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Snacking Habits and Caries in Young Children

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Key Words
Breast-feeding · Caries · Children · Snacks

Abstract
Dental caries is caused by a combination of infection and diet. This disease, if left untreated, may lead to pain, and impair the quality of life, nutritional status and development of young children. The objective was to investigate the association between snacking and caries in a population at high risk of dental caries. American preschool children (n = 1,206) were recruited in the offices of paediatricians. Data on sociodemographic characteristics, oral hygiene, breast-feeding, use of bottle and snacking were collected by questionnaire. Plaque presence, the number of teeth and their caries status (deft) were scored. The children sampled were 61% Black, 27% White and 10% Asian. Of the 1- to 2-, 2- to 3- and 3- to 4-year-old children, 93.8, 82.4 and 77.3% were caries free, and their mean caries scores were 0.16, 0.58 and 0.93, respectively. Multivariate partial least squares (PLS) modelling revealed plaque presence, lowest income, descriptors for tooth exposure time (number of teeth and age) and cariogenic challenge (total intake of sugar-containing snacks and chips/crisps, and chips intake with a sugar-containing drink) to be associated with more caries. These differences were also found in univariate analyses; in addition, children who continued breast-feeding after falling asleep had significantly higher deft values than those who did not. PLS modelling revealed that eating chips clustered with eating many sweet snacks, candies, popcorn and ice cream. We conclude that, in addition to the traditional risk indicators for caries – presence of plaque, sugar intake and socioeconomic status –, consumption of chips was associated with caries in young children.

Dietary habits have shifted in all age groups in the Western populations in recent decades, including a nearly doubled intake of energy-dense, low-nutrient-dense snack foods [Briefel and Johnson, 2004; Adair and Popkin, 2005]. In children, more than 30% of the daily energy intake was reported to come from such foods and, on average, 75% of Americans report daily snacking [Briefel and Johnson, 2004]. In addition, different snacking patterns have been reported based on household income: individuals with income at or below the poverty line in the USA more frequently consumed po-

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tato chips, fried potatoes, whole milk and fruit drinks, whereas those with higher incomes consumed more grain-based salty snacks, fruits, skim milk, soft drinks, coffee and tea [Briefel and Johnson, 2004]. The shifted dietary patterns have been associated with increased risk of endemic diseases such as type 2 diabetes, obesity and dental caries.

Dental caries is a chronic infectious disease characterized by demineralization of tooth tissues at lowered pH following bacterial fermentation of dietary carbohydrates. The period of critically lowered pH needed for caries to occur is mainly a function of the type and frequency of carbohydrates consumed, the microbial composition of the tooth biofilm and salivary factors. Sucrose and monosaccharides induce a rapid and deep pH drop, and accordingly increase the risk of caries [Azevedo et al., 2005; Seow et al., 2009]. Energy-dense, low-nutrient-dense foods are often characterized by a high content of added sugar, but several modern snack products such as chips (crisps), popcorn and shrimp crackers, while not sweet, are still potentially cariogenic due to their content of extensively hydrolysed starch [Lingström et al., 2000]. Snacking has gained an increasing role as a risk indicator for caries development in children [Milgrom and Reisine, 2000; Marshall, 2005], but so far the impact of products with extensively hydrolysed starch, such as potato chips, on caries risk has not been demonstrated in children or adults.

Caries in young children, often referred to as early childhood caries [American Academy of Pediatric Dentistry, 2008], may, if left untreated, lead to pain, reduced quality of life and impaired eating, and may impair a child's nutritional status and development. The prevalence of early childhood caries varies between communities but is frequently high in underprivileged communities and among disadvantaged immigrants [Grindefjord et al., 1993; Milnes, 1996; Petersen and Esheng, 1998; Wennhall et al., 2002; Jose and King, 2003; Stecksen-Blicks et al., 2004; Vachirarojpisan et al., 2004; Beltrán-Aguilar et al., 2005; Schroth et al., 2005]. Understanding the role of lifestyle-associated risk indicators for dental caries in young children in groups prone to caries development forms the basis for targeted caries prevention programs. The aim of the present study has been to investigate the association between snacking habits and caries, considering oral hygiene and socioeconomics as possible confounders, in a cohort of young children living in a population at high risk of dental caries in an industrialized country (USA).

