Original Article

Prechewing infant food, consumption of sweets and dairy and not breastfeeding are associated with increased diarrhoea risk of 10-month-old infants in the United States

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Abstract

Prechewing of food by caregivers is a common infant feeding practice both globally and in the United States, where the highest rates of the practice are found among African-Americans and Alaska Natives. The objective of this study was to determine if prechewing of infant food is associated with increased diarrhoea prevalence of 10-month-old infants in the United States. The study used cross-sectional data from the Infant Feeding Practices Study II to test for associations between prechewing and 2-week-period prevalence of infant diarrhoea. At 10 months of age, infants who received prechewed food ($n=203$) had a diarrhoea prevalence of 16.1%, compared with 10.9% of children who did not receive prechewed food ($n=1567$) [relative risk (RR) = 1.48, 95% confidence interval (CI) 1.03–2.11]. After adjusting for covariates, including breastfeeding and consuming sweets and dairy, prechewing was associated with a 58% higher risk (RR = 1.58, 95% CI 1.10–2.26) of 2-week diarrhoea prevalence. Consumption of sweets (RR = 1.35, 95% CI 1.03–1.78) and dairy (RR = 1.41, 95% CI 1.03–1.93) was also associated with increased diarrhoea risk. Continued breastfeeding at 10 months of age was associated with a reduced risk of diarrhoea (RR = 0.68, 95% CI 0.50–0.91). Prechewing of infant food is associated with increased diarrhoea among 10-month-old infants. The high RR found in this study suggests that prechewing may be an important factor in public health efforts to reduce the burden of diarrhoeal disease. However, further research is needed to establish that prechewing causes increased diarrhoea risk and to explore potential benefits of prechewing.

Keywords: child feeding, childhood infections, cultural issues, behaviour, care-giving, diarrhoea.

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Introduction

Diarrhoeal disease is the second leading cause of child mortality globally, causing 760 000 (11%) deaths of children under 5 years (Liu *et al.* 2012). In the United States, diarrhoea does not account for a high percentage of child deaths because of improved access to health care, but 369 children die annually because of diarrhoea (Esposito *et al.* 2011), and it is a major cause of seeking health care for children. After the introduction of the rotavirus vaccine in 2006, care seeking for child diarrhoea was reduced; however, as of 2011, diarrhoea accounted for more than 58 000 hospitalizations, 308 000 emergency department visits and 2 426 000 outpatient visits annually. The estimated

annual medical cost of diarrhoea in children under 5 years is USD 536m (Leshem *et al.* 2014), not including expenditures outside of health facilities.

Prechewing of infant food by adults, also known as premastication, is a traditional solution for offering solid food before a child has teeth. In written history, prechewing was recommended in Persia as early as 1025 AD, when it appears in the Canon of Medicine of Avicenna as the proper way to slowly introduce bread and avoid abrupt weaning (Gruner 1930). In the 1600s, Etmuller recommended prechewing for quick digestion by the infant in Germany, but he also provided a warning about the practice, stating that a person whose gums are affected by scurvy can pass disease to the child (Wickes 1953). Analysis of the

Human Relations Area Files, a database of information on cultures around the world, revealed that premastication exists on every inhabited continent and in approximately one-third of societies represented in the database (Pelto *et al.* 2010). Prechewing was common before the introduction of agriculture, and it has continued to present day because it supplemented the post-agricultural diet of porridge to prevent malnutrition (Pelto *et al.* 2010). Studies from the mid-1900s lend some support to the role of premastication in the prevention of malnutrition. In the 1940s, a study among the displaced Shoshone residing in Nevada, United States, partially attributed infant iron deficiency anaemia to abandoning the practice of premastication (Pijoan & Elkin 1943), and in the 1950s, a study among Polynesians revealed that child stunting increased after stopping traditional feeding practices, including prechewing (Fry 1957).

