not shown in tables). Table 1 shows the prevalence and 95% CI for dental caries according to baseline socioeconomic characteristics, feeding and oral hygiene practices at age of 2 years. Among all study participants (n = 800), 14.3% and 60% were breastfed and bottle fed at age of 2 years, respectively. Sugar consumption up to 5 times per day (66.7%) was reported for most of the children at age of 2 years, while only 2.8% had never consumed sugar. Overall, the frequency of tooth brushing was 96.9%. However, among those who brushed their teeth (n = 775), 82.9% and 17.1% brushed daily and weekly, respectively. Of them, 81.2% reported the use of fluoride toothpaste. The use of bottle-feeding at age of 2 years was inversely associated with dental caries, which can be explained with the positive association between bottle use and wealth index (mean and SD of wealth index z-scores: 1.82 ± 0.04 vs 1.93 ± 0.04 for not use and use of bottle-feeding, respectively, Student t test, p = .037; data not shown in Tables). The associations between breastfeeding and sugar consumption, and between sugar consumption and dental caries, adjusted for the confounders (family wealth index, maternal education, maternal age and maternal skin colour) suggested that a longer duration of breastfeeding could be related to lower frequency of sugar consumption, although not statistically significant (p > .05) (Table S1).

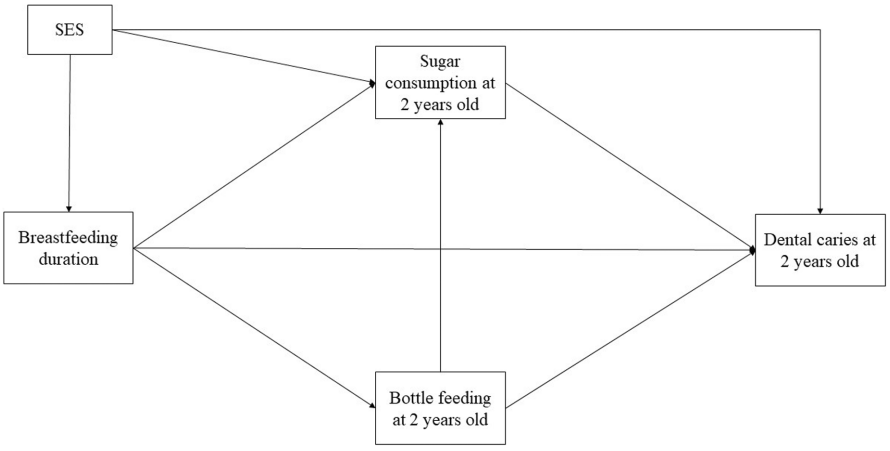

FIGURE 2 Direct acyclic graph for breastfeeding and dental caries at age of 2 years old. Breastfeeding (BF) duration was analysed as any type of BF duration (days) categorized as <12, 12–23 and ≥24 months. Socioeconomic status (SES) baseline confounders included wealth index, maternal education, maternal age and skin colour. Bottle feeding at the 2-year follow-up was considered an intermediate confounder. An interaction term between exposure × mediator (breastfeeding duration × sugar consumption) was included.

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TABLE 1 Baseline socioeconomic characteristics, feeding practices and prevalence ratio (PR) for dental caries (DC) at 2 years of age

