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Early life factors and dental caries in 5-year-old children in China

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ABSTRACT

Objectives: This study aimed to explore the association between early life factors and dental caries among 5-year-old Chinese children.

Methods: Data from 9722 preschool children who participated in the third National Oral Health Survey of China were analysed. Information on early life (birth weight, breastfeeding and age when toothbrushing started), child (sex, ethnicity, birth order and dental behaviours) and family factors (parental education, household income, place of residence, number of children in the family, respondent's age and relation to the child) were obtained from parental questionnaires. Children were also clinically examined to assess dental caries experience using the decayed, missing and filled teeth (dmft) index. The association of early life factors with dmft was evaluated in negative binomial regression models.

Results: We found that birth weight was not associated with dental caries experience; children who were exclusively and predominantly formula-fed had lower dmft values than those exclusively breastfed; and children who started brushing later in life had higher dmft values than those who were brushing within the first year. Only one in seven of all children received regular toothbrushing twice per day, and only 34.7% had commenced toothbrushing by the age of 3 years.

Conclusions: This study shows certain early life factors play a role in dental caries among Chinese preschool children and provides important insights to shape public health initiatives on the importance of introducing early toothbrushing.

Clinical significance: The early environment, especially the age when parents introduce toothbrushing to their children, can be an important factor to prevent childhood dental caries.

1. Introduction

Untreated tooth decay is the most common health problem worldwide [1,2]. The Global Burden of Disease (GBD) Study showed 9% of children had untreated decay into dentine in primary teeth − sufficiently severe to require a filling or extraction − with a peak at age 5–6 years [2]. Dental caries can negatively affect children's well-being, including growth and school performance [3,4], and is very costly to treat, thereby placing a major financial burden on families and the healthcare system [5]. Researchers have recently started to examine distal determinants of dental caries, i.e. those beyond child behaviours and oral factors, to identify high-caries risk children early in life [6].

A life course approach to chronic disease epidemiology recognises how exposures early in the lifespan influence disease risk later in life, and hence, may help explain inequalities in child and adult morbidity and mortality [7,8]. Early life factors refer to socially-patterned experiences during prenatal and infant life which may lead to changes in the structure or function of organs and systems, thus affecting health in childhood and later life [7,8]. They can impact on children's growth and development [9], and are associated with a number of chronic conditions [10,11]. Two notable factors in early life are low birth weight and breastfeeding. Low birth weight, a marker of fetal growth, has been linked to a variety of chronic diseases in later life [10]. Impaired fetal nutrition and growth may affect the development of primary teeth, which commences in utero [12]. A systematic review of the relationship between low birth weight and subsequent development of caries identified 4 papers, one reporting a longitudinal study, and none of which supported an association [13]. Three subsequent longitudinal

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studies show contradicting results [14–16]. Whilst the benefits of exclusive breastfeeding on child and maternal health are well known [17,18], the picture remains unclear with regard to childhood dental caries. Two recent reviews, based mainly on cross-sectional studies, are equivocal [19,20]. There is growing evidence that breastfeeding beyond 12 months [20,21], and nocturnal feeding [20], may be associated with greater caries experience in primary teeth.

Toothbrushing, a positive health behaviour, is the primary method of mechanical plaque removal [22], and delivery of fluoride in toothpaste to protect against caries [23–26], with professional guidance recommending brushing with a fluoride toothpaste once the first tooth appears and doing so at least twice per day [27].

Based on the above background, further research is needed to explore possible pathways between the multiple layers of influences potentially accounting for how determinants of early childhood caries operate and traverse individual, familial, community, and socio-cultural contexts [28], at national, rather than merely at local level.

The aim of this research was to explore the association between early life factors and dental caries in 5-year-old children in China. We hypothesised that childhood dental caries was positively associated with breastfeeding and negatively associated with low birth weight and late commencement of toothbrushing.