Despite the importance of prechewing as a traditional practice that is sustained in many parts of the world, it is not included in the World Health Organization's indicators for assessing infant and young child feeding practices. A limited number of small studies have revealed that prechewing is still common in many places, but the rates vary dramatically, from less than 5% in Brazil, Argentina and Peru to 24% in Gabon to 80% in Nigeria (Gaur *et al.* 2013; Ogunshe *et al.* 2013; Auer-Hackenberg *et al.* 2014). In most developed countries, it is likely that prechewing is no longer widely practised. However, in the United States, prechewing among African-Americans and Alaska Natives was documented as a common practice (Walburn *et al.* 1988; Bulkow *et al.* 2002), and recent data from the Infant Feeding Practices Study II (IFPS-II) show that prechewing is not rare in the United States. In

IFPS-II, 50% of self-reported Black mothers practise prechewing when their infant is 10 months of age. Among White and Hispanic people, the rate was just below 10%.

In settings where prechewing is the only means to complement breast milk and porridge with foods rich in macronutrient and micronutrient, it may be an important practice for child nutrition and could have net benefits for child health, but little is known about the overall health impact of this infant feeding practice because few studies have looked at health benefits. In addition to improved health from better foods, it is hypothesized that saliva transfer during prechewing may confer health benefits. Pelto *et al.* argue that saliva and breast milk have many substances in common and that like breast milk, saliva may provide health benefits for the infant, including improved digestion and immunological health (Pelto *et al.* 2010). An observational study in Alaska, United States, showed that prechewing was associated with less hospitalization for acute respiratory infection from syncytial virus for children <6 months (Bulkow *et al.* 2002), lending some support to the hypothesis on immunological health. We are aware of no studies that have assessed prechewing and infant digestion, and the benefits of prechewing remain largely theoretical.

Of the few studies to look at prechewing, nearly all have focused on the disease-causing effects of the practice. Studies from Thailand and Nigeria showed that pathogens can be transferred to food from the mother's mouth during prechewing (Imong *et al.* 1995; Ogunshe *et al.* 2013), including the diarrhoea-causing *Shigella dysenteriae* and *Shigella flexneri*. There is also some evidence that prechewed food can transfer blood-borne disease as well. Recently, prechewing gained attention

Key messages

- Prechewing of infant food is a traditional feeding practice that was sustained, and is common among certain groups of people in the USA and in countries around the globe.
- Prechewing of infant food is associated with a range of illnesses. This study shows an association with increased risk of infant diarrhoea in the USA, but it is not yet established that prechewing causes diarrhoea.
- Prechewing is an understudied practice that affects a large number of infants. Research, particularly on the potential benefits of prechewing, is needed to build the evidence-base for general recommendations on the practice.

in the United States because three children who were not breastfeeding contracted HIV. In two of the three cases, phylogenetic analysis confirmed that prechewing with bleeding gums was the likely route of transmission (Gaur *et al.* 2009). The US Centers for Disease Control and Prevention (CDC) now recommends that HIV-infected caregivers not prechew food for HIV-uninfected children. In observational studies, prechewing is associated with the transfer of pathogens responsible for a range of illnesses, including hepatitis B, pharyngitis, syphilis, Kaposi's sarcoma, Epstein-Barr virus, *Helicobacter pylori* and dental caries (Huang 1990; Taylor & Blaser 1991; Steinkuller *et al.* 1992; Mbulaiteye *et al.* 2003; Mbulaiteye *et al.* 2006; Zhou *et al.* 2009; Pattanaporn *et al.* 2013). The American Academy of Pediatrics recommends that all caretakers not prechew because of the increased risk of dental caries. There are, however, virtually no studies on the association between prechewing and one of the biggest killers of children: diarrhoea. We found only one study that examined associations between prechewing and diarrhoea, but that study failed to find statistically significant results because of a small sample size (Cao *et al.* 2000). Evidence suggests that diarrhoea-causing pathogens are transferred to food from prechewing (Ogunshe *et al.* 2013), although immunoglobulins found in saliva could prevent the child from becoming infected (Pelto *et al.* 2010). The impact of prechewing on diarrhoea is not established.

In this paper, we examine the association between prechewing and diarrhoea using data from the IFPS-II, a large study of pregnant women and their infants in the United States. We hypothesized that 10-month-old infants who received prechewed food had higher exposure to diarrhoea-causing pathogens, which led to a higher prevalence of diarrhoea. To our knowledge, this is the first study to test for associations between prechewing and diarrhoea in a developed country context.