Variables[a]	Sample *n* (%)	% DC[b] (95% CI)	PR (95% CI)	*p*-value
Family wealth index at delivery (*n* = 800)				
1° tertile (lowest)	218 (27.7)	31.2 (25.1–37.8)	1	
2° tertile	264 (33.6)	26.1 (20.9–31.9)	0.84 (0.63–1.11)	.221
3° tertile (highest)	305 (38.7)	13.4 (1.0–17.8)	0.43 (0.30–0.61)	<.001
Maternal education level at delivery (*n* = 787)				
<=9 years	222 (28.2)	36.9 (30.6–43.7)	1	
10–12 years	406 (51.6)	17.9 (14.3–22.1)	0.49 (0.37–0.64)	<.001
>12 years	159 (20.2)	14.4 (10.0–20.9)	0.39 (0.256–0.59)	<.001
Maternal age at delivery (*n* = 799)				
<19 years	124 (15.5)	30.7 (22.7–39.6)	1	
19–24 years	269 (33.7)	20.4 (15.7–25.7)	0.66 (0.47–0.95)	.025
25 29 years	182 (22.8)	20.9 (15.2–27.5)	0.68 (0.46–1.00)	.052
≥30 years	224 (28.0)	22.8 (17.4–28.9)	0.74 (0.52–1.06)	.104
Maternal skin colour (*n* = 787)				
White	103 (13.1)	18.5 (11.5–27.3)	1	
Black/indigenous	70 (8.9)	22.8 (13.7–34.4)	1.24 (0.69–2.24)	.478
Brown	614 (78.0)	23.3 (20.0–26.8)	1.26 (0.82–1.94)	.289
Breastfeeding duration (*n* = 800)				
<12 months	247 (30.9)	11.7 (0.8–16.4)	1	
12–23 months	439 (54.8)	25.1 (21.1–29.4)	2.13 (1.46–3.11)	<.001
≥24 months	114 (14.3)	37.7 (28.8–47.3)	3.21 (2.12–4.87)	<.001
Frequency of sugar consumption at 2 years old (*n* = 800)				
Without consumption	22 (2.8)	13.6 (0.3–34.9)	1	
1–3 times a day	277 (34.6)	21.2 (16.6–26.6)	1.56 (0.53–4.58)	.417
≥4 times a day	501 (62.6)	23.9 (20.3–27.9)	1.76 (0.61–5.09)	.299
Use of bottle feeding at 2 years old (*n* = 800)				
No	320 (40.0)	30.6 (25.6–36.0)	1	
Yes	480 (60.0)	17.5 (14.2–21.2)	0.57 (0.44–0.74)	<.001
Toothbrushing presence (*n* = 800)				
No	25 (3.1)	52.0 (31.3–72.2)	1	
Yes	775 (96.9)	21.8 (18.9–24.9)	0.42 (0.28–0.63)	<.0001
Toothbrushing frequency (*n* = 800)				
Daily	641 (82.9)	20.9 (17.8–24.2)	1	
Weekly	132 (17.1)	25.8 (18.5–34.1)	1.23 (0.89–1.71)	.210
Use of fluoride toothpaste (*n* = 648)				
No	122 (18.8)	18.9 (12.3–26.9)	1	
Yes	526 (81.2)	21.7 (18.2–25.4)	1.15 (0.77–1.72)	.497

[a]Totals differ due to missing values for covariates.

[b]Dental caries was assessed according to the WHO criteria (WHO, 2013) for primary teeth that were decayed, missing due to caries, or filled.

Table 2 shows the TCE, NDE and NIE of the association between breastfeeding duration and dental caries at 2 years. Compared to children who were breastfed up to 12 months, children who were breastfed from 12 to 23 months presented an OR 13% higher of having caries at age of 2 years (TCE; OR = 1.13, 95% BC-CI: 1.05–1.20). There was a NIE through sugar consumption (OR = 0.95, 95% BC-CI: 0.91–0.97). The mediated protective effect (OR < 1) suggests that children who were breastfed from 12 to 23 months presented reduced sugar consumption at age of 24 months when compared with children in the reference category. This lower sugar consumption, in turn, slightly reduced the risk of prolonged breastfeeding on dental caries. Taken together, the natural direct effect is detrimental and the natural indirect effect is protective. In other words, the prolonged breastfeeding (from 12 to 23 months of age) affected

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TABLE 2 Estimated odds ratio for the total causal effect and natural direct effect of breastfeeding duration (reference category: <1 year of age) and dental caries at the 2-year follow-up and natural indirect effect of this association by sugar consumption (continuous variable) at 2 years of age in the MINA-Brazil Study Group

Breastfeeding duration	Relative effects[a]	Odds ratio	95% BC-C
12–23 months	Total causal effect	1.13	1.05–1.20
	Natural direct effect	1.19	1.15–1.27
	Natural indirect effect	0.95	0.91–0.97
≥ 24 months	Total causal effect	1.27	1.14–1.40
	Natural direct effect	1.27	1.13–1.41
	Natural indirect effect	1.00	0.94–1.04

Abbreviation: 95% BC-CI, 95% bootstrap-corrected confidence intervals.

[a]Relative to the reference category (<1 year of age); adjusted for family wealth index, maternal education, maternal age and maternal skin colour as baseline confounders and bottle feeding at the 2-year follow-up as an intermediate confounder.

the occurrence of caries through pathways other than lower sugar consumption, but there was a protective effect mediated by lower sugar consumption. Similarly, compared to the reference group (breastfeeding duration <12 months), children who were breastfed for ≥24 months presented a higher risk, at 27%, of having caries at 2 years of age (TCE; OR = 1.27, 95% BC-CI: 1.14–1.40). No evidence of a mediating effect through sugar consumption was found for this exposure category (NIE; OR = 1.00, 95% BC-CI: 0.94–1.04).