2. Materials and methods

2.1. Data source

This cross-sectional study used data from the 3rd National Oral Health Survey of China (2005), which covered the four World Health Organization (WHO) index ages [29]. All 31 provinces of Mainland China participated in the survey, except for Tibet. Participants were selected using multistage stratified cluster sampling. First, each province was divided into urban and rural areas; urban areas were classified into 3 strata by population size, whereas rural areas were classified into 3 strata by Gross Domestic Product (GDP). Second, one city or county was randomly selected from each stratum. Hence, 3 cities from urban areas and three counties from rural areas were selected from each province. Third, 3 streets or townships were randomly chosen from every city or county, respectively. Fourth, two kindergartens in these streets or townships were chosen randomly from the list of kindergartens provided by the council. Fifth and finally, at each kindergarten, a random sample of 20 children aged 5 years was recruited using the list of enrolees. A target sample of 720 participants was initially set per province, for a total of 21,600 children nationally. A total of 23,365 5-year-olds were clinically examined and questionnaire data were available for 12,692 children as only parents or guardians of half the survey participants were invited to complete questionnaires. Ethical clearance was not required as the present study was based on secondary analysis of anonymised data from an existing national health survey.

2.2. Variables

The number of decayed, missing and filled primary teeth (dmft) was the outcome measure. Dental clinical examinations were carried out with participants seated on a chair, using artificial light, plane mouth mirrors and standard WHO CPI probes. All deciduous teeth were examined and dental caries was diagnosed according to the WHO criteria [29]. Unified training sessions were provided to over 200 survey examiners in Kunming city, Yunnan, before the national survey began. For reliability assessment, duplicate examinations were conducted during the main survey. Five percent of participants were re-examined to calculate inter-examiner reliability, and the Kappa score was 0.94.

Three early life factors, namely birth weight, breastfeeding and age of commencement of toothbrushing, were collected through parental questionnaires. Birth weight, a continuous variable (grams), was recoded into two groups: normal ($\geq$2500 g) and low ($<$ 2500 g) weight at birth. Child feeding approaches during the first four months of life were reported across five categories: exclusively breastfed, predominantly breastfed, mixed-fed (50/50), predominantly formula-fed, and exclusively formula-fed. The age of commencement of toothbrushing was reported as being within first 6 months, 1st, 2nd, 3rd, 4th, or 5th year of life and never/seldom. The first two categories were combined into one variable (within first year), thus providing six categories for analysis.

A number of child and family factors were included in the analysis as potential confounders based on previous literature [9,28]. Child factors were sex, ethnicity, birth order and dental behaviours. Children's ethnicity was assigned by their parents using a list of officially recognised ethnic groups in China, and responses later grouped as Han or minority ethnic group. Dental behaviours included toothbrushing frequency (less often than daily, once a day, and twice a day or more often), last dental visit for any reason (never, within last year, and more than 1 year ago) and frequency of sugar intake. Parents reported their child's intake frequency of five common sugary items (biscuits, cake or sweet bread, candy or chocolate, sugared water, soft drinks and fruit juice) on 6-point ordinal scales. Each sugary item was scored as follows: twice or more a day [2], once a day [1], 2–6 times a week (2/7 = 0.286), once a week (1/7 = 0.143), 1–3 times per month (1/30 = 0.033), seldom/never (0). The weighted scores were chosen to match the lower frequency of consumption in each response category [30,31]. A total score, ranging from 0 to 10, was generated by aggregating scores for the 5 sugary items. Based on this, participants were grouped into 3 categories: less often than daily, once or twice a day, and more than twice a day. Family factors included parental education, household income, place of residence (urban or rural), number of children in the family, respondent's age and their relationship to the child (father, mother and other). Parents were asked to provide an estimate of the annual household income with no pre-set categories. Income data were equivalised using the Luxembourg Income Study scale to account for family size [32,33]. This involved dividing the total household income by the square root of the number of individuals in the family [32]. After equivalisation, household income in Chinese Yuan was categorised into five groups: very low (0–4,999), low (5000–9999), medium (10,000–14,999), high (14,999–19,999) and very high (20,000+).