Methods

Study design and participants

The IFPS-II is a longitudinal study carried out by the US Food and Drug Administration in collaboration

with the CDC and the National Institutes of Health. The study recruited 4900 pregnant women from a nationwide consumer opinion panel and collected data via mail questionnaires from the woman's seventh month of pregnancy until the infant was 1 year of age. Data were collected from May 2005 to June 2007; questionnaires were sent nearly monthly from birth until 1 year of age. IFPS-II includes information on infant feeding, infant health and care, and maternal diet. The data are not nationally representative, and all data are self-reported by the mother. The use of a consumer opinion panel as a sampling frame resulted in a sample where White people are overrepresented and people from the 'South' region are underrepresented. Detailed methods for the study are published elsewhere (Fein *et al.* 2008).

While the IFPS-II is a longitudinal study, our analysis utilized exposure and outcome data from the Ten-month Questionnaire. As such, our analysis represents a single cross-section. The Ten-month Questionnaire was sent between May 2006 and January 2007. Of the 2855 questionnaires mailed, 1808 (63%) were returned. No additional exclusion criteria were used for our analysis, but IFPS-II required that the mother be at least 18 years old, that the infant be a singleton and nearly full term, that the mother and baby be healthy at birth and that the infant did not have a long-term illness that would affect feeding.

Data

Our outcome of interest was 2-week-period prevalence of diarrhoea. In the questionnaire, diarrhoea is included in a list of 13 problems, and mothers are instructed to select all of the problems the child has had in the previous 2 weeks. Data are recorded as binary (yes or no), and the severity and duration of the diarrhoeal episode were not collected.

The primary exposure of interest is prechewing in the previous 2 weeks. Mothers were asked 'In the past two weeks, have you chewed up food and then given it to your baby, so the food was already chewed up before you fed it to your baby?' The prechewing exposure is a binary; data were not collected on prechewing frequency. Data from the Ten-month Questionnaire were selected for analysis because the proportion of

mothers reporting prechewing was highest at this age, improving the study power.

Additional variables are included in the analysis to control for potential confounding. Variables from the Ten-month Questionnaire include child feeding variables such as breastfeeding, animal source food consumption, dairy consumption and sweets consumption coded as binary variables (yes/no). Sweets and dairy categories include both food and beverages, such as 'soda', 'cookies', 'milk' and 'cheese'. Animal source food is non-dairy and includes 'meat', 'chicken', 'combination dinners', 'fish', 'shellfish' and 'eggs'. Variables on socio-economic characteristics were obtained from other questionnaires of IFPS-II and include mother's age, child's age, household size, household income, mother's education, ethnicity, child's sex and residence. Age and household size are treated as continuous variables. The categorical variables income, education and ethnicity were coded to reduce the number of categories, which was carried out to ensure that each category had at least five expected diarrhoea cases based on the overall diarrhoea prevalence and the category sample size. All other categorical variables utilize the coding employed in the questionnaire. For all ordinal and nominal categorical variables, dummy variables were created.

Statistical analysis

We used STATA MP 11.0 (StataCorp, College Station, TX, USA) for all analyses. Power calculations were carried out before analysis and are based on an overall diarrhoea prevalence of 11.4% among the unexposed and an estimated difference of 10 percentage points among those that prechew (Cao *et al.* 2000). An analysis of the association between prechewing and diarrhoea based on a two-sided test [*sampsi .115 .215, n1 (1571) n2(184)*] using the sample size of the 10-month survey yielded a power of 0.93 with $\alpha < 0.05$.