A similar pattern of effects was observed when using the dichotomized mediator, that is sugar consumption categorized as 0–5 times/day and ≥6 times/day (Table S2). The CDEs were $CDE_{OR} = 1.17$ (95% BC-CI: 1.1.29) and $CDE_{OR} = 1.37$ (95% BC-CI: 1.27–1.63) for 12–23 and ≥24 months of age for breastfeeding duration, respectively, when compared to the reference category (<12 months).

4 | DISCUSSION

In this study, the observed dental caries risk in children who were breastfed for prolonged periods from 12 to 23 months of age was slightly mediated by sugar consumption during the first 2 years of life. However, this mediating effect was not observed when compared with breastfeeding from ≥24 months, probably related to lack of statistical power (as very few children were breastfed ≥24 months of age; $n = 114$). It is well known from previous cohort studies that early introduction of sugar intake during the first year of life places children on a trajectory of a high risk of severe dental caries.[28,29] Thus, in a population exposed to sugar in childhood, our study confirmed the positive impact of prolonged breastfeeding on the risk for caries.

In the current context of scientific understanding, high sugar consumption results in increasing proportions of saccharolytic, acidogenic and aciduric species that contribute to a cariogenic dental biofilm. Within this cariogenic biofilm, human milk can ferment, provoking enamel demineralization; however, it is sugar consumption that initiates this process, thereby setting off a causal chain.[30] Sugar-rich diets and the type and virulence of biofilm bacteria could plausibly account for the cariogenicity of prolonged breastfeeding.[15] Based on our findings, the sugar consumption mediated the association between breastfeeding beyond 12 months and the risk for dental caries at 2 years of age. The increased risk of prolonged breastfeeding on dental caries was probably related to cariogenic biofilm exposed to human milk in high frequency.

On the other hand, our analysis also observed a weak direct effect of prolonged breastfeeding on dental caries risk; however, this result could be overestimated since our sample is from a population exposed to sugar in childhood. Therefore, our study would have been better able to observe and confirm this effect on dental caries if we had included a category of children aged ≥12 months with no sugar exposure. While prospective birth cohort studies including an adequate proportion of infants with no sugar consumption at early ages in their samples would be ideal, such population-based cohorts would require larger sample sizes than ours, and it is currently unknown whether there are infant populations with this characteristic worldwide. In our study, only 7.6% and 2.8% of the participants had no sugar consumption at 1 and 2 years, respectively, and this is probably the main reason why most previous birth cohort studies have found an association between prolonged breastfeeding and dental caries with high sugar exposure in childhood.[9–13] An Australian birth cohort study did not find an association between breastfeeding beyond 12 months and dental caries.[14] Although that study did not include infants who consumed no sugar, one reason for its contradictory result could be related to the fact that almost 30% of the study children under the age of 2 years had a <5% free-sugar daily intake.[14] This explanation is supported by a recent laboratory study showing a low cariogenic potential for enamel in isolated dental biofilms when breast milk is the exclusive nutrition source.[31]

In our study, the mediation analysis added new evidence of a NIE on sugar consumption in those who were breastfed beyond 12 months of age, suggesting that children who were breastfed for 12–23 months had reduced sugar consumption at 2 years. This lower sugar consumption reduced some of the risk of breastfeeding on dental caries. Our results corroborate those of another cohort study that showed that children who were breastfed beyond 6 months had, on average, a lower intake of sugar-sweetened beverages than those who were never breastfed.[32]

The WHO recommends exclusive breastfeeding for up to 6 months and continued complementary breastfeeding thereafter, for up to 2 years or more.[33] This recommendation is based on the well-known robust evidence for breastfeeding health benefits for the mother–child binomial, which expand into the life cycle regardless of socioeconomic

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position. Moreover, the WHO currently supports recommendations for very young children to avoid free-sugar consumption,[34] and other international agencies also recommend limiting free-sugar consumption, particularly among infants and toddlers younger than 2 years of age.[35,36] These recommendations are based on evidence for a strong association between free-sugar consumption and the development of NCDs, such as dental caries, overweight/obesity, type 2 diabetes and cardiovascular diseases, in children and adults.[5,6]