2.3. Statistical analysis

Post-stratification weights were used to adjust for differences in the age-by-sex-by-ethnicity-by-province distribution between the sample and the general population in the 30 provinces involved in the study, according to the 5th National Demographic Census in 2000. Analyses also took into account the complex survey design (stratification and clustering) to produce corrected standard errors. All analyses were performed in STATA 14 (Stata Corp LP, College Station, TX).

We first present the composition of the sample according to child and family factors. The impact of missing data was evaluated comparing the characteristics of participants with complete data (study sample) and those excluded due to missing values in relevant variables, using the Chi-square test. The proportion of children that were lighter at birth, exclusively breastfed and had started toothbrushing at one year of age or beforehand, was then examined by child and family factors using the Chi-square test.

The association between each early life factor and dmft index was explored in crude and adjusted models using negative binomial regression, as the outcome measure was a count variable with over-dispersion. Rate ratios (RRs) and 95% confidence intervals (95% CI) were therefore reported as the measure of association. The modelling strategy was first to estimate the crude association of each early life factor with dmft, and then, to adjust these estimates for potential confounders at child (sex, ethnicity, birth order, toothbrushing frequency, last dental visit and sugar intake frequency) and family level

Table 1
Characteristics of the sample of 5-year-olds (n = 9722).

Factors	Categories	n[a]	%
Sex	Boy	4961	54.3%
	Girl	4761	45.7%
Ethnicity	Han	8823	90.4%
	Minority ethnic groups	899	9.6%
Place of residence	Rural	4546	67.2%
	Urban	5176	32.8%
Birth order	First child	7958	77.9%
	Second child	1585	19.4%
	Third or later	179	2.7%
Number of children in the family	1 child	7189	67.7%
	2 children	2232	27.5%
	3 or more	301	4.8%
Parental education	Up to primary school	1437	21.2%
	Junior middle school	3485	41.4%
	Senior middle school	2479	21.4%
	Higher education	2321	16.0%
Household income	Very low	2652	38.3%
	Low	2482	25.7%
	Medium	1918	15.4%
	High	979	7.4%
	Very high	1691	13.1%
Respondent's relationship to child	Father	2795	28.8%
	Mother	6734	68.8%
	Other relatives	193	2.4%
Respondent's age	< 30 years	2195	25.2%
	30–39 years	6937	68.6%
	40+ years	590	6.2%
Toothbrushing frequency	Less often than daily	3450	41.1%
Once a day	4530		44.7%
	Twice a day or more	1742	14.2%
Last dental visit	Never	7451	79.3%
	Within last year	1489	13.4%
	Over 1 year ago	782	7.3%
Sugar intake frequency	Less often than daily	5805	59.3%
	Once or twice a day	2467	25.0%
	More than twice a day	1450	15.7%

[a] Counts are unweighted.

(parental education, household income, place of residence, number of children in the family, respondent's age and relation to the child). The adjusted model also included the other early life factors in order to explore their relative contribution to explain variations in dental caries experience.

Undertaking sensitivity analysis, we evaluated the impact of the respondent's relationship to the child as this might have an influence on the findings [34,35]. To that end, we repeated our set of regression models with the subgroup of children for whom the mother completed the parental questionnaire.

3. Results

A total of 9722 children with complete data in all relevant variables were included in this analysis (representing 77% of those whose parents were invited to complete the questionnaire). The characteristics of the study sample are presented in Table 1. Children in urban, wealthier and single-child families were more likely to be included in the study sample. No other differences, even for the three early life factors and dental caries experience, were found between the study sample and those excluded because of missing data. The mean dmft was 3.59 (95% CI: 3.37–3.81) and 66.9% (64.5–69.2%) of children had experienced dental caries. The average number of decayed teeth was 3.49 (3.26–3.71), representing 97.2% of the dmft index.

Overall, 3.7% (CI: 3.0–4.5%) of children were lighter at birth, 62.2% (CI: 61.0–63.3%) were exclusively breastfed and only 2% (CI: 1.5–2.6%) were toothbrushing at the age of one year. Low birth weight was significantly more common in girls, later-born children within the family, larger families and less educated parents (Table 2). Exclusively breastfeeding was more common in later-born children, those living in rural areas, and amongst less educated, poorer and younger parents. Early toothbrushing (aged 1 year or below) was more common in first-born children, smaller and urban families, and those children with older, more educated and wealthier parents Toothbrushing was not a social norm with only 34.7% of children reported as having started toothbrushing by 3 years of age.