All tests of significance, unadjusted odds ratios (ORs) and confidence intervals (CIs) were calculated using logistic regression. For the multivariable logistic regression models, each variable category had more than five expected cases of diarrhoea based on applying the overall diarrhoea prevalence to the category sample size. The number of variables included in the full

model was restricted so that there are >10 cases of diarrhoea per variable in order to avoid bias (Peduzzi *et al.* 1996). The reduced model was created using backward stepwise selection on the full model with $\alpha > 0.1$ as the significance level for removal. All variables included in the final multivariable logistic model were tested for interactions with the exposure variable, and no interactions were found to be statistically significant. Multivariable model goodness of fit is evaluated with the Hosmer–Lemeshow test, with the number of groups set to 10. In addition to ORs, relative risk (RR) is calculated for the unadjusted and reduced models using a Poisson regression model with robust error variance (Zou 2004; Spiegelman & Hertzmark 2005). All tests of statistical significance are two sided using $\alpha < 0.05$ as the cut-off for statistical significance.

Results

At 10 months, the prevalence of diarrhoea was 16.1% among children who received prechewed food, compared with 10.9% for children who did not receive prechewed food (RR = 1.48, 95% CI 1.03–2.11). Analysis of other survey months revealed that prechewing was associated with higher diarrhoea prevalence at three of five age points ($P < 0.05$) with differences at the other two age points not statistically significant (Fig. 2a).

There were significant differences between the prechew and non-prechew groups for many demographic characteristics. The proportion of mothers who reported prechewing increased with infant age, peaking at 10.5% at the 10-month survey (Fig. 1a). The largest differences in prechewing were seen by race–ethnicity groups; 50% of self-reported Black mothers prechewed infant food at 10 months of age, while it was below 20% in every other group (Fig. 1c). Although Black mothers were more likely to prechew, they were underrepresented in the overall sample relative to the general US population; the majority in the prechew group were White mothers. Table 1 compares the demographics between mothers who prechewed and those who did not prechew at 10 months of age. The prechew group was evenly spread over the four categories of income, and the majority (70%) were college educated.

Fig. 1. Proportion of infants receiving prechewed food by age, income, race/ethnicity and region at 10 months of age, IFPS-II.

Table 2 details the bivariate associations between all of the covariates and 2-week diarrhoea prevalence at 10 months of age. As expected, breastfeeding was associated with lower diarrhoea (OR=0.59, 95% CI 0.43–0.82), whereas the consumption of sweets and dairy consumption was associated with increased diarrhoea prevalence (OR=1.64, 95% CI 1.22–2.22 and OR=1.67, 95% CI 1.21–2.30). Table 3 presents regression models of prechewing and covariates on 2-week diarrhoea prevalence at 10 months of age. Unadjusted logistic and Poisson regression models showed that prechewing was associated with increased diarrhoea risk (OR=1.57, 95% CI 1.03–2.39 and RR=1.48 95% CI 1.03–2.11). Adjusted multivariable logistic regression models showed an association between prechewing and diarrhoea when controlling for potential confounders. In the reduced model, the RR of diarrhoea for children who received prechewed food was 1.58 (95% CI 1.10–2.26). In adjusted models, breastfeeding remained a statistically significant protective feeding practice, while sweets and dairy consumption was shown to increase diarrhoea risk (Fig. 2c). The highest rates of diarrhoea were found among children who received both prechewed food and sweets or dairy (Fig. 2b), but no interaction terms were found to be statistically significant.

Discussion

To our knowledge, this is the first study that is adequately powered to look at the association between prechewing and diarrhoea. Prechewing was associated with nearly a 50% increase in diarrhoea risk, and the association was statistically significant when controlling for potential confounders. Diarrhoea, the second leading cause of child mortality globally, can be added to a list of infections associated with prechewing that includes HIV, dental caries and many others (Huang 1990; Gaur *et al.* 2009; Pattanaporn *et al.* 2013). The more that prechewing is studied as a possible route of pathogen transmission, the more apt seems Etmuller's advice from the 1600s – that caregivers who are sick should not prechew infant's food (Wickes 1953). The American Academy of Pediatrics has taken advice a step further and recommends against prechewing for all caregivers. However, the potential benefits of prechewing have not been studied, and for many diseases that are associated with prechewing, causality is not firmly established. There is still much to learn about how prechewing relates to disease.

