Community Dent Oral Epidemiol 2008; 36: 249–257

COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY

Parental smoking behavior and caries experience in preschool children

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Leroy R, Hoppenbrouwers K, Jara A, Declerck D. Parental smoking behavior and caries experience in preschool children. Community Dent Oral Epidemiol 2008; 36: 249–257. © 2007 The Authors. Journal compilation © 2007 Blackwell Munksgaard

Abstract – *Objectives:* The study aimed to explore the association between parental smoking behavior and caries experience in young children, taking into account the socioeconomic status and oral health-related behavior. *Methods:* Cross-sectional data from 1250 3-year-old and 1283 5-year-old children from four geographical areas in Flanders (Belgium) were analyzed. Children were examined at school by trained dentist-examiners, using standard criteria and calibrated examination methodology. Data on oral hygiene and dietary habits, oral health behavior, sociodemographic variables, and parental smoking behavior were obtained through structured questionnaires, completed by the parents. *Results:* Visible caries experience (i.e. $d_3mft > 0$) was seen in 7% of 3-year olds and 31% of 5-year olds. In both age groups, 30% of the parents reported smoking behavior. Univariable logistic regression analysis with caries prevalence as the dependent variable, revealed that parental smoking was a significant independent variable. After controlling for age, gender, sociodemographic characteristics, oral hygiene, and dietary habits, the effect of family smoking status was no longer significant in 3-year-old children (OR = 1.98; 95% CI: 0.68–5.76). In 5-year olds the significant relationship between parental smoking behavior and caries experience persisted after adjusting for the other evaluated variables (OR = 3.36; 95% CI: 1.49–7.58). *Conclusion:* The results of this study illustrate the existence of a significant association between parental smoking behavior and caries experience in 5-year-old children.

Key words: dental caries; environmental tobacco smoke; preschool children; primary dentition

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Submitted 12 July 2006;
accepted 15 January 2007

Tobacco smoking is related to major general health problems. In the dental literature there is an increasing awareness of the role of active smoking on the prevalence of oral precancers and cancers, and on the prevalence and severity of destructive periodontal disease (1–6). In addition, smoking has been associated with increased failure rates in implant dentistry (7, 8).

Active smokers not only run personal risk of serious health hazards, they may also expose their nonsmoking spouse and children to environmental tobacco smoke (ETS). Exposure of children to ETS is a major concern because of its long-term consequences in terms of increased disease risk and morbidity during childhood (9). Maternal smoking during pregnancy has for instance been associated with increased risk of miscarriage, lower birth weight, perinatal mortality, poor infant growth, and increased use and costs of health services (10–12). When parents do not quit smoking after delivery, their offspring are more vulnerable to sudden infant death syndrome, respiratory illnesses, school absence, behavioral problems, and neurocognitive deficits (9, 13, 14).

Recently, it was suggested that children exposed to ETS have also an increased risk of dental caries in the deciduous dentition (15–17). An important finding, as it may provide insights into the complex multifactorial etiology of dental caries and offer additional tools to tackle

doi: 10.1111/j.1600-0528.2007.00393.x

disparities in caries prevalence through general health preventive measures. The question, however, arises whether the impact of passive smoking on children's oral health can be explained by differences in socioeconomic status, dietary habits, or oral hygiene habits between smoking and nonsmoking families. Therefore, the present study aimed to further elucidate the association between parental smoking behavior and caries experience in preschool children, considering these and other possible confounders.

Material and methods

Sample

Data for this study were obtained from baseline assessments (September to December 2003) at ages 3 and 5 years in the Smile for Life (Tandje de Voorste) project, a prospective oral health promotion project in preschool children. The studied samples included 1250 and 1283 children born in 2000 and 1998, respectively, from four distinct geographical areas in Flanders (Belgium) (Table 1). They were selected using a technique of stratified cluster sampling without replacement. The target population was divided into three strata, representing the three types of educational systems (public, municipal and private schools), taking care of an equal spread on rural and urban regions. The selection was performed in such a way that each child had the same probability of being selected. Whenever a school was selected, all children in the first and/or third preschool class of the selected school were included. Selecting individual children instead of schools would not have been feasible for ethical, practical and economic reasons. The schools were selected with a probability proportional to their size; this approximates selecting children with equal probability. The samples represented about 30% of the population of interest in the four regions.

