Bottle feeding to sleep beyond 12 months is associated with higher risk of tooth decay and overweight in Australian children: Findings from the Healthy Smiles Healthy Kids cohort study

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Abstract

Objective: Bottle feeding to sleep may increase early childhood caries (ECC) and overweight risk through sugar exposure and overfeeding. This study examined the association between feeding to sleep at 24 and 36 months on both ECC and overweight at 3-4 years.

Methods: Participants were children in the Healthy Smiles Healthy Kids longitudinal birth cohort. Exposure was bottle feeding to sleep at 24 and 36 months. Outcomes were ECC (prevalence; number of caries-affected tooth surfaces, dmfs) and overweight at 3-4 years.

Results: 718 and 729 children had dental examinations and anthropometric measurements, respectively. 30.3% and 21.7% of children were bottle-fed to sleep at 24 and 36 months, respectively. Feeding to sleep at 24 months was associated with higher odds of overweight (OR 1.90, 95%CI 1.06-3.38) and moderately associated with higher caries (dmfs 1.48, 95%CI 1.00-2.20). Feeding to sleep at 36 months was associated with higher caries (dmfs 1.88, 95%CI 1.22-2.91).

Conclusions: Feeding to sleep was associated with higher odds of overweight and higher numbers of caries-affected tooth surfaces. Communicating appropriate sleep, settling and bottle cessation methods throughout early childhood may prevent ECC and overweight.

Implications for Public Health: Early interventions addressing bottle feeding could reduce the dual burden of ECC and obesity.

Key words: early childhood caries, overweight, bottle feeding, toddler health, feeding behavior, cohort study

Introduction

Bottle feeding of infants may increase the risk of early childhood caries (ECC, dental caries in any primary teeth for a child aged under six years) and overweight/obesity through exposure to sugar and overnutrition.[1] Bottle feeding can cause prolonged exposure of teeth to sugar from feeding to sleep or lead to prolonged bottle use if infants do not transition to cup use at the recommended age.[2] Bottle feeding may be non-responsive to hunger and appetite cues, through the practice of feeding to sleep, or due to the relative ease of feeding by bottle sucking compared to cup drinking–which in turn leads to overfeeding.[3,4] Prolonged bottle use, when infants should transition to cup use, may be associated with increased obesity risk through the cumulative effects of obesogenic bottle content, non-appetitive feeding with bottles, and bottle feeding to settle behaviour (e.g. crying, tantrums).[5] Prolonged bottle use is

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associated with unhealthy feeding behaviours, such as excessive milk or formula intake, which can displace regular meals or food groups and increase the risk of iron depletion and deficiency.[6–8] Bottle content—including expressed breast milk, infant or toddler formula, cow's milk and fruit juice—may also vary in cariogenic or obesogenic risk.[9] While educational interventions in primary and community health settings may support behaviour change for bottle cessation,[10] prolonged bottle feeding exists in complex sociocultural environments that are exacerbated by parenting challenges and resource constraints, which maintain the prolonged use of bottles to settle infant and young child behaviour.[11,12]

Existing guidelines on the recommended age of bottle cessation and transition to cup use, advise cessation at 12 months—the recommendation in the Australian national dietary guidelines—or between 12-18 months of age.[13] However, bottle use can frequently persist beyond recommended ages. For example, just over a third of Aboriginal Australian children in the Gudaga birth cohort were drinking with bottles at 18 months of age,[14] while nearly two-thirds of 18-month toddlers were fed with bottles in the Avon Longitudinal Study of Pregnancy and Childhood in the UK,[15] and 92% and 53% of 18-24 and 48 months of age children were fed with bottles in one Hong Kong study.[8]

A common risk factor approach to ECC and overweight/obesity prevention in early childhood can target inappropriate bottle feeding practices. The most recent Australian national health surveys found that 24.6% of children, aged 2-4 years, had overweight or obesity in 2017-2018,[16] while 34.3% of children, aged 5-6 years, had ECC in 2012-2014.[17] These surveys also showed sociodemographic factors related to prevalence–for example, 20.8% and 28.1% of children, aged 2-17 years, in the highest and lowest socioeconomic areas, respectively, had overweight or obesity,[16] and 31.7% and 39.0% of children, aged 5-6 years, for parents' country of birth being Australia or overseas, respectively.[17] These sociodemographic factors may overlap to influence the risk of developing ECC and overweight, thereby exacerbating the risk of dental caries and overweight persisting past early childhood. Furthermore, sociodemographic factors also influence other factors, such as access to timely preventative dental care, waiting time to access public dental care, or financial ability to maintain healthy diets that reduce the risk of ECC and overweight/obesity.[1,18–20] This exemplifies the need for equitable health care for populations with increased vulnerability. Therefore, addressing sub-optimal bottle-feeding behaviours may help in reducing the risk of both ECC and overweight. This study examined the association between bottle feeding to sleep with any non-water drinks beyond the age of 12 months, and risk of dental caries and overweight/obesity, measured in a birth cohort at 3-4 years of age.