Subjects and Methods

Study Cohort

Preschool children presenting for well-child visits at the paediatric clinics at Boston Medical Center, Boston University, and the Floating Hospital, Tufts Medical Center, Boston, USA, were recruited in a 12-month period in 2003–2005. These hospitals serve all racial and ethnic groups living in the Boston area but have a special mission for underserved groups [Kressin et al., 2009]. Inclusion criteria were that a child was 6 months to no more than 5 years of age, and that a parent or guardian was willing to consent to the child's clinical examinations [Kressin et al., 2009]. Children with congenital diseases affecting the dentition were excluded. The study design, protocol, questionnaire and informed consent were approved by the institutional review boards of the institutions involved.

Data Collection

Data on sociodemographic characteristics (gender, family income, education level, race and ethnicity) and oral hygiene, feeding (breast-feeding or use of bottle) and snacking habits were obtained from parents or guardians, collected at the offices of paediatricians via a structured questionnaire [Kressin et al., 2009].

The number of teeth, and their status as sound, precavitated (white spot lesion), cavitated, filled or sealed was recorded [Drury et al., 1999], using good light, a disposable mirror and an explorer. For each child, the total number of decayed (d; non-cavitated and cavitated), filled (f; sealants not included) and extracted (e) primary teeth (t) was calculated. Visible plaque was recorded on a 0–3 scale (no plaque, and plaque covering a mean surface area of $<$1/3, 1/3 to $<$2/3 or $>$2/3 of the tooth) [Kanasi et al., 2010]. Data collection and oral examinations were performed by 2 specially research-trained dental hygienists.

Data Analyses

For descriptive data and associated univariate analyses, family income status was dichotomized as relatively high or low [equal to or higher than or below the median income in 2006 in the state of Massachusetts (USD 56,292 in 2008) according to the US Census Bureau news release (www.census.gov)], education to high (higher than high school) or low (equal to or lower than high school), and other variables as yes or no – for example, presence of caries (deft $\geq$1) or not (deft = 0), visible plaque (score $\geq$1) or no visible plaque (score 0), daily cleaning of teeth or not, and reporting eating a snack most days or not.

Categorical data are presented as proportions (percent children), and distribution differences between groups were tested by a χ^2 test with $p < 0.01$ considered statistically significant. Caries data (deft scores) are presented as means with 95% CI after standardization for age group or number of teeth in age-merged and age-stratified groups, respectively. Standardized least square means with 95% CI were calculated using the general linear model (GLM) procedure followed by the Bonferroni multiple mean test, with $p < 0.05$ considered statistically significant. The SPSS software (version 16.0.1 for Windows; SPSS Inc., Chicago, Ill., USA) was used.

Table 1. Description of study cohort

	1–2 years (n = 678)	2–3 years (n = 312)	3–4 years (n = 216)
Teeth	9.6 (9.3–10.0)	18.0 (17.8–18.3)	19.9 (19.8–20.0)
Caries[1]			
deft score	0.16 (0.11–0.21)	0.58 (0.39–0.78)	0.93 (0.58–1.28)
Caries free, %	93.8	82.4	77.3
Gender, %			
Boys	51.0	56.1	46.8
Girls	49.0	43.9	53.2
Race, %			
Black	58.1	61.2	70.8
White	28.5	28.2	22.2
Asian	12.5	10.3	6.9
Other	0.8	0.3	0
Ethnicity[2], %			
Hispanic	14.3	17.6	12.0
Non-Hispanic	85.7	82.4	88.0
Education, % ≤high school	45.8	48.7	54.0
Income[3], % low	71.3	72.8	75.0
Tooth cleaning[4], %			
Daily	73.2	92.6	96.8
Never	13.4	0.6	0.5
Visible plaque, % with score ≥1	23.0	49.8	44.2
Snack intake[5], % of children			
Fresh fruit	76.5	79.2	81.5
Crackers	69.9	68.6	65.7
Yoghurt	50.3	48.6	60.8
Cookies	47.8	47.4	60.2
Cereals (dry)	48.7	41.0	32.4
Chips	23.0	40.7	44.0
Cereals with milk	25.4	32.1	33.3
Ice cream	15.9	24.0	35.2
Candies	9.3	21.2	31.9
Dried fruit	11.2	17.3	15.7
Popcorn	5.3	15.4	27.6
Others	28.2	32.6	32.9
Breast-feeding, %			
Yes (currently)	8.9	3.7	1.7
Daily at sleep	7.3	3.0	1.2
Drink from bottle, %			
Yes (usually)	67.3	26.6	13.0
Bottle in bed	49.6	21.6	12.1

Values other than percentages denote means with 95% CI in parentheses.