Table 1. Sample characteristics

	3-year olds	5-year olds
Number of examined children	1250	1283
Girls (%)	47.4	49.2
Mean age (SD)	3.3 (0.3)	5.3 (0.3)
Caries-free (d_3 level) deciduous dentition (%)	93.1	69.2
Restorative Index = 0 (%)	89.2	54.8

SD, standard deviation.

Clinical examination

The oral health examinations were carried out in a class room by one of eight trained dentist-examiners, who participated in two calibration sessions. The first calibration session consisted of the examination of children of the same age but not participating in the survey. The sensitivity and specificity in scoring dental caries was estimated for each dental examiner versus the benchmark scorer (D.D.). The sensitivity ranged between 0.57 and 0.71, and the specificity between 0.87 and 1.00. Afterwards, the dentist-examiners received feedback from the benchmark scorer. A second calibration session was performed based on scoring clinical slides. Both calibration sessions were performed before the examination period.

The birth date of the child, obtained through school records, and the examination date were recorded. Teeth were examined using a mirror with a built-in light source (Mirrorlite™ by Defend® from Medident, Sint Truiden, Belgium) and a WHO/Community Periodontal Index of Treatment Needs (CPITN) type-E screening probe. If necessary, teeth were cleaned and/or dried with cotton rolls before caries experience was recorded. Caries experience was scored on all primary teeth using standardized criteria and calibrated examination methodology, according to the guidelines published by the British Association for the Study of Community Dentistry (BASCD) (18). Decay was scored up to d_1 level; for the present study however, only data at the level of cavitation (d_3) were analyzed. As the examinations were not performed as part of routine dental treatment appointments, no radiographic information was available.

The oral hygiene status was evaluated by means of the index described by Alaluusua and Malmivirta (19). It involves the visual recording of the presence or absence of dental plaque on the buccal surfaces of teeth 55, 52, 72 and 75. For the present analyses, these data were dichotomized into 'child presented without visible plaque accumulation on any of the reference teeth' versus 'child presented with visible dental plaque accumulation on at least one reference tooth'.

Questionnaire data

Data on oral health behavior, sociodemographic variables and parental smoking behavior were obtained through structured questionnaires, completed by the parents. The evaluated independent variables are presented in Table 5. If one of the parents, partners or others [e.g. (one of the)

Table 2. Visible caries experience by reported exposure to environmental tobacco smoke

Family smoking status	3-year olds				5-year olds			
	dmft = 0	dmft > 1	Total	%	dmft = 0	dmft > 1	Total	%
Never	585	30	615	59.2	489	165	654	59.8
Not anymore	96	6	102	9.8	82	27	109	10.0
Yes	288	33	321	30.9	192	138	330	30.2
Total	969	69	1038		763	330	1093	

grandparents if the child is raised by the grandparents] smoked on a regular basis in a place where the child was raised, the family smoking status was recorded as 'yes'; if parents, partners or others quit smoking, the child belonged to the 'not anymore' category (see Table 2). The socioeconomic status of the child was evaluated based on the reported educational level of the mother and the father. Distinction was made between parents who did not continue educational training after primary and/or secondary school (Primary & secondary school), parents who received education at the level of college or non-university higher education (College or higher education) and parents who received education at the university level (University).

Data analysis

Clinical data were entered in a database using the Dental Survey Plus Programme (Providence software, Cary, NC, USA). Questionnaire data were entered twice (by two different persons) using Excel (Microsoft); Excel Compare™ Version 2.0.3 (http://www.formulasoft.com/) was used to check correspondence between the two databases. All inconsistencies between both files were checked with the original questionnaires until two identical files were obtained. Clinical and questionnaire data were first converted and then merged into SAS® (SAS Institute, Cary, NC, USA) data files (version 8.2).