Methods

The Healthy Smile Healthy Kids (HSHK) longitudinal birth cohort, which was undertaken in a culturally diverse and socioeconomically diverse area of Sydney, Australia, has been previously described.[21] Briefly, mother-infant dyads, without known medical conditions or disability, were recruited during their first postnatal visit with child and family health nurses at 4-6 weeks of age. Recruitment was undertaken between October 2009 and February 2010, in public hospitals within Sydney and South Western Sydney Local Health Districts. Data were collected at 8 weeks, 4 months, 8 months, 1 year, 2 years and 3 years age, through telephone interviews. At 3-4 years of age, children were invited to attend dental assessment and anthropometric measurements, conducted by trained health professionals.[22]

Outcome measures

The two primary outcomes were ECC and overweight or obesity at 3-4 years of age. ECC was characterised by any primary teeth with decayed, missing (due to caries) or filled surfaces (dmfs).[9] Child height and weight were measured to calculate a BMI z-score (zBMI) for age and sex, using WHO AnthroPlus software for child growth standards.[23] zBMI was classified into underweight (<-2 standard deviation [SD]), healthy (≥-2 and ≤+2 SD), overweight (>+2 and ≤+3 SD) or obesity (>3 SD) categories. Overweight and obesity categories were combined, due to only a few children having obesity–referred, hereafter, as 'overweight'. Children with underweight were omitted from logistic regression analysis, due to the small sample. To eliminate the influence of extreme values, improbable values (≥5 zBMI) were omitted from analysis.[24]

Potential predictors of outcome measures

A series of family and infant characteristics were recorded. Data collected are summarised in Supplementary Table 1. Sociodemographic characteristics included area-level socioeconomic status, reported by the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD),[25] and maternal age, education, occupation, marital status, smoking status, alcohol intake, and country of birth as proxy for ethnicity. Birth characteristics were birth method, gestational age, birth weight and term pregnancy. Of the various feeding practices assessed, the primary exposure was bottle feeding to sleep with non-water drinks at bedtime and/or nap time–i.e. any caloric drink with cariogenic potential, including formula, expressed breast milk, cow's milk, juice or other sugary drinks (Supplementary Table 1). Timepoints selected for analysis were 24 and 36 months, which demonstrate prolonged bottle use past the recommended 12-month age of cessation.[26] Dental health behaviours and physical activity were assessed at 36 months.

Statistical analysis

Statistical analysis was undertaken in R Statistical Software (v4.2.2, R Core Team, Vienna, Austria). Continuous data were reported as mean ± SD. Categorical data were reported as frequency and percentage. Comparison of categorical variables was analysed with chi-squared tests or McNemar's test for paired data.[27]

Multivariable logistic and linear regression was used to assess the relationship between bottle feeding to sleep with ECC or overweight, and the number of caries-affected tooth surfaces (dmfs) and zBMI score, respectively. Based on the prevalence of overweight and ECC, this was reported as odds ratios (ORs) or prevalence ratios (PRs), with 95%CI, respectively. Poisson distribution, using negative binomial distribution was used to model change in dmfs. PR and negative binomial distribution modelling used the logbin and MASS R packages.[28,29] Cases with missing variables were excluded from regression analysis.

Multivariable regression was informed by confounders determined from univariable analysis and previous literature.[2,4] Univariable analysis determined the covariate selected from similar multicollinear variables, e.g. birth weight, gestational age, term birth. The final confounders were IRSAD; maternal age, education, country of birth, parity and smoking status during pregnancy; child age and sex; and outcome-specific confounders, such as term birth and outdoor physical activity for overweight and tooth brushing frequency for ECC. Significance was set at $p \leq 0.05$, two-tailed.

Sensitivity analysis was undertaken with different categories for maternal country of birth (Australia, English-language overseas country, non-English language overseas country) and child parity, as ethnicity or immigrant status, and categories of multiparity, has been associated with the risk of ECC and overweight.[2,18] Sensitivity analysis was also undertaken with variables of dietary exposure that have been associated with ECC risk: prolonged nighttime breastfeeding past 12 months of age and frequency of sugary food and drink intake.[30]

Results

HSHK participation is summarised in Supplementary Fig. 1. Of 1500 mothers approached, 934 consented to participate and completed baseline and follow-up interviews up to 3 years of age. Data of children who completed dental assessments or anthropometric measurements at 3-4 years of age were analysed for ECC (718, 76.9%) and overweight (729, 78.1%). Nine children with underweight or improbable ≥5 zBMI scores were omitted from the overweight regression analysis.