This study has several strengths. Because information about breastfeeding practices was obtained early, the possibility of recall bias in our study is decreased. A prospective birth cohort design is the best observational epidemiological design to provide causal evidence. In addition, DAGs and MSMs are recommended statistical analysis techniques to study the causal association between breastfeeding and dental caries.[15] However, some limitations should be noted. Causal mediation analysis relies on strong assumptions that no confounding among exposure-outcome, exposure-mediator and mediator-outcome associations exists. Although we adjusted the analysis for several measured confounders, the presence of unmeasured confounders cannot be ruled out. Moreover, mediators (sugar consumption and bottle-feeding) and outcome were estimated at the same time, which may compromise the validity and precision of the casual inference assessment. In this study, dental caries was assessed as dmft, which did not allow a comparison in terms of disease severity.[11–13] We considered only cavitated caries lesions, and it is possible that, in some children, the occurrence of the outcome preceded the consumption of sugar. However, the literature suggested that the consumption of sugar at 2 years of age can be similar to that in the first year of life,[28,29] and for the causal analyses between breastfeeding and cavitated caries lesions, this does not influence the results.

5 | CONCLUSION

In this study, prolonged breastfeeding was a weak risk factor for dental caries. A decreased frequency of sugar consumption at 2 years of age associated with prolonged breastfeeding slightly reduced breastfeeding effects on dental caries. The 22.8% occurrence of early childhood caries in our study highlights the need to implement focused actions and interventions to ensure healthy feeding practices for NCD prevention in the first 1000 days of life, from pregnancy through the first 2 years of life. We suggest targeting feeding practices for caries prevention and promoting breastfeeding while avoiding sugar consumption for at least the first 2 years.

AUTHOR CONTRIBUTIONS

J.A. coordinated and performed the oral health data collection, conceptualized the study, and drafted the initial manuscript; J.M.M.and J.F.L.A. carried out statistical analyses and revised the manuscript; E.P. performed oral health examinations and data collection, and revised the manuscript; A.M. and M.B. contributed to data analysis and critically reviewed the manuscript; M.A.C. coordinated all stages of the birth cohort study and, together with J.A., conceptualized the study and revised the data analyses and initial manuscript; and all authors approved the final version of the manuscript.

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CONFLICT OF INTEREST

The authors have indicated they have no conflicts of interest relevant to this article to disclose.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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REFERENCES

1. World Health Organization. *Sugars and Dental Caries*. WHO. 2017. Accessed October 10, 2021. https://apps.who.int/iris/bitstream/handle/10665/259413/WHO-NMH-NHD-17.12-eng.pdf?sequence=1&isAllowed=y
2. Tinanoff N, Baez RJ, Diaz Guillory C, et al. Early childhood caries epidemiology, aetiology, risk assessment, societal burden, management, education, and policy: global perspective. *Int J Paediatr Dent*. 2019;29:238-248.