[1] deft = sum of decayed, extracted (caries) and filled deciduous teeth; caries free = no detectable white or cavitated lesions, restorations or teeth extracted due to caries.

[2] <0.5% were native Hawaiian or American Indian, respectively.

[3] Low income = annual income less than median income in Massachusetts (USD 56,000).

[4] Remaining children cleaned teeth several times a week or month. Tested among all levels.

[5] Daily snacking was reported for 96, 97 and 99% of the children in the 3 age groups, respectively. Snacks reported to be eaten daily by a child are listed. The numbers indicate the proportion (%) of children for whom daily intake was reported (consumer).

Table 2. Caries status by gender, socioeconomic factors and oral hygiene measures

	Numbers	Children with caries[1]		Caries experience[2]	
		%	p	deft	p
Gender					
Boy	622	14.0	0.039	0.59 (0.47–0.71)	0.383
Girl	584	10.1		0.52 (0.38–0.66)	
Race					
Black	738	13.3	0.291	0.55 (0.43–0.67)	0.150
White	329	9.1		0.51 (0.33–0.69)	
Asian	132	13.6		0.73 (0.48–0.98)	
Other	7	0		0	
Ethnicity					
Hispanic	178	12.4	0.911	0.56 (0.32–0.80)	0.988
Non-Hispanic	1,028	12.1		0.56 (0.46–0.66)	
Education[3]					
Low	571	13.8	0.080	0.60 (0.46–0.74)	0.378
High	618	10.5		0.52 (0.38–0.66)	
Income[4]					
<Median (low)	704	14.5	0.001	0.68 (0.56–0.80)	0.009
≥Median (high)	269	7.1		0.38 (0.28–0.58)	
Plaque					
Yes	344	23.8	<0.0001	0.96 (0.84–1.08)	<0.0001
No	668	6.4		0.29 (0.13–0.45)	

[1] Crude numbers tested by χ^2 test for differences in group proportions. $p < 0.01$ for statistical significance.
[2] Means (95% CI) standardized for age group by the GLM procedure (standardization for number of teeth had no further effect). Differences between groups tested by the Bonferroni post hoc test. $p < 0.05$ for statistical significance.
[3] Low education defined as low when equal to or lower than high school.
[4] Low income defined as an annual income less than the median income in Massachusetts (USD 56,000).

Multivariate Analysis

Partial least squares (PLS) modelling using SIMCA P+ (v. 12.0; Umetrics AB, Umeå, Sweden) was used for multivariate analysis. PLS is a multivariate linear regression model method that detects correlations between matrices of independent and covarying descriptor and response variables. The variables used were snack items and risk indicators or factors for dental caries in small children. These were modelled using logarithmically (ln) transformed deft (after addition of 0.01 to all values) and the dichotomized caries score. All variables were autoscaled to unit variance.

The importance of each variable of interest (x-variable) in explaining the variation among the outcome variables (y-variables) is given by a correlation coefficient and a variable importance in projection (VIP) value. A VIP value of >1.0 is influential, and a VIP value of ≥1.5 highly influential. The R^2 and Q^2 values give the capacity of the x-variables to explain (R^2) and predict (Q^2) the variance among the y-value(s). Q^2 values, which preferentially should not differ by more than 0.2 from model R^2 values, were obtained by cross-validation where every 7th observation was kept out of the model and predicted by a model from the remaining observations. This was repeated until all observations had been kept out once.

Results

A total of 1,291 children were examined, but the data are restricted to 1,206 children because 13 children were predentate and 43 children non-cooperative (no information on tooth status); further dentate children younger than 1 year of age (n = 29) were omitted as the distribution of several variables deviated markedly from the other age groups, including lack of clinical caries measurements (data not shown). No child was older than 4 years.

Demographic and Oral Characteristics

The racial and ethnic distributions of the 1,206 children examined were 61% Black, 10% Asian, 27% White and 15% Hispanic (table 1). Boys and girls were equally represented. Approximately half of the parents or guardians had an education lower than or equal to high school, and more than 70% had an annual income below the median income in the state (table 1). The variations between the 3 age groups are shown in table 1.