Our database contained no information on intensity of prechewing or severity of disease. We do not know if diarrhoea risk diminishes when prechewing is

Table 1. Descriptive statistics of differences between exposed (prechew) and non-exposed (non-prechew) groups at 10 months of age, IFPS-II

	Prechew (<i>n</i> = 189)		Non-prechew (<i>n</i> = 1604)		<i>P</i>
	<i>n</i>	Mean or %	<i>n</i>	Mean or %	
Mother's age (years)		28.1		29.7	<0.001
Child's age (weeks)		45.9		46.0	0.791
Household size (# people)		3.4		3.3	0.116
Household income (annual \$)					
Below 20 000	48	25.4	184	11.5	<0.001
20 000–40 000	56	29.6	470	29.3	
40 000–60 000	37	19.6	386	24.1	
Above 60 000	48	25.4	565	34.2	
Mother's education (%)					<0.001
No college	52	29.7	264	17.3	
College	123	70.3	1266	82.8	
Ethnicity (%)					<0.001
White	128	70.0	1384	88.3	
Black	33	18.0	33	2.1	
Hispanic	9	4.9	84	5.4	
Asian/other	13	7.1	67	4.3	
Child's sex (%)					0.430
Male	88	46.6	795	49.6	
Female	101	53.4	808	50.4	
Residence (%)					<0.001
Rural (non-MSA)	35	18.5	307	19.1	
City <0.5 m – central	29	15.3	182	11.3	
City <0.5 m – non-central	26	13.8	158	9.8	
City 0.5–2 m – central	8	4.2	174	10.8	
City 0.5–2 m – non-central	18	9.5	232	14.5	
City >2 m – central	32	16.9	119	7.4	
City >2 m – non-central	41	21.7	433	26.9	
Breastfeeding status at 10 months (%)					0.132
Breastfeeding	79	42.3	587	36.6	
Not breastfeeding	108	57.8	1016	63.4	
Information on child feeding (%)					0.045
Received from WIC	63	34.8	435	27.7	
Did not receive from WIC	118	65.2	1135	72.3	
Diet last 7 days – animal source (%)					0.011
None	9	4.8	172	10.7	
≥1 per week	178	95.2	1431	89.3	
Diet last 7 days – dairy (%)					0.252
None	62	33.2	125	37.4	
≥1 per week	125	66.8	1003	62.6	
Diet last 7 days – sweets (%)					<0.001
None	105	56.2	1141	71.2	
≥1 per week	82	43.9	462	28.8	

IFPS-II, Infant Feeding Practices Study II; MSA, Metropolitan Statistical Area; WIC, The Special Supplemental Nutrition Program for Women, Infants, and Children. *P*-values calculated with *t*-test and Pearson's chi-squared test.

practised routinely, nor do we know if prechewing reduces the severity of diarrhoeal episodes as is seen with syncytial virus (Bulkow *et al.* 2002). These are both areas for future research. This study is not a randomized trial and does not firmly establish a causal

relationship between prechewing and diarrhoea. For our study, it is possible that there are unmeasured differences between infants who did and did not receive prechewed food and that these unknown differences confound the association between prechewing and

Table 2. Unadjusted association between covariates and 2-week-period prevalence of diarrhoea at 10 months of age, IFPS-II