Breastfeeding, and age when brushing started, but not birth weight, were significantly associated with dental caries experience in un-adjusted models (Table 3). Children who were exclusively, and predominantly, formula-fed had significantly lower dmft values than those exclusively breastfed. Children who commenced toothbrushing later in life, however, had higher dmft values than those who started within the first year after birth. These associations were attenuated, but remained significant, after adjustment for child and family factors. In the adjusted model, children who were 'exclusively' and 'predominantly' formula-fed had significantly lower dmft values than those who were exclusively breastfed, whereas children who started toothbrushing after their first year later had significantly higher dmft values than those who started aged one or before, with dmft values increasing with each year of delay in commencement of toothbrushing. Other significant factors were parental education, child birth order, sugar intake frequency and dental attendance (Table 4).

Associations were slightly attenuated when analysis was restricted to mothers. Only children that were exclusively formula-fed had a lower dmft than those who were exclusively breastfed. The later children commenced toothbrushing, the higher the dmft values, with those who started brushing in the 2nd, 3rd, 4th and 5th year of life showing 34%, 43%, 57% and 60% higher dmft values than those who had started brushing during or before their first year.

4. Discussion

This study shows that certain early life factors were associated with childhood dental caries among Chinese pre-school children. Formula-fed children and those who started brushing earlier had lower caries experience by age 5 years. However, birth weight was not associated with children's caries experience. These findings were not accounted for by several well-known determinants of early childhood caries.

Some limitations of this study need to be addressed. First, this analysis was based on cross-sectional data and therefore only able to test for association rather than causal relationships. Second, we used data from a survey conducted in 2005. Despite being conducted over a decade ago, the 3rd national Oral Health Survey remains the latest data available and the contemporary reference in China. Third, our study sample included only 77% of the participants with parental questionnaire, which may raise some concerns about the impact of missing data and the representativeness of the sample. However, no major differences were found between the study sample and those excluded because of missing values, suggesting that the present findings could be generalised to the study population. Fourth, information on early life factors was based on parental reports with a long recall period, which might result in greater measurement error. However, parental reports of their children's birth weight [34,36], and breastfeeding practices [35,37], after many years have been shown to be valid and reliable when compared with medical records. Whilst parental reports are considered to be more accurate if provided by mothers, who tend to be more involved in child care in the early years [34,35], our sensitivity analysis, however, found similar results for parents overall as when restricting the analysis to participants whose mother completed the questionnaire.

The most controversial finding of this study is that exclusively and predominantly formula-fed children have lower caries experience than exclusively breastfed children. Although available evidence is far from settled, most of the debate has focused on whether breastfeeding has a protective effect on children's dental status or not, rather than whether

Table 2
Low birth weight, exclusive breastfeeding and early toothbrushing (within the first year of life) according to child and family factors (n = 9722).