The number of erupted teeth ranged from 1–20, with an average of 13.6 teeth (95% CI: 13.3–14.0) and an expected increase by age (table 1). A high proportion of the parents or guardians stated that the teeth of the children were cleaned daily (73–97% by age group), but plaque was still visible in a considerable portion of the children (23–50% by age group) (table 1). In all age groups, most of the children did not have visible caries, i.e. 94% among the 1- to 2-year-olds, 82% among the 2- to 3-year-olds and 77% among the 3- to 4-year-olds were caries free. Accordingly, the mean deft scores (numbers in parenthesis for means among children with caries) increased by age group from 0.16 (0.48) over 0.58 (1.75) to 0.93 (2.78) (table 1). The proportion of children with untreated cavities increased from 1.3 over 8.7 to 17.2% by increasing age group.

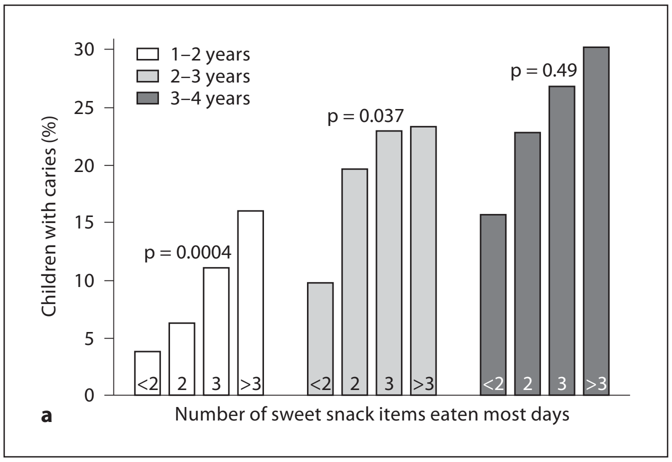
Visible Plaque and Income Are Highly Associated with Caries

A significantly higher proportion of the children with visible plaque had caries, and their age-standardized deft score was higher compared to plaque-free children (table 2). Similarly, children from homes with an income below the median, compared to those with an income at or above the median level, had more caries (table 2). The proportions of children with caries or mean deft scores did not differ between boys and girls, race or ethnicity, or parent/guardian education level groups (table 2).

Eating and Snacking Habits Are Associated with Caries

Nearly all children (97%) were reported to eat snacks most days, and 60% ate 1–2 sweet snack items most days (data not shown). The proportions of children with caries increased by increasing number of sweet items reported to be eaten most days (fig. 1a). There was less caries in children who drank milk compared with other drinks (non-sweetened or sweet) with the snacks (fig. 1b).

Caries was significantly more prevalent among children who ate chips most days, and their mean deft score was higher than in those who did not (table 3). Snacking on candies, cookies and ice cream was also associated with a higher proportion of children with caries. The mean deft score was significantly higher in children eating dry cereals and dried fruit. The most frequently consumed snack foods (fresh fruit, crackers and yoghurt), however, were not associated with caries (table 3).



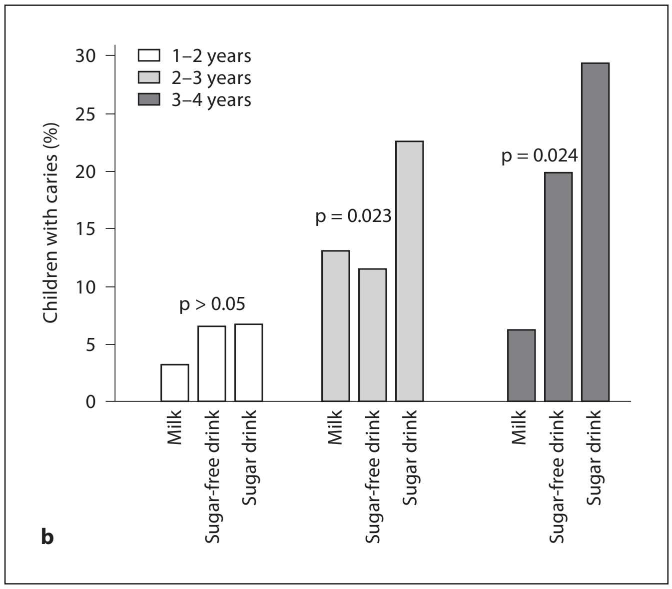


Fig. 1. p values from χ^2 analyses within each age category are indicated in the figures. p values for merged age categories were $p < 0.0001$ (**a**) and $p = 0.002$ (**b**). **a** Proportion of children with caries by number of sweet snack items eaten most days. **b** Proportion of children with caries by type of drink reported to be consumed with snack.