	<i>n</i>	% Diarrhoea	OR	CI	<i>P</i>
Mother's age (years)			0.97	0.94–0.99	0.028
Child's age (weeks)			1.10	1.04–1.16	0.001
Household size (# people)			1.04	0.93–1.17	0.486
Household income (annual \$)					
Below 20 000	231	15.4	ref.		
20 000–40 000	524	10.9	0.66	0.42–1.04	0.071
40 000–60 000	420	11.0	0.67	0.42–1.06	0.090
Above 60 000	608	10.9	0.66	0.43–1.02	0.062
Mother's education (%)					
No college	314	11.2	ref.		
College	1385	11.4	1.02	0.66–1.51	0.895
Ethnicity (%)					
White	1506	11.7	1.28	0.54–3.01	0.572
Black	64	9.4	ref.		
Hispanic	93	14.0	1.57	0.56–4.38	0.388
Asian/other	79	10.1	1.09	0.36–3.31	0.880
Child's sex (%)					
Male	881	12.5	ref.		
Female	900	10.6	0.83	0.62–1.11	0.202
Residence (%)					
Rural (non-MSA)	341	14.1	ref.		
City <0.5 m – central	211	12.8	0.89	0.54–1.49	0.670
City <0.5 m – non-central	182	9.9	0.66	0.38–1.19	0.172
City 0.5–2 m – central	179	12.9	0.89	0.53–1.53	0.699
City 0.5–2 m – non-central	249	11.7	0.80	0.49–1.32	0.388
City >2 m – central	151	8.6	0.58	0.30–1.10	0.093
City >2 m – non-central	470	10.0	0.68	0.44–1.04	0.076
Breastfeeding status at 10 months (%)					
Not breastfeeding	1120	13.4	ref.		
Breastfeeding	659	8.4	0.59	0.43–0.82	0.001
Information on child feeding (%)					
Received from WIC	494	11.7	ref.		
Did not receive from WIC	1245	11.5	0.99	0.71–1.37	0.949
Diet last 7 days – animal source (%)					
None	182	7.7	ref.		
≥1 per week	1597	12.0	1.69	0.93–2.87	0.090
Diet last 7 days – dairy (%)					
None	662	8.5	ref.		
≥1 per week	1172	13.3	1.67	1.21–2.30	0.002
Diet last 7 days – sweets (%)					
None	1243	9.9	ref.		
≥1 per week	536	15.3	1.64	1.22–2.22	0.001

IFPS-II, Infant Feeding Practices Study II. *P*-values calculated with *t*-test and Pearson's chi-squared test.

infant diarrhoea risk. It is also possible that the observed association is a result of reverse causality, where the practice of prechewing is carried out as a response to infant diarrhoea. Additional quantitative and qualitative research employing a longitudinal design is needed to better understand the causal relationship between prechewing and diarrhoea. If prechewing causes

increased diarrhoea to the extent seen in this study, the findings have important policy and public health implications both in the United States and elsewhere. The potential implications are explored further in the remainder of the discussion to support the need for more data collection and research on the practice of prechewing infant food.

Table 3. Multivariable logistic regression of infant feeding practices on 2-week-period prevalence of diarrhoea at 10 months of age, IFPS-II

	Unadjusted				Adjusted – full		Adjusted – parsimonious			
	OR	95% CI	RR	95% CI	OR	95% CI	OR	95% CI	RR	95% CI
Current prechewing	1.57*	1.03–2.39	1.48*	1.03–2.11	1.82*	1.13–2.92	1.72*	1.10–2.68	1.58*	1.10–2.26
Current breastfeeding					0.62**	0.44–.88	0.64**	0.46–0.89	0.68**	0.50–0.91
Fed dairy last 7 days					1.39	0.96–2.00	1.47*	1.03–2.09	1.41*	1.03–1.93
Fed sweets last 7 days					1.39	1.00–1.95	1.42*	1.03–1.97	1.35*	1.03–1.78
Fed animal source last 7 days					1.28	0.68–2.41				
Mother's age (years)					0.97	0.94–1.01				
Mother's education (any college)					1.35	0.87–2.10				
Child's age (weeks)					1.09*	1.03–1.15				
Household size					1.03	0.91–1.18				
Child's sex (female)					0.84	0.62–1.15				
Received WIC feeding information					0.67	0.44–1.02				
Household income (annual \$)										
Below 20 000					ref.					
20 000–40 000					0.75	0.45–1.25				
40 000–60 000					0.73	0.42–1.28				
Above 60 000					0.80	0.45–1.43				
Ethnicity										
White					ref.					
Black					0.68	0.25–1.86				
Hispanic					0.96	0.46–2.00				
Asian					1.10	0.5–2.42				
Residence										
Rural (non-MSA)					ref.					
City <0.5 m – central					0.92	0.53–1.58				
City <0.5 m – non-central					0.62	0.34–1.12				
City 0.5–2 m – central					0.85	0.47–1.53				
City 0.5–2 m – non-central					0.74	0.43–1.28				
City >2 m – central					0.52	0.25–1.08				
City >2 m – non-central					0.73	0.45–1.18				

OR, odds ratio; CI, confidence interval; RR, relative risk. Full model adjusted for mother's age, child's age, household size, household income, mother's education, ethnicity, child's sex, residence and WIC participation. Parsimonious model adjusted for child's age; RR calculated with Poisson regression model with robust error variance. Hosmer–Lemeshow goodness of fit $\text{Prob} > \chi^2$: full model $P = 0.68$, parsimonious model $P = 0.41$. * $P < 0.05$; ** $P < 0.01$.