Factors	Categories	Low birth weight	Exclusively breastfed	Early toothbrushing
		% (95% CI)	% (95% CI)	% (95% CI)
Sex	Boy	3.2% (2.6–3.9%)	61.2% (59.4–63.0%)	1.8% (1.2–2.4%)
	Girl	4.2% (3.2–5.2%)	63.3% (61.9–64.7%)	2.2% (1.5–3.0%)
	P value[a]	*0.012*	*0.072*	*0.229*
Ethnicity	Han	3.6% (2.9–4.3%)	62.7% (61.3–64.1%)	2.1% (1.5–2.7%)
	Minority ethnic groups	4.3% (3.0–5.6%)	56.9% (50.2–63.7%)	1.0% (0.0–2.1%)
	P valuea	*0.148*	*0.107*	*0.186*
Place of residence	Rural	4.0% (3.0–5.0%)	66.4% (64.9–67.8%)	0.7% (0.1–1.2%)
	Urban	3.0% (2.1–3.9%)	53.6% (52.0–55.2%)	4.7% (3.4–6.0%)
	P value[a]	*0.128*	*< 0.001*	*< 0.001*
Birth order	First child	3.3% (2.8–3.9%)	61.2% (59.6–62.9%)	2.4% (1.8–3.0%)
	Second child	4.9% (2.7–7.2%)	64.8% (62.4–67.2%)	0.5% (0.1–0.9%)
	Third or latter	4.7% (2.4–7.0%)	71.1% (59.8–82.4%)	1.1% (0.0–3.3%)
	P value for trend[a]	*0.008*	*0.022*	*0.009*
Number of children in the family	1 child	3.1% (2.6–3.6%)	61.4% (59.5–63.2%)	2.6% (1.9–3.3%)
	2 children	4.8% (2.7–6.9%)	63.4% (61.6–65.3%)	0.6% (0.2–1.0%)
	3 or more	5.2% (2.8–7.6%)	66.7% (58.6–74.7%)	0.8% (0.0–2.1%)
	P value for trend[a]	*0.006*	*0.154*	*0.001*
Parental education	Up to primary school	6.1% (3.8–8.4%)	70.1% (67.4–72.8%)	0.2% (0.0–0.6%)
	Junior middle school	3.1% (2.4–3.9%)	65.7% (63.4–68.1%)	0.9% (0.4–1.4%)
	Senior middle school	2.6% (1.5–3.8%)	55.8% (52.4–59.3%)	2.6% (1.8–3.3%)
	Higher education	3.3% (2.1–4.6%)	51.0% (48.2–53.8%)	6.4% (4.5–8.3%)
	P value for trend[a]	*0.011*	*< 0.001*	*< 0.001*
Household income	Very low	3.9% (3.0–4.8%)	67.6% (64.8–70.4%)	0.4% (0.2–0.5%)
	Low	4.3% (2.9–5.7%)	62.7% (59.9–65.5%)	1.2% (0.5–1.9%)
	Medium	3.0% (1.9–4.2%)	59.4% (57.4–61.3%)	2.4% (1.6–3.3%)
	High	3.2% (1.0–5.4%)	59.8% (53.0–66.6%)	3.7% (2.1–5.2%)
	Very high	2.9% (1.4–4.5%)	49.9% (47.2–52.7%)	6.9% (4.6–9.2%)
	P value for trend[a]	*0.208*	*< 0.001*	*< 0.001*
Respondent's relationship to child	Father	4.0% (2.9–5.1%)	60.9% (56.9–64.8%)	1.7% (1.3–2.1%)
	Mother	3.5% (2.8–4.3%)	62.3% (60.7–64.0%)	2.2% (1.4–2.9%)
	Other relatives	3.8% (1.1–6.5%)	73.6% (67.1–80.1%)	0.3% (0.0–0.9%)
	P value[a]	*0.326*	*0.206*	*0.604*
Respondent's age	< 30 years	3.3% (2.5–4.1%)	66.1% (63.8–68.4%)	1.3% (0.5–2.1%)
	30–39 years	3.5% (2.5–4.5%)	60.9% (59.4–62.3%)	2.3% (1.6–2.9%)
	40+ years	6.5% (3.9–9.1%)	60.8% (56.4–65.3%)	1.9% (0.5–3.2%)
	P value for trend[a]	*0.063*	*0.001*	*0.013*

[a] Chi-square test was used with unordered categories and Chi-square test for linear trends with ordered categories.