Participant baseline characteristics are reported in Table 1, with separate analysis by child sex and inclusion and exclusion at 3-4 years analysis in Supplementary Table 2. The only difference at baseline by child sex was birth weight. There was a significant difference between children included or excluded at 3-4 year analysis, based on maternal age, marital status, education, occupation and working status at 1 year post-birth. Feeding and behavioural characteristics after baseline are described in Supplementary Table 3. Further information about participant diets is available in prior publications.[22,31] At the 3-4 year follow-up, the mean age of children was 3.58 ± 0.25 years (median 3.53 years, interquartile range 3.41-3.69 years; range 2.8-4.6 years), with 239 (33.3%) and 65 (8.9%) having ECC and overweight. For children who had ECC, a mean of 5.90 (SD 6.15) tooth surfaces were affected. For children having overweight, the mean zBMI was 2.69 (SD 0.60). There was no association between ECC and weight status (X^2 = <0.01, p=1.000). There was notable prevalence of bottle feeding at bed and/or nap times at 24 and 36 months (30.3% and 21.7%). Bottle feeding to sleep at 24 months was associated with bottle feeding to sleep at 36 months (McNemar's X^2 = 34.18, p=0.001). For children who were bottle-fed to sleep at either 24 or 36 months, bottles contained cow's milk (73.4% to 83.1% of bottles) or formula (21.5% to 22.3% of bottles), with few bottles containing expressed breast milk or other drinks. While most children used toothpaste, just over half met recommended guidelines to brush twice a day.

Unadjusted analysis

Bottle feeding to sleep at 24 months (PR 1.32, 95%CI: 1.06-1.63; dmfs 1.49, 95%CI: 1.00, 2.23) and 36 months (PR 1.56, 95%CI: 1.26-1.93; dmfs 2.41, 95%CI: 1.57, 3.71) was associated with higher prevalence of ECC and caries experience (Supplementary Table 4). Bottle feeding to sleep at 24 months (OR 1.90, 95%CI: 1.11-3.26) was associated with a higher odds of overweight, but not a significant difference in zBMI score. There was no significant association between formula or cow's milk as bottle content and prevalence of ECC or odds of overweight.

Table 1: Participant baseline characteristics.

	Participants (N=934)
Baby gestational age, weeks (mean, SD)	39.1 (2.2)
Term pregnancy (n, %)	
- Pre-term (≤36 weeks)	70 (7.5%)
- Full-term (37-41 weeks) and late (≥42 weeks) term	864 (92.5%)
Baby birth weight, kg (mean, SD)	3.4 (0.6)
Birthweight category (n, %)	
- Low (<2.5 kg)	47 (5.0%)
- Normal (2.5-4 kg) and higher (≥4 kg)	887 (95.0%)
Baby birth method (n, %)	
- Normal vaginal delivery	652 (69.8%)
- Caesarean section	281 (30.1%)
Baby sex (n, %)	
- Male	477 (51.1%)
- Female	457 (48.9%)
IRSAD (n, %)	
- Decile 1-2, most disadvantaged/least advantaged	303 (32.4%)
- Decile 3-4, highly disadvantaged/less advantaged	220 (23.6%)
- Decile 5-6, moderately disadvantaged	30 (3.2%)
- Decile 7-8, low disadvantaged/more advantaged	160 (17.1%)
- Decile 9-10, least disadvantaged/most advantaged	221 (23.7%)
Maternal age, years (mean, SD)	31.2 (5.3)
Maternal marital status (n, %)	
- Single	90 (9.6%)
- Married or de facto	944 (90.4%)
Child parity	
- Primiparous	465 (49.8%)
- Multiparous (range: 2-8 children; mode: 2 children)	469 (50.2%)
Maternal education (n, %)	
- Less than year 12	168 (18.0%)
- Completed year 12	192 (20.6%)
- Vocational/certificate	170 (18.2%)
- University	404 (43.3%)
Maternal occupation (n, %)	
- Home duties/low skilled/student	337 (36.1%)
- Sales and clerical	295 (31.6%)
- Manager or professional	302 (32.3%)
Maternal work status at 1 year (n, %)[a]	
- Not working	485 (56.4%)
- Working	375 (43.6%)
Mother smoking (n, %)	85 (9.1%)
Mother smoking during pregnancy (n, %)	53 (5.7%)
Mother consuming alcohol (n, %)	297 (31.8%)
Mother consuming alcohol during pregnancy (n, %)	100 (10.7%)
Mother's country of birth (n, %)	
- Australia	437 (46.8%)
- Overseas	497 (53.2%)

IRSAD = Index of Relative Socio-economic Advantage and Disadvantage.
[a]Missing data not reported

Further information about the unadjusted analysis is found in the Supplementary File.

Adjusted analysis

During variable selection for multivariable analysis, toothpaste use, as a dental health behaviour, was excluded from analysis as nearly all respondents used toothpaste (84.2% of all children; 97.5% of respondents at 3-4 years).