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3. Abanto J, Carvalho TS, Mendes FM, et al. Impact of oral diseases and disorders on oral health-related quality of life of preschool children. *Community Dent Oral Epidemiol*. 2011;39:105-114.
4. Peres MA, Macpherson LMD, Weyant RJ, et al. Oral diseases: a global public health challenge. *Lancet*. 2019;394:249-260.
5. Moynihan PJ, Kelly SA. Effect on caries of restricting sugars intake: systematic review to inform WHO guidelines. *J Dent Res*. 2014;93:8-18.
6. World Health Organization. *Guideline: Sugars Intake for Adults and Children*. WHO. 2015. Accessed October 10, 2021. https://apps.who.int/iris/handle/10665/149782
7. Tham R, Bowatte G, Dharmage SC, et al. Breastfeeding and the risk of dental caries: a systematic review and meta-analysis. *Acta Paediatr*. 2015;104:62-84.
8. Moynihan P, Tanner LM, Holmes RD, et al. Systematic review of evidence pertaining to factors that modify risk of early childhood caries. *JDR Clin Trans Res*. 2019;4:202-216.
9. Manohar N, Hayen A, Scott JA, Do LG, Bhole S, Arora A. Impact of dietary trajectories on obesity and dental caries in preschool children: findings from the healthy smiles healthy kids study. *Nutrients*. 2021;13:2240.
10. Van Meijeren-van Lunteren AW, Voortman T, Elfrink ME, Wolvius EB, Kragt L. Breastfeeding and childhood dental caries: results from a socially diverse birth cohort study. *Caries Res*. 2021;55:153-161.
11. Feldens CA, Giugliani ER, Vigo Á, Vítolo MR. Early feeding practices and severe early childhood caries in four-year-old children from southern Brazil: a birth cohort study. *Caries Res*. 2010;44:445-452.
12. Chaffee BW, Feldens CA, Vítolo MR. Association of long-duration breastfeeding and dental caries estimated with marginal structural models. *Ann Epidemiol*. 2014;24:448-454.
13. Peres KG, Nascimento GG, Peres MA, et al. Impact of prolonged breastfeeding on dental caries: a population-based birth cohort study. *Pediatrics*. 2017;140:e20162943.
14. Devenish G, Mukhtar A, Begley A, et al. Early childhood feeding practices and dental caries among Australian preschoolers. *Am J Clin Nutr*. 2020;111:821-828.
15. Peres KG, Chaffee BW, Feldens CA, et al. Breastfeeding and oral health: evidence and methodological challenges. *J Dent Res*. 2018;97:251-258.
16. Robins JM, Hernan MA, Brumback B. Marginal structural models and causal inference in epidemiology. *Epidemiology*. 2000;11:550-560.
17. De Stavola BL, Daniel RM. Marginal structural models: the way forward for life-course epidemiology? *Epidemiology*. 2012;23:233-237.
18. Wang A, Arah OA. G-computation demonstration in causal mediation analysis. *Eur J Epidemiol*. 2015;30:1119-1127.
19. Cardoso MA, Matijasevich A, Malta MB, et al. Cohort profile: the maternal and child health and nutrition in Acre, Brazil, birth cohort study (MINA-Brazil). *BMJ Open*. 2020;10:e034513.
20. World Health Organization. *Oral Health Surveys: Basic Methods*. 5th ed. World Health Organization. 2013. Accessed October 10, 2021. https://apps.who.int/iris/handle/10665/97035
21. Knutson JW. An index of the prevalence of dental caries in school children. *Public Health Rep*. 1944;59:253-263.
22. Filmer D, Pritchett LH. Estimating wealth effects without expenditure data--or tears: an application to educational enrollments in states of India. *Demography*. 2001;38:115-132.
23. Garcia MT, Granado FS, Cardoso MA. Complementary feeding and nutritional status of 6-24-month-old children in Acrelândia, Acre State, Western Brazilian Amazon. *Cad Saude Publica*. 2011;27:305-316.
24. Ribeiro CCC, Silva MCBD, Nunes AMM, et al. Overweight, obese, underweight, and frequency of sugar consumption as risk indicators for early childhood caries in Brazilian preschool children. *Int J Paediatr Dent*. 2017;27:532-539.
25. Daniel RM, De Stavola BL, Cousens SN. Gformula: estimating causal effects in the presence of time-varying confounding or mediation using the G-computation formula. *Stata J*. 2011;11:479-517.
26. Naimi AI, Cole SR, Kennedy EH. An introduction to g methods. *Int J Epidemiol*. 2017;46:756-762.
27. Snowden JM, Rose S, Mortimer KM. Implementation of G-computation on a simulated data set: demonstration of a causal inference technique. *Am J Epidemiol*. 2011;173:731-738.
28. Chaffee BW, Feldens CA, Rodrigues PH, et al. Feeding practices in infancy associated with caries incidence in early childhood. *Community Dent Oral Epidemiol*. 2015;43:338-348.
29. Bernabé E, Ballantyne H, Longbottom C, et al. Early introduction of sugar-sweetened beverages and caries trajectories from age 12 to 48 months. *J Dent Res*. 2020;99:898-906.
30. Sheiham A, James WP. Diet and dental caries: the pivotal role of free sugars reemphasized. *J Dent Res*. 2015;94:1341-1347.
31. Ricomini Filho AP, de Assis ACM, Costa Oliveira BE, et al. Cariogenic potential of human and bovine milk on enamel demineralization. *Caries Res*. 2021;55:260-267.
32. Ha DH, Do LG, Spencer AJ, et al. Factors influencing early feeding of foods and drinks containing free sugars: a birth cohort study. *Int J Environ Res Public Health*. 2017;14:1270.
33. Kramer MS, Kakuma R. Optimal duration of exclusive breastfeeding. *Cochrane Database Syst Rev*. 2012;2012:CD003517.
34. World Health Organization. *Ending childhood dental caries: WHO implementation manual*. WHO. 2019. Accessed October 10, 2021. https://apps.who.int/iris/handle/10665/330643
35. Pitts N, Baez R, Diaz- Guallory C, et al. Early childhood caries: IAPD Bangkok declaration. *Int J Paediatr Dent*. 2019;29:384-386.
36. Dewey KG, Pannucci T, Casavale KO, et al. Development of food pattern recommendations for infants and toddlers 6-24 months of age to support the Dietary Guidelines for Americans, 2020-2025. *J Nutr*. 2021;151:3113-3124.

SUPPORTING INFORMATION

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

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