it is bad for teeth. A recent longitudinal study in Japan found that infants who had been breastfed for 6–7 months, both exclusively and partially, were at higher risk of dental caries at 30 months than those who had been exclusively formula-fed; however, the adverse effect of breastfeeding waned as children grew older and were no longer significant beyond 42 months for the partially breastfed group and 54 months for the exclusively breastfed group [38]. Based on our findings, we argue that in China, like in most low and middle income countries, artificial feeding is mostly available to wealthier families given the cost of infant formula, and as such, it may represent a very strong indicator of family socioeconomic position (SEP) at birth. Indeed, we found higher proportions of breastfed children at lower levels of parental education and income as well as an association between household income and childhood dental caries in the crude but not in the adjusted model. If breastfeeding reflects family SEP at birth in China, family SEP when children are 5 years old would be an intermediate factor in the association between family SEP at birth and dental caries and its association with the outcome may be evident after controlling for family SEP at birth. Adjusting for indicators of family SEP at birth would shed some light on this area and should be tested in future research. At present, the American Academy of Paediatrics (AAP) recommends mothers to adopt breast feeding for the first year as this helps the infant develop their immune system [39], whilst WHO suggests exclusive breast feeding for the first 6 months for similar reasons [40]. It might therefore be too early to set a final recommendation about breastfeeding and dental caries.

A very important finding from this research is the clear dose-response relationship between the age when toothbrushing commenced and children's caries experience, suggesting that the later children start brushing their teeth, the greater their caries experience by the age of 5 years. Furthermore, our findings reveal that only a very small minority of children (2%) had started toothbrushing within the first year after birth, and only one third of children had started toothbrushing at the age of 3 years, when the full primary dentition is in place, whereas only 14.2% of the total were brushing twice per day or more. Early toothbrushing is clearly not the societal norm in China and our findings provide evidence of higher caries experience with each passing year toothbrushing is delayed. Whether this finding reflects the effect of mechanical plaque removal, use of fluoride toothpaste or a combination of both is unknown in this population. However, given the strong evidence on the benefits of fluoride [23–26], the advice should be for parents to start toothbrushing with a standard (1000–1500 ppm) fluoride toothpaste [41], when teeth erupt [42], which is generally well before a child's first birthday; and to brush at least twice per day [42], last thing at night and at one other time. The importance of parental brushing and supervision until a child is aged 7 years of age is also important [42], and should be explored in future research.

Interestingly, birth weight was not associated with childhood dental caries in the present study. A suggested mechanism linking low birth weight and childhood caries is the effect on the development of the dentition in utero [12]. Although it is now clear that developmental enamel defects, hypoplasia in particular, increase the susceptibility of caries development [43], stronger evidence for an association between impaired fetal growth and enamel hypoplasia has been found in infants

Table 3
Association between early life factors and the number of decayed, missing and filled primary teeth (dmft) among 5-year-old Chinese children (n = 9722).