After adjusting for confounders, bottle feeding to sleep at 24 months was moderately associated with higher caries experiences (dmfs 1.48, 95%CI: 1.00-2.20, *p*=0.051) and associated with higher odds of overweight (OR 1.90, 95%CI: 1.06-3.38), but not associated with prevalence of ECC or zBMI score (Tables 2 and 3). Bottle feeding to sleep at 36 months was strongly associated with higher caries experience (dmfs 1.88, 95%CI: 1.22-2.91) but not associated with prevalence of ECC, odds of overweight or zBMI score (Tables 2 and 3). There remained no association of formula or cow's milk as bottle content and prevalence of ECC or odds of overweight (data not shown).

Compared to children of mothers born in Australia, children of mothers born overseas had a higher prevalence of ECC and caries experience (24 months, PR 1.47, 95%CI: 1.13-1.90, dmfs 2.77, 95%CI: 1.81-4.23; 36 months, PR 1.44, 95%CI: 1.10-1.87, dmfs 2.66, 95%CI: 1.74-4.08). Index children of multiparous mothers had marginally higher prevalence of ECC, but not caries experience (24 months, PR 1.23, 95%CI: 0.99-1.53; 36 months, PR 1.24, 95%CI: 1.24, 1.00-1.55). Children living in the highest areas of socioeconomic disadvantage or born pre-term had marginal (OR 2.56, 95%CI: 0.97-6.78) and strong (OR 3.13, 95%CI: 1.44-6.79) higher odds of overweight, respectively.

Sensitivity analysis

Three sensitivity analysis models for the ECC or overweight outcomes were undertaken, with different categories of maternal country of birth (model 1), child parity (model 2) and both maternal country of birth and child parity (model 3) (Supplementary Tables 5–8).

Table 2: Multivariable logistic regression of early childhood caries prevalence and caries experience at 3-4 yrs.

Dependent variable	Outcomes for bottle feeding to sleep, 24 months					Outcomes for bottle feeding to sleep, 36 months				
	n	PR ECC (95%CI)	*p*-value	dmfs (95%CI)	*p*-value	n	PR ECC (95%CI)	*p*-value	dmfs (95%CI)	*p*-value
Bottle feeding to sleep[a]			0.118		0.051			0.079		0.004
- No bottle feeding (ref)	412	-		-		498	-		-	
- Bottle feeding	242	1.18 (0.96, 1.45)		1.48 (1.00, 2.20)		176	1.22 (0.98, 1.51)		1.88 (1.22, 2.91)	
IRSAD			0.408		0.795			0.596		0.856
- Most disadvantaged/least advantaged (ref)	214	-	-	-	-	224	-	-	-	-
- Highly disadvantaged/less advantaged	158	0.87 (0.68, 1.11)	0.263	0.99 (0.60, 1.63)	0.972	164	0.88 (0.69, 1.14)	0.335	0.94 (0.57, 1.54)	0.805
- Moderately disadvantaged	20	0.65 (0.26, 1.61)	0.346	0.73 (0.23, 2.38)	0.604	19	0.69 (0.28, 1.72)	0.428	0.93 (0.28, 3.06)	0.903
- Less disadvantaged/more advantaged	113	0.86 (0.62, 1.20)	0.384	0.74 (0.41, 1.34)	0.318	118	0.90 (0.64, 1.26)	0.521	0.74 (0.41, 1.34)	0.321
- Least disadvantaged/most advantaged	149	0.72 (0.50, 1.04)	0.083	0.69 (0.39, 1.24)	0.217	149	0.76 (0.53, 1.10)	0.147	0.75 (0.42, 1.35)	0.335
Maternal occupation			0.094		0.445			0.230		0.377
- Home duties/low skilled/student (ref)	215	-	-	-	-	232	-	-	-	-
- Sales and clerical	215	0.81 (0.63, 1.05)	0.113	0.71 (0.43, 1.17)	0.180	212	0.84 (0.64, 1.09)	0.191	0.69 (0.42, 1.12)	0.134
- Manager or professional	224	0.71 (0.51, 1.00)	0.049	0.85 (0.46, 1.58)	0.602	230	0.77 (0.55, 1.08)	0.129	0.80 (0.44, 1.47)	0.474
Maternal education			0.050		0.411			0.177		0.749
- Less than high school (ref)	99	-	-	-	-	104	-	-	-	-
- Finished high school	135	0.72 (0.54, 0.96)	0.027	0.65 (0.34, 1.24)	0.189	139	0.84 (0.63, 1.12)	0.239	0.80 (0.42, 1.52)	0.491
- Vocational/certificate	120	0.65 (0.45, 0.93)	0.020	0.58 (0.29, 1.16)	0.125	122	0.65 (0.45, 0.96)	0.030	0.70 (0.35, 1.40)	0.315
- University	300	0.87 (0.63, 1.19)	0.370	0.83 (0.41, 1.66)	0.596	309	0.89 (0.64, 1.23)	0.466	0.94 (0.47, 1.86)	0.847
Maternal age, years	654	1.00 (0.98, 1.02)	0.610	0.99 (0.95, 1.03)	0.634	674	0.98 (0.96, 1.00)	0.117	0.99 (0.95, 1.02)	0.463
Maternal country of birth			0.004		<0.001			0.007		<0.001
- Australia (ref)	333	-		-		314	-		-	
- Overseas	385	1.47 (1.13, 1.90)		2.77 (1.81, 4.23)		360	1.44 (1.10, 1.87)		2.66 (1.74, 4.08)	
Maternal smoking during pregnancy			0.360		0.822			0.273		0.807
- No (ref)	621	-		-		640	-		-	
- Yes	33	0.79 (0.48, 1.31)		0.89 (0.36, 2.21)		34	0.73 (0.42, 1.28)		0.88 (0.36, 2.20)	
Parity			0.066		0.948			0.052		0.895
- Primiparous (ref)	334	-		-		347	-		-	
- Multiparous	320	1.23 (0.99, 1.53)		0.99 (0.66, 1.47)		327	1.24 (1.00, 1.55)		1.03 (0.70, 1.53)	
Child sex			0.814		0.140			0.974		0.191
- Male (ref)	331	-		-		345	-		-	
- Female	323	0.98 (0.80, 1.19)		0.74 (0.50, 1.07)		329	1.00 (0.81, 1.22)		0.77 (0.53, 1.11)	
Child age, years	654	1.15 (0.77, 1.72)	0.507	0.58 (0.26, 1.31)	0.254	674	1.00 (0.69, 1.45)	1.000	0.58 (0.27, 1.24)	0.222
Child tooth brushing frequency, 3-4 years			0.807		0.807			0.911		0.583
- <2 times/day (ref)	275	-		-		280	-		-	
- ≥2 times/day	379	0.98 (0.80, 1.20)		1.05 (0.72, 1.54)		394	1.01 (0.82, 1.25)		1.12 (0.76, 1.63)	