Children who were allowed to continue breast-feeding after falling asleep (mainly the same children reported to be breast-fed) had significantly higher deft values than those who were not (table 4). Allowing a bottle in bed was unrelated to caries prevalence in this population (table 4).

Multivariate Analysis

A multivariate PLS model with caries status was used to simultaneously evaluate the caries associations identified in the prior univariate analyses, and it included age

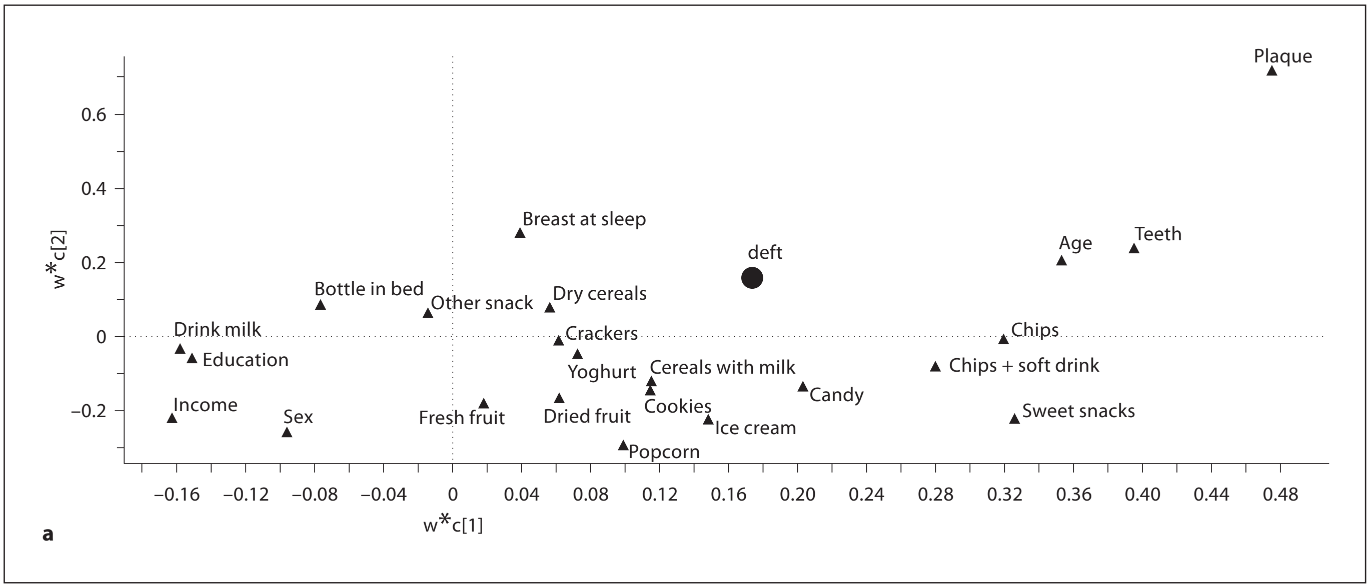
Table 3. Caries status by snack intake

Snack	Consumer	Numbers	Children with caries[1]		Caries experience[2]	
			%	p	deft	p
Chips	no	828	8.7	<0.0001	0.43 (0.31–0.56)	<0.0001
	yes	378	19.6		0.79 (0.64–0.94)	
Candies	no	1,008	10.3	<0.0001	0.53 (0.43–0.63)	0.217
	yes	198	21.2		0.68 (0.46–0.90)	
Ice cream	no	947	10.7	0.003	0.52 (0.42–0.62)	0.127
	yes	259	17.4		0.68 (0.50–0.86)	
Cookies	no	604	9.8	0.013	0.51 (0.37–0.65)	0.247
	yes	602	14.5		0.61 (0.49–0.73)	
Cereals + milk	no	862	10.7	0.014	0.51 (0.39–0.63)	0.124
	yes	344	15.7		0.66 (0.50–0.82)	
Cereals (dry)	no	678	11.2	0.279	0.46 (0.34–0.58)	0.008
	yes	528	13.3		0.70 (0.56–0.84)	
Dried fruit	no	1,042	11.7	0.286	0.52 (0.42–0.62)	0.039
	yes	164	14.6		0.78 (0.54–1.02)	
Popcorn	no	993	11.8	0.044	0.60 (0.48–0.78)	0.728
	yes	134	17.9		0.54 (0.29–0.59)	
Yoghurt	no	544	11.0	0.146	0.54 (0.40–0.68)	0.340
	yes	583	13.9		0.63 (0.49–0.77)	
Fresh fruit	no	264	11.4	0.676	0.54 (0.34–0.74)	0.837
	yes	942	12.3		0.56 (0.46–0.66)	
Crackers	no	376	10.4	0.214	0.47 (0.31–0.63)	0.941
	yes	830	12.9		0.60 (0.48–0.72)	
Others	no	841	12.4	0.698	0.56 (0.44–0.68)	0.941
	yes	363	11.6		0.55 (0.39–0.71)	

$p < 0.01$ considered statistically significant.
[1] Crude numbers tested by χ^2 test for differences in group proportions. $p < 0.01$ for statistical significance.