First, chi-squared tests were performed to evaluate the association between family smoking status and other evaluated covariates. Subsequently, univariable (i.e. simple analyses with only one covariate) and multivariable (i.e. several variables are simultaneously controlled for) logistic regression analyses were performed for all studied covariates with caries experience (expressed as a binary outcome, i.e. $d_3mft = 0$ versus $d_3mft > 0$) as outcome variable. These analyses were corrected for examiner misclassification, based on the results of the calibration exercises (20). For all statistical tests, *P*-values below 0.05 were considered statistically significant.

Results

About 7% of 3-year olds and 31% of 5-year olds presented with visible caries experience (i.e. $d_3mft > 0$ – no correction for examiner misclassification) (Table 1). Information on reported parental smoking behavior was available for 1038 3-year olds (83%) and 1093 5-year olds (85%) (Table 2). In both age groups, about 30% of the children grew up in homes where they were exposed to environmental tobacco smoke; about 60% of the children came from families where none of the family members ever smoked.

In 3-year olds, 5% of children growing up in a smoke-free environment (i.e. 30 children of a total of 615 – no correction for examiner misclassification) showed signs of visible caries experience. For children whose housemates did smoke at home, this proportion was twice as high. In the older age group, the respective proportions were 25% and 42%. In both age groups, univariable logistic regression analyses with correction for examiner misclassification revealed a significant association between reported family smoking status and presence of visible caries experience.

Several significant associations between reported family smoking status and parental educational level, dietary and oral hygiene habits were observed (Tables 3 and 4). Parental smoking was significantly associated with a lower educational level, more single-parent families, with more parents who tended to apply sweetener on the pacifier and 'clean' the pacifier in the mouth, and with more children and parents who consume sugar containing drinks in between main meals frequently. In 3-year olds, parents who smoked, used to brush less frequently. Five-year olds who grew up in a smoke-free environment, received significantly more help with brushing, brushed more frequently and consumed snacks in between meals and drinks at night less frequently. Moreover, a higher proportion of their parents had seen a dentist during the previous year for a check-up. No significant association between

Table 3. Bivariate association between parental smoking behavior and other evaluated independent variables in 3-year olds

Variable	*P*-value	Parental smoking behavior[a] (*n*)			
		Never	Not anymore	Yes	Total
Educational level mother	<0.001				
Primary & secondary school		198	34	170	402
College or higher education		288	51	86	425
University		70	9	18	97
Educational level father	<0.001				
Primary & secondary school		172	37	135	344
College or higher education		164	26	50	240
University		69	9	18	96
Home situation	<0.001				
Both parents		566	91	264	921
Other		27	11	46	84
Application of sweet on a pacifier	<0.001				
Never		527	93	250	870
Sometimes or always		58	7	59	124
Cleaning a pacifier in the own mouth	0.014				
Never		299	53	133	485
Sometimes or always		247	37	160	444
In between drinks	<0.001				
Less than once a day		208	28	76	312
Daily		183	28	75	286
More than once a day		199	46	159	404
In between drinks by parents	<0.001				
Less than once a day		348	63	121	532
Daily		114	16	50	180
More than once a day		131	23	139	293
Brushing frequency of parents	0.039				
More than once a day		196	26	85	307
Daily		360	68	190	618
Less than once a day		37	8	35	80

[a]Totals less than 1250 are because of missing observations; only significant results presented.

the exposure to environmental tobacco smoke and the presence of dental plaque was observed.

In 3-year-old children, univariable logistic regression analyses revealed significant associations between visible caries experience and age, educational level of the mother, presence of dental plaque, help with brushing, application of sweetener on pacifier, consumption of sugar containing drinks in between main meals, drinks at night, and family smoking status (results not presented). Following the epidemiological approach, all covariates under investigation were adopted in the multivariable model, irrespective of their statistical significance in the univariable analyses. In the multivariable model only the presence of dental plaque and drinks at night had a significant positive association with visible caries experience; the impact of family smoking status was no longer statistically significant (Table 5).

In 5-year olds univariable logistic regression analyses revealed that age, gender, educational level of the mother and father, the presence of dental plaque, the reported consumption of in between drinks and snacks at night, and family smoking status were significantly associated with visible caries experience (results not presented). The multivariable model indicated that age, gender, the presence of dental plaque, in between drinks, as well as family smoking status were significantly associated with visible caries experience (Table 5).

Discussion

The present study confirms recent reports that children who are raised in families where they