IRSAD = Index of Relative Socio-economic Advantage and Disadvantage; PR = prevalence ratio.

Toothpaste use, as a dental health behaviour, was excluded from multivariable analysis due to unequal sample size (97.5% of respondents using tooth paste at 3-4 years).

[a]Bottle feeding with any non-water cariogenic, caloric drink (formula, expressed breast milk, cow's milk, fruit juice, fruit drink, other drinks) at bed or nap time

Table 3: Multivariable logistic regression of overweight and zBMI score at 3-4 yrs.

Dependent variable	Outcomes for bottle feeding to sleep, 24 months					Outcomes for bottle feeding to sleep, 36 months				
	n	OR overweight (95%CI)	*p*-value	zBMI (95%CI)	*p*-value	n	OR overweight (95%CI)	*p*-value	zBMI (95%CI)	*p*-value
Bottle feeding to sleep[a]			0.031		0.348			0.474		0.360
-No bottle feeding (ref)	418	-		-		508	-		-	
-Bottle feeding	250	1.90 (1.06, 3.38)		0.08 (-0.08, 0.24)		181	1.25 (0.68, 2.30)		0.09 (-0.10, 0.27)	
IRSAD			0.325		0.095			0.387		0.100
-Most disadvantaged/least advantaged (ref)	212	-	-	-	-	222	-	-	-	-
-Highly disadvantaged/less advantaged	156	0.74 (0.37, 1.48)	0.388	0.02 (-0.19, 0.23)	0.827	164	0.79 (0.40, 1.53)	0.476	0.06 (-0.15, 0.27)	0.574
-Moderately disadvantaged	19	0.94 (0.19, 4.64)	0.944	0.49 (0.02, 0.97)	0.043	18	0.96 (0.19, 4.72)	0.955	0.59 (0.09, 1.08)	0.021
-Less disadvantaged/more advantaged	119	0.52 (0.21, 1.32)	0.169	-0.14 (-0.38, 0.10)	0.257	123	0.60 (0.25, 1.44)	0.248	-0.09 (-0.33, 0.15)	0.457
-Least disadvantaged/most advantaged	162	0.39 (0.15, 1.03)	0.058	-0.12 (0.35, 0.11)	0.307	162	0.40 (0.15, 1.06)	0.064	-0.06 (-0.30, 0.18)	0.610
Maternal occupation			0.265		0.601			0.182		0.684
-Home duties/low skilled/student (ref)	217	-	-	-	-	233	-	-	-	-
-Sales and clerical	218	0.61 (0.31, 1.21)	0.157	-0.09 (-0.30, 0.11)	0.375	216	0.59 (0.30, 1.16)	0.127	-0.05 (-0.25, 0.16)	0.654
-Manager or professional	233	0.53 (0.20, 1.39)	0.196	-0.11 (-0.37, 0.14)	0.386	240	0.48 (0.19, 1.22)	0.123	-0.11 (-0.37, 0.14)	0.384
Maternal education			0.653		0.365			0.929		0.562
-Less than high school (ref)	100	-	-	-	-	106	-	-	-	-
-Finished high school	133	0.66 (0.27, 1.58)	0.347	-0.22 (-0.49, 0.05)	0.107	137	0.80 (0.35, 1.85)	0.598	-0.12 (-0.39, 0.15)	0.385
-Vocational/certificate	123	0.98 (0.40, 2.43)	0.968	-0.22 (-0.51, 0.06)	0.124	125	0.98 (0.40, 2.38)	0.956	-0.21 (-0.49, 0.08)	0.152
-University	312	0.66 (0.25, 1.77)	0.410	-0.20 (-0.49, 0.09)	0.173	321	0.81 (0.32, 2.09)	0.665	-0.13 (-0.41, 0.16)	0.388
Maternal age, years	668	1.00 (0.95, 1.06)	0.887	0.01 (-0.01, 0.02)	0.509	689	0.99 (0.37, 1.30)	0.792	0.00 (-0.01, 0.02)	0.691
Maternal country of birth			0.362		0.125			0.255		0.068
-Australia (ref)	317	-		-		319	-		-	
-Overseas	351	0.74 (0.39, 1.41)		-0.13 (-0.31, 0.04)		370	0.70 (0.37, 1.30)		-0.16 (-0.34, 0.01)	