[2] Means (95% CI) standardized for age group by the GLM procedure (standardization for number of teeth had no further effect). Differences between groups tested by the Bonferroni post hoc test. $p < 0.05$ for statistical significance.

and number of teeth. In this model (ln-transformed deft) as y, and all variables describing intake of snacks, breast- and bottle-feeding, oral hygiene, tooth exposure time (child age, number of teeth), socioeconomic status (income, education) and gender were tested. The model had 2 significant components explaining 13% ($R^2 = 0.134$) and predicting 11% ($Q^2 = 0.109$) of the caries variation (fig. 2a, loading scatter plot; fig. 2b, correlation coefficient plot). The most influential variables in the model (all associated with high caries scores) were presence of plaque (VIP value = 2.39), descriptors for tooth exposure time (number of teeth: VIP value = 1.68; child age: VIP value = 1.50) and several dietary components: total intake of sugar-containing snacks (VIP value = 1.56), intake of chips (VIP value = 1.36), and chips intake with a sugar-containing drink (VIP value = 1.24). Snacking on candies had a borderline effect (VIP value = 0.96), whereas all other snacks had a minimal effect (VIP values <0.9). Models using a dichotomous caries variable provided the same results (data not shown).

PLS modelling also indicated that eating chips as a snack clustered with eating a high number of sweet snacks most days, eating candies, popcorn and ice cream (fig. 3, encircled factors all have VIP values >1.0).



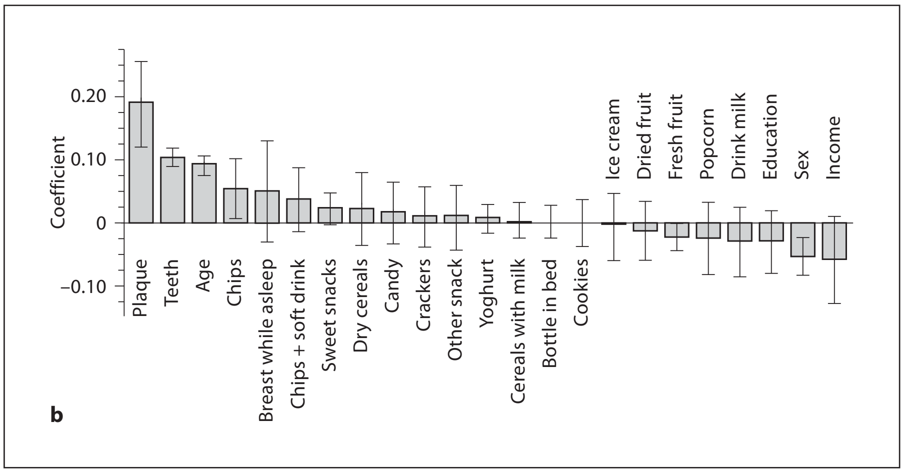


Fig. 2. a PLS loading scatter plot with deft as dependent variable. **b** Correlation coefficient plot displaying means with 95% CI for correlation coefficients.