In the United States, the burden of diarrhoeal disease due to rotavirus was large enough to warrant a vaccination programme. After introduction of the vaccine, diarrhoea-associated hospitalization for children under 1 year of age dropped by 45%, with rotavirus-associated hospitalizations approaching 0 (Leshem *et al.* 2014). If prechewing is indeed a route of transmission, preventing this source of infection could help to achieve further reductions in the need for and costs of diarrhoea-associated health care seeking. However, with such a scarcity of information on the practice of prechewing itself,

and little to no evidence on its nutrition and health impact, hypothesized benefits of prechewing cessation are speculative. Including the feeding practice in regular, national surveys such as the National Health and Nutrition Examination Survey can provide an accurate estimate of the rate of prechewing and could help to spur further research on the health benefits and risks of the practice. As minority groups are much more likely to prechew in America, a better understanding of infant feeding may also provide new insights into health disparities observed in the country.

Fig. 2. Association between prechewing infant food and 2-week-period prevalence of infant diarrhoea reported by mother; IFPS-II.

In low-income countries, diarrhoea remains an important killer of young children (Collaborators GMaCoD 2015). The main strategies in the 2013 Integrated Global Action Plan for Pneumonia and Diarrhoea to address the burden of diarrhoea are to prevent deaths with oral rehydration solution and to prevent diarrhoea with improved water, sanitation and hygiene. The increased diarrhoea risk from prechewing observed in this study in a high-income country (RR: 1.58) is similar to the risk observed in the low-income area of NE Thailand in 1999 (RR: 1.64) (Cao *et al.* 2000), and both observed risks are higher than the increased risk found in meta-analysis of not having an improved water source (RR: 1.34) and not having an improved toilet (RR: 1.33) (Engell & Lim 2013). Prechewing may be an important

behaviour for diarrhoea prevention in low-income countries, but unlike water, sanitation and hygiene, causality is yet to be established. Furthermore, the relationship between prechewing and undernutrition, another important cause of child deaths in low-income countries, has never been adequately studied. Prechewing has been discouraged as an unhygienic practice (Pelto *et al.* 2010). However, in certain contexts, it is possible that prechewing could improve dietary diversity, child nutrition and child survival, even with an increased diarrhoea risk. The scarcity of information on prechewing in low-income countries means that the public health costs and benefits of prechewing are unknown. As a first step to building the evidence base, prechewing can be included as an official infant and young child

feeding indicator by the United Nations. More information on prechewing is also needed for current nutrition programming. Two of the main strategies to address high rates of child anaemia and stunting are promotion of appropriate complementary feeding and in-home fortification with multiple micro-nutrient powders. Both of these interventions require behaviour change of infant feeding practices, and in the design stage, both ignore prechewing – a widespread, common, current feeding practice.

Our analysis provides much needed information on the health risks of an understudied infant feeding practice. Combined with earlier work that describes prechewing as a common practice in both developed and developing countries, the association seen with diarrhoea reveals that a poorly understood infant feeding practice may contribute a substantial amount to the infant disease burden seen across the world. Our evidence does not support a recommendation on prechewing in any country context but should raise the profile of the need to study this behaviour as a practice that affects a large number of people and that is deserving of further attention by those working on infant health and nutrition.

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Conflicts of interest

The authors declare that they have no conflict of interest.

Human participant protection

The IFPS-II questionnaires and survey methods were approved by the US FDA Institutional Review Board. Participants received information on informed consent.

Contributions

JC was responsible for acquiring data. JC and MF were responsible for conceptualization and design of the study. JC was responsible for data analysis, initial interpretation of results and drafting the initial article. MF and UR were responsible for further interpretation of results and critical revision of the article. JC was responsible for article finalization, and all authors approved the final article for publication.

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