Maternal smoking during pregnancy			0.524		0.818			0.957		0.865
-No (ref)	635	-		-		655	-		-	
-Yes	33	1.45 (0.48, 4.44)		0.04 (-0.33, 0.42)		34	0.97 (0.29, 3.20)		0.03 (-0.34, 0.41)	
Parity			0.399		0.743			0.569		0.653
-Primiparous (ref)	342	-		-		356	-		-	
-Multiparous	326	0.78 (0.43, 1.40)		0.03 (-0.13, 0.19)		333	0.85 (0.48, 1.50)		0.04 (-0.12, 0.20)	
Child gestational age			0.007		0.249			0.011		0.372
-Term or late term (ref)	619	-		-		638	-		-	
-Preterm	49	3.13 (1.44, 6.79)		0.17 (-0.12, 0.47)		51	2.87 (1.35, 6.13)		0.13 (-0.16, 0.43)	
Child sex			0.513		0.345			0.600		0.619
-Male (ref)	342	-		-		356	-		-	
-Female	326	1.21 (0.69, 2.12)		-0.07 (-0.23, 0.08)		333	1.16 (0.67, 1.98)		-0.04 (-0.19, 0.11)	
Child age, years	668	1.73 (0.55, 5.40)	0.352	0.05 (-0.27, 0.38)	0.750	689	1.44 (0.53, 3.95)	0.479	-0.00 (-0.31, 0.31)	0.991
Child physical activity, 36 months			0.863		0.700			0.756		0.969
-<180 minutes/day (ref)	421					440				
-≥180 minutes/day	247	1.06 (0.58, 1.93)		0.03 (-0.13, 0.19)		249	0.91 (0.51, 1.64)		-0.00 (-0.16, 0.16)	

zBMI = BMI-for-age z-score; IRSAD = Index of Relative Socio-economic Advantage and Disadvantage.
[a]Bottle feeding with any non-water cariogenic, caloric drink (formula, expressed breast milk, cow's milk, fruit juice, fruit drink, other drinks) at bed or nap time

The marginal association between bottle feeding to sleep at 24 months and caries experiences at 3-4 years was made significant by re-categorising maternal country of birth (model 1, Supplementary Table 5). This model also identified a strong association between mothers born in a non-English language-speaking country with higher prevalence of ECC and caries experience in children (models 1 and 3, Supplementary Tables 5 and 6). However, this comparison was limited by the small sample size of mothers born in an English language-speaking country. Re-categorising child parity in the sensitivity analysis models attenuated the relationship between bottle feeding to sleep and caries experience (models 2 and 3, Supplementary Tables 5 and 6); however, this led to non-convergence with perfect prediction in the model for ECC prevalence.[32]

There was minimal change in the association between bottle feeding to sleep and overweight or zBMI score in the sensitivity analysis. In a model that re-categorised maternal country of birth, children whose mothers were born in a non-English language-speaking country had a lower zBMI score (model 1, Supplementary Tables 7 and 8) compared to children whose mothers were born in Australia, but this did not impact odds of overweight. The comparison remains limited by the small sample of mothers born in a non-English language-speaking country.