Factors	Categories	Mean dmft (95% CI)	Crude RR[a] (95% CI)	Adjusted RR[a] (95% CI)
Birth weight	Normal	3.60 (3.38–3.82)	1.00 (Reference)	1.00 (Reference)
	Low	3.39 (2.81–3.97)	0.94 (0.82–1.09)	0.98 (0.83–1.15)
Breastfeeding	Exclusively breastfed	3.63 (3.42–3.85)	1.00 (Reference)	1.00 (Reference)
	Predominantly breastfed	3.83 (3.42–4.24)	1.05 (0.96–1.16)	1.03 (0.93–1.15)
	mixed-fed (50/50)	3.66 (3.03–4.29)	1.01 (0.86–1.18)	1.04 (0.91–1.19)
	Predominantly formula-fed	2.99 (2.59–3.39)	0.82 (0.71–0.95)**	0.83 (0.71–0.97)*
	Exclusively formula-fed	2.93 (2.43–3.43)	0.81 (0.70–0.92)**	0.84 (0.75–0.94)**
Age when toothbrushing started	Before or within first year	2.21 (1.83–2.59)	1.00 (Reference)	1.00 (Reference)
	2nd year	3.39 (2.73–4.06)	1.54 (1.22–1.94)**	1.41 (1.21–1.64)***
	3rd year	3.40 (3.18–3.61)	1.54 (1.30–1.82)***	1.42 (1.22–1.66)***
	4th year	3.77 (3.39–4.14)	1.70 (1.40–2.08)***	1.54 (1.29–1.84)***
	5th year	4.14 (3.80–4.49)	1.87 (1.55–2.26)***	1.67 (1.36–2.05)***
	Never/seldom	3.45 (3.15–3.76)	1.56 (1.26–1.93)***	1.34 (1.12–1.61)**
Sex	Boy	3.64 (3.35–3.92)	1.00 (Reference)	1.00 (Reference)
	Girl	3.54 (3.32–3.75)	0.97 (0.90–1.05)	0.97 (0.90–1.03)
Ethnicity	Han	3.54 (3.30–3.79)	1.00 (Reference)	1.00 (Reference)
	Minority ethnic groups	4.03 (3.46–4.60)	1.14 (0.96–1.34)	1.07 (0.86–1.34)
Place of residence	Rural	3.80 (3.50–4.11)	1.00 (Reference)	1.00 (Reference)
	Urban	3.16 (2.81–3.50)	0.83 (0.72–0.95)*	0.89 (0.74–1.06)
Birth order	First child	3.58 (3.38–3.79)	1.00 (Reference)	1.00 (Reference)
	Second child	3.60 (3.15–4.06)	1.01 (0.91–1.11)	0.85 (0.75–0.98)*
	Third or latter	3.66 (3.08–4.24)	1.02 (0.87–1.20)	0.73 (0.56–0.94)*
Number of children in the family	1 child	3.48 (3.28–3.68)	1.00 (Reference)	1.00 (Reference)
	2 children	3.77 (3.45–4.10)	1.08 (1.01–1.17)*	1.14 (1.00–1.30)
	3 or more	4.12 (3.27–4.97)	1.18 (0.97–1.44)	1.36 (0.96–1.91)
Parental education	Up to primary school	3.86 (3.59–4.12)	1.00 (Reference)	1.00 (Reference)
	Junior middle school	3.81 (3.44–4.19)	0.99 (0.87–1.12)	0.96 (0.85–1.09)
	Senior middle school	3.43 (3.08–3.79)	0.89 (0.78–1.02)	0.85 (0.72–1.00)
	Higher education	2.87 (2.62–3.12)	0.74 (0.68–0.82)***	0.73 (0.61–0.88)**
Household income	Very low	3.77 (3.51–4.02)	1.00 (Reference)	1.00 (Reference)
	Low	3.74 (3.43–4.05)	0.99 (0.92–1.07)	0.97 (0.92–1.03)
	Medium	3.43 (3.14–3.72)	0.91 (0.85–0.98)*	0.97 (0.90–1.04)
	High	3.28 (2.89–3.66)	0.87 (0.78–0.97)*	0.94 (0.83–1.07)
	Very high	3.15 (2.81–3.49)	0.84 (0.74–0.94)**	0.92 (0.81–1.04)
Respondent's relation to child	Father	3.62 (3.22–4.01)	1.00 (Reference)	1.00 (Reference)
	Mother	3.60 (3.39–3.81)	1.00 (0.90–1.10)	0.99 (0.91–1.08)
	Other relatives	3.00 (2.02–3.98)	0.83 (0.61–1.13)	0.73 (0.50–1.07)
Respondent's age	< 30 years	3.76 (3.41–4.11)	1.00 (Reference)	1.00 (Reference)
	30–39 years	3.53 (3.32–3.73)	0.94 (0.87–1.01)	0.98 (0.92–1.04)
	40+ years	3.60 (3.23–3.97)	0.96 (0.86–1.06)	1.10 (0.98–1.23)
Toothbrushing	Less often than daily	3.64 (3.36–3.91)	1.00 (Reference)	1.00 (Reference)
	Once a day	3.62 (3.34–3.91)	1.00 (0.91–1.10)	0.95 (0.87–1.04)
	Twice a day or more	3.35 (2.96–3.74)	0.92 (0.82–1.04)	0.92 (0.83–1.03)
Last dental visit	Never	3.12 (2.89–3.35)	1.00 (Reference)	1.00 (Reference)
	Within last year	5.70 (5.36–6.04)	1.82 (1.69–1.97)***	2.04 (1.86–2.25)***
	Over 1 year ago	4.77 (4.24–5.30)	1.53 (1.37–1.70)***	1.65 (1.47–1.85)***
Sugar intake frequency	Less often than daily	3.38 (3.17–3.59)	1.00 (Reference)	1.00 (Reference)
	Once or twice a day	3.67 (3.38–3.96)	1.08 (1.03–1.14)**	1.08 (1.01–1.14)*
	More than twice a day	4.25 (3.90–4.61)	1.26 (1.16–1.36)***	1.27 (1.16–1.39)***