Table 4. Caries status by eating habits

	Numbers	Children with caries[1]		Caries experience[2]	
		%	p	deft	p
Breast-feeding continued at sleep					
Yes (daily)	49	16.3	0.411	1.48 (1.01–1.95)	0.0003
Never/sparsely	906	13.1		0.61 (0.49–0.73)	
Bottle in bed at night or nap time					
Yes (daily)	429	9.6	0.047	0.53 (0.42–0.64)	0.233
Never/sparsely	773	13.5		0.64 (0.47–0.81)	

[1] Crude numbers tested by χ^2 test for differences in group proportions. $p < 0.01$ for statistical significance.
[2] Means (95% CI) standardized for age group by the GLM procedure (standardization for number of teeth had no further effect). Differences between groups tested by the Bonferroni post hoc test. $p < 0.05$ for statistical significance.

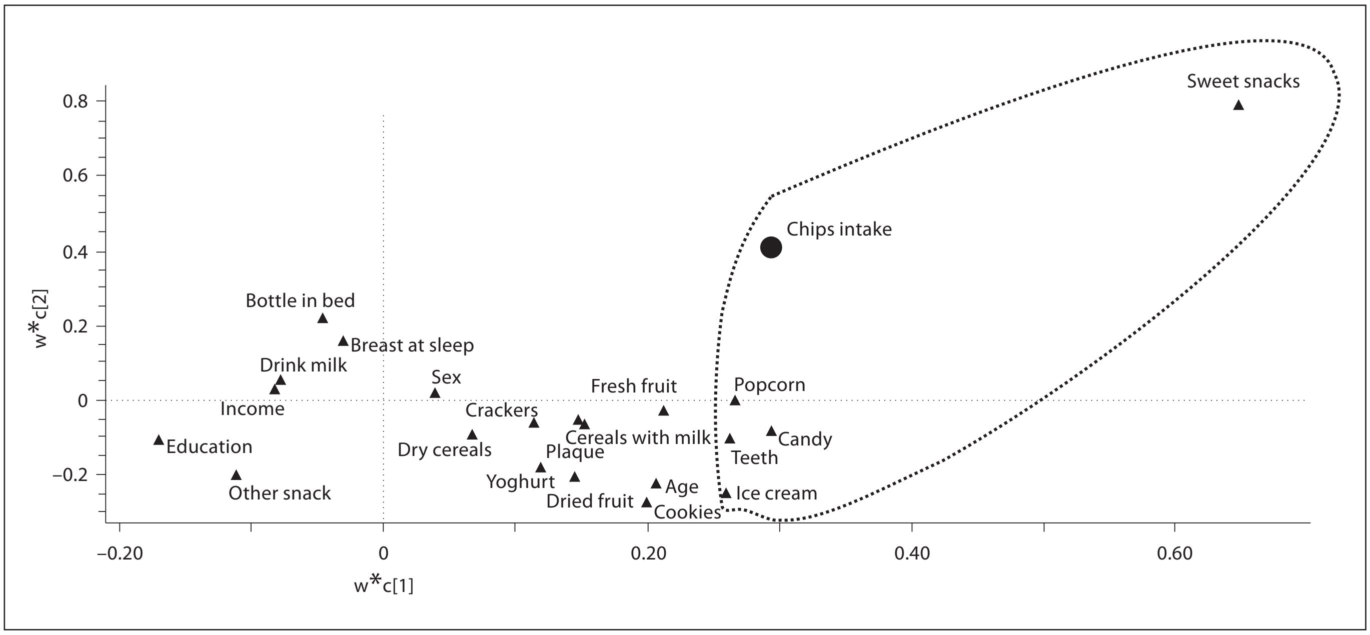


Fig. 3. PLS loading scatter plot modelled with intake of chips as the dependent variable.

Discussion

Repeated pH drop on the tooth surface from carbohydrate fermentation by dental biofilm bacteria is aetiologic to dental caries, but disease outcome is modulated by host and other factors. The relative role of various risk indicators, however, differs between populations [Mattos-Graner et al., 1998; Ramos-Gomez et al., 1999; Tada et al., 1999; Dini et al., 2000; Dasanyake and Caufield, 2002; Santos and Soviero, 2002; van Palenstein Helderman et al., 2006]. Notably, an association between sugar intake and caries development could not be demonstrated in many industrialized 'low-caries' countries [Garcia-Closas et al., 1997; Dye et al., 2004; Öhlund et al., 2007]. The present study shows that snacking on sucrose-containing products, as well as starch-containing chips and presence of plaque are associated with caries in children living in a low-socioeconomic-status, 'high-caries' area in an industrialized country (USA) [Kressin et al., 2009; Nunn et al., 2009].