Three sensitivity analysis models for caries and weight outcomes were undertaken with dietary variables of prolonged nighttime breastfeeding past 12 months of age and frequency of sugary food and drink intake at 36 months (Supplementary Tables 9 and 10). Inclusion of prolonged nighttime breastfeeding had minimal change in the association between bottle feeding to sleep at 24 or 36 months with caries experience at 3-4 years. While the inclusion of frequency of sugary food and drink intake attenuated the relationship between bottle feeding to sleep at 24 months and caries experience at 3-4 years, there was no change in the relationship with bottle feeding to sleep at 36 months. Inclusion of these variables were limited by non-convergence with perfect prediction in the models for prevalence of ECC. There was minimal change in the relationship between bottle feeding to sleep with odds of overweight and zBMI score in further sensitivity analysis (Supplementary Table 10).

Discussion

In this cohort of children from an area with cultural diversity and mixed socioeconomic backgrounds, bottle feeding to sleep at 24 months was associated with a higher odds of overweight and bottle feeding to sleep at 36 months was associated with higher caries experience. However, an association was not observed between bottle feeding to sleep at 24 months with tooth decay outcomes or zBMI score, and bottle feeding to sleep at 36 months with prevalence of ECC or weight outcomes.

These findings contribute to a body of observational research with prospective and retrospective design on bottle feeding to sleep across the age span, and mixed findings on ECC or overweight/obesity outcomes. These studies suggest that ECC and overweight/obesity as chronic conditions may be affected by early exposure of bottle feeding to sleep that manifest over time. Indeed, qualitative research with parents of toddlers have identified challenges with bottle cessation after use of bottle feeding to bed or to soothe crying is normalised.[12,33,34] A case-control study in India found that bottle feeding during different stages of sleep was associated with a five- to eight-fold odds of ECC in toddlers aged 12-36 months,[35] while a national cohort of South Korean infants found that children who were bottle-fed to sleep from 9-12 months of age had higher risk of dental caries and obesity at 18-65 months and 6-7 years of age, respectively.[36] Conversely, the Study of Mothers' and Infants' Life Events dental cohort study in Australia found no association between feeding to sleep with bottle feeding, breastfeeding or both at 1 year of age, and ECC at 2-3 years of age for Australian toddlers; however, there was low ECC prevalence of 8.8%,[37] and while it is possible there is no effect, it would seem prudent, from a public health perspective, to maintain bottle cessation recommendations at 1 year of age. Similarly, mixed findings are found for weight outcomes: in the Early Childhood Longitudinal Study, children who bottle-fed to sleep at 9 months or had prolonged bottle use at 2 years of age had higher odds of being overweight at 5-6 years of age,[38,39] while another study found that 3-year-old toddlers who were still bottle fed in bed had two-fold odds of overweight/obesity.[40] Conversely, the Infant Feeding Practices Study II found no association between any bottle feeding in bed between 6-12 months and weight percentiles in 1-year-old children; however, the authors suggest that while bottle feeding in bed may be negligible between 9-12 months of age, habitual maintenance of this behaviour may be more substantial if maintained into toddlerhood.[41] These outcomes are coherent with the findings of the HSHK cohort: bottle feeding to sleep at 24 months was associated with higher odds of overweight occurring at 3-4 years of age, even if bottle feeding to sleep at 36 months did not show this association; and the marginal association between bottle feeding to sleep at 24 months and caries experience at 3-4 years was a precursor to the strong association between bottle feeding to sleep at 36 months and caries experience. These findings highlight the need to communicate age-appropriate bottle cessation and sleep and settling methods throughout early childhood, as part of addressing bottle feeding as a common risk factor in both ECC and overweight/obesity prevention.[9,18]

Sociodemographic characteristics associated with ECC and overweight/obesity risk, such as area-level socioeconomic advantage or maternal education past high school, highlight the importance of healthcare equity and continuous engagement in preventative health behaviours.[1,2,4,18] Furthermore, there was a strong association between ECC prevalence for children of mothers born overseas, compared to those with mothers born in Australia, which may reflect an increased risk in culturally and linguistically diverse populations. Bottle feeding to sleep as a risk factor for obesity and dental caries exists across populations, but may be higher in immigrant families who experience language and financial barriers to information seeking and health care access–notably, this forms the basis of ongoing prevention trials, including the Child Health Action to Lower Obesity and Oral health risk[42] and Nurture Early for Optimal Nutrition[43] studies with South Asian families in New York and London, respectively, and a motivational interviewing-focused intervention with immigrant families in Norway.[44] Additionally, in US-based studies, Hispanic mothers more frequently put 1-year-old infants to bed with bottles in the Rise & SHINE longitudinal cohort,[45] while a higher proportion of Mexican American children had prolonged bottle feeding from 24-48 months age, compared to White and Black children in the National Health and Nutrition Examination Survey III.[7] These findings indicate a need for increased accessibility to healthcare for families experiencing socioeconomic disadvantage, particularly for paediatric dental care[2]; child health communication and resources, with health literacy accessibility, information accessibility, and appropriate readability[46]; and targeted resources designed for culturally and linguistically diverse communities, including messaging from trusted sources, culturally relevant messages, appropriate language or pictorial communication.[47–49]