[a] Negative binomial regression models were fitted and rate ratios (RRs) reported.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

with very low birth weight [12]. It is thus possible that an effect exists, but was masked because very low birth weight, which leads to severe fetal growth restriction, was not recorded in this study.

The present findings have very important implications for public health policy and further research. With rapid economic development in the last decade, dental caries has emerged as one of the major health problems affecting the Chinese population, especially children. As a highly preventable disease, we must emphasise the importance of controlling modifiable early life risk factors, the simplest and easiest of which is toothbrushing with fluoride toothpaste. Health public policy and environmental and community action should promote and support the practice of regular twice-daily toothbrushing. Given the links with other health care professionals during infancy, it will be important to ensure that this modifiable early life factor is addressed. As for research, further studies, ideally using prospective designs and more elaborate methods of assessment of breastfeeding and family factors at birth should be conducted.

5. Conclusion

In conclusion, our analysis of national survey data shows that early life factors play a role in childhood dental caries among pre-schoolers in China. Whilst low birth weight was not associated with children's dental caries experience, children exclusively breast-fed and those starting toothbrushing at a later age were more likely to have greater caries experience at 5 years of age. Toothbrushing frequency among young children falls well below evidence-based prevention norms and demands urgent public health action.

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Table 4
Association between early life factors and the number of decayed, missing and filled primary teeth (dmft) among 5-year-old Chinese children whose mothers completed the questionnaire (n = 6734).

Factors	Categories	Crude RR[a] (95% CI)	Adjusted RR[a] (95% CI)
Birth weight	Normal	1.00 (Reference)	1.00 (Reference)
	Low	0.85 (0.69–1.06)	0.88 (0.69–1.13)
Breastfeeding	Exclusively breastfed	1.00 (Reference)	1.00 (Reference)
	Predominantly breastfed	1.08 (0.94–1.24)	1.05 (0.91–1.21)
	mixed-fed (50/50)	0.91 (0.79–1.06)	0.97 (0.84–1.13)
	Predominantly formula-fed	0.84 (0.69–1.02)	0.83 (0.68–1.02)
	Exclusively formula-fed	0.75 (0.64–0.88)**	0.82 (0.72–0.93)**
Age when toothbrushing started	Before or within first year	1.00 (Reference)	1.00 (Reference)
	2nd year	1.42 (1.05–1.91)*	1.34 (1.03–1.75)*
	3rd year	1.49 (1.17–1.91)**	1.43 (1.13–1.82)**
	4th year	1.63 (1.24–2.14)**	1.57 (1.18–2.08)**
	5th year	1.74 (1.33–2.26)***	1.60 (1.16–2.19)**
	Never/seldom	1.51 (1.15–1.98)**	1.42 (1.07–1.89)*

[a] Negative binomial regression were fitted and rate ratios (RRs) reported. The adjusted model included the three early life factors plus all child (sex, ethnicity, birth order, low birth weight, breastfeeding, age when toothbrushing started, toothbrushing frequency, last dental visit and sugar intake frequency) and family factors (parental education, household income, place of residence, number of children in the family, respondent's age and relation to the child) as explanatory variables.

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

None.

Author contributions

Jennifer E. GALLAGHER and Shuguo ZHENG conceived the programme of research. Xiangyu SUN and Eduardo BERNABÉ undertook analysis with equal contribution. Xiangyu SUN, Eduardo BERNABÉ and Jennifer E. GALLAGHER drafted the paper. Xuenan LIU and Shuguo ZHENG provided important instructions on the protocol of the survey and critically revised the draft.

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