The present study showed an association between consumption of chips and caries status not previously demonstrated in humans. This association might be explained by a direct caries-inducing effect of chips, or by chips intake clustering with other caries-promoting lifestyle factors. The present study design did not allow for such a distinction, and both aspects might well be involved. In vitro and in vivo studies have shown the pH-lowering effect of hydrolysed starch to be as rapid and deep as that of sucrose [Lingström et al., 1994], and in animal studies there has been shown a caries-inducing potential similar to that of sucrose [Mundorff-Shrestha et al., 1994]. In addition, animal studies have demonstrated that starch potentiates the cariogenic effect of sucrose [Ribeiro et al., 2005]. The PLS modelling using chips intake as the dependant variable, however, showed that children who were given chips as a snack most days also had a high intake of sweet snacks, ice cream and candies, illustrating a clustering of an unfavourable dietary patterns. Notably, chips intake was unrelated to presence of visible plaque.

Besides chips intake and indicators of possible total tooth exposure to cariogenic products – i.e. child age and number of teeth –, presence of visible plaque, number of sweet items used for daily snacking and low family income were independently associated with caries status in the multivariate PLS modelling in this study population. This conforms with earlier studies showing childhood caries was experienced more frequently in children who live under poor economic circumstances, belong to ethnic and racial minorities, have single mothers or have parents with low education, as well as with studies identifying plaque presence and sugar intake as risk indicators for caries [Harris et al., 2004; Vachirarojpisan et al., 2004; Gussy et al., 2006; Kanasi et al., 2010]. We found

PLS modelling to be a useful tool for identifying caries risk indicators as it allows a large number of explanatory variables to be examined simultaneously even though these variables covary [Jonasson et al., 2007; Kanasi et al., 2010].

The cariogenic potential of human milk with approximately 7% lactose has been questioned [Caplan et al., 2008; Mohebbi et al., 2008]. Several recent studies have shown that breast-feeding by itself does not increase the risk of caries in infants [Mohan et al., 1998; Iida et al., 2007; Mohebbi et al., 2008], with the possible exception of continued feeding after the child has fallen asleep [Roberts et al., 1993; Valaitis et al., 2000], as supported by the present data. Thus, children who were breast-fed after having fallen asleep tended to have more caries, but this finding would need confirmation by additional study since only a few children were breast-fed, and only the mean deft value, and not the proportion of breast-fed children with caries, was higher in breast-fed children. Bottle-feeding with sucrose-containing infant formulas, fruit soups or syrups, especially in bed, were reported to be risk indicators for caries in young children [Seow et al., 2009], but this was not confirmed in the present children. In contrast, consumption of cow's milk together with the suspected cariogenic snacks was associated with less caries than consumption of sugar-free or sugar-containing drinks.

The strengths of the present study were that (i) children were recruited from the general population in an area where caries in very young or preschool children is prevalent, and that recruitment was not restricted to those seeing a dentist, (ii) the children represented diverse races and ethnicities, and (iii) the number of children was high. Limitations were (i) the potential for recall bias in the survey information, (ii) the highly skewed low-caries distribution, and (iii) the lack of radiographs to examine teeth (which was not possible in the paediatrician's office). Bratthall [2000] has suggested the use of a Significant Caries Index, corresponding to data from the highest caries tertile to overcome a skewed distribution, but this was not applicable to this population since less than one third of the children had carious lesions.

Caries in early childhood is frequently observed, which preferentially should be addressed by preventive measures as treatment is costly and children with caries in early childhood are prone to high caries activity in the permanent dentition [Alm et al., 2007]. Caries risk is especially high in underprivileged or vulnerable groups [Nunn et al., 2009]. The present study suggests that good oral hygiene and promotion of healthy snacking remain targets for prevention in these children. In the present study, however, the risk indicators examined only explained 13.4% of the disease variation; thus, further studies using additional and new improved risk markers are still desirable.

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