In Australia, public health messages are guided by the national dietary guidelines, which advise bottle cessation at 12 months of age and cup use from 6 months of age.[26] The 2011 and 2022 national oral health messages for health promotion include bottle cessation, with 'avoiding putting babies and children to bed with a bottle' in the 2022 update.[50,51] However, understanding of public health recommendations in the target group of Australian parents may be mixed: a qualitative study with mothers living in disadvantaged areas felt the national dietary guidelines were based on maternal opinion instead of scientific research, or were unreliable due to changes in advice over time,[52] while nearly all mothers in a long-term follow-up of a midwifery-initiated oral health education program believed that bottle feeding babies in bed was safe.[53] The 2022 national oral health messages are intended for population-level interventions, for use by service providers, policy makers, researchers and health professionals, and it is advised that they are disseminated with appropriate language and methods of communication for communities for interest.[50] Public health resources addressing bottle use for oral health, nutrition and sleep should be co-designed with families and stakeholders.

Strengths of this study include a strong follow-up response, exceeding 75% at 3-4 years of age. Repeated measurement of the bottle feeding to sleep exposure for a longitudinal cohort demonstrates the proximity of the exposure and changes in the strength of association at 24 and 36 months, to ECC and overweight at 3-4 years of age. Oral health birth cohort studies are rare–the HSHK cohort was the first longitudinal study in Australia investigating childhood feeding practices and obesity with ECC. It contributes to the evidence of chronic disease risk from prolonged bottle feeding, and supports a common risk factor approach to addressing ECC and overweight/obesity risk through behavioural (e.g. feeding to sleep) and nutritional factors (e.g. cariogenic drink intake) concurrently.

Limitations include social desirability in self-reported feeding data, such as mothers reporting 'never' for frequency of bottle feeding to sleep while also reporting use of cariogenic, caloric beverages in bed or nap time bottles given to babies. Use of other dietary assessments methods, such as 24 hour recalls, may reduce social desirability; however, this is limited by increased resource intensity and participant burden. Parental dietary intake, experience of dental caries or overweight/obesity also affects prevalence in children[2,4,18]; however, this impact was not modelled as only parental sociodemographic variables was collected. Bottle feeding to sleep is one aspect of child dietary intake that may affect the risk of caries–sensitivity analysis was conducted, including exposure for prolonged nighttime breastfeeding and frequency of sugary food and drink intake, but this was limited by non-convergence of the model with perfect prediction and fewer than ten observations per predictor variable as required for multivariable regression models.[54] Likewise, structural factors largely determine oral health outcomes. Greater accessibility of paediatric dental care and public health resources, which support health literacy and is suitable for culturally and linguistically diverse populations, is required as part of ECC prevention. As HSHK was a cohort study, dental examination of children were embedded in real-world settings, and dental examinations by community-based health professionals could not be conducted at a consistent age point. Child age at 3-4 year of data collection ranged from 2.8 to 4.6 years–while this means that the outcome is concurrent for some children and prospective for others, age is accounted for as a covariate of the multivariable models, and mean age at data collection was 3.58 years. This age range reflects real-world limitations—e.g. waiting time to access community dental services; child dental fear leading to delays in dental assessment—but it is not dissimilar to time needs associated with dental examination, which is also seen in the Study of Mothers' and Infants' Life Events cohort, where 24-month of age dental examinations were conducted at a mean age of 30 ± 3.6 months or median age of 29 months (interquartile range 27-32 months)[37,55]; and a subset of the Born in Bradford cohort, who participated in the Oral Health Survey of 5-year-old children at a mean age of 5.4 years (range 4-6 years).[56]

Conclusion

Consistent with the recommendations in national infant feeding guidelines, these findings contribute to the importance of avoiding bottle feeding to sleep at bed or nap times, and is consistent with the recommendations for age-appropriate cessation of bottles after 12 months age and transition to cup use. Bottle feeding at 24 and 36 months of age, beyond the recommended age of bottle cessation, is associated with greater ECC prevalence and overweight risk in early childhood, and highlights the importance of communicating bottle cessation and appropriate sleep and settling behaviours as part of a common risk factor approach to ECC and overweight prevention.

Conflicts of interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Amit Arora reports financial support was provided by National Health and Medical Research Council.

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Ethics

This study was conducted according to the Declaration of Helsinki. Ethics approval was received from the former Sydney South West Area Health Service, RPAH Zone (ID number X08-0115); Liverpool Hospital; The University of Sydney; and Western Sydney University. Written informed consent was obtained from all participants.

Author contributions

The study was conceived by AA, LD, JS and SB. HC undertook statistical analysis. AA, JJ and HC interpreted the results. HC wrote the manuscript with critical feedback and input from all authors.

Data availability

The data of this study cannot be shared publicly due to the presence of sensitive participant information. RStudio syntax used for statistical analysis is available from the corresponding author on request.

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Appendix A Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.anzjph.2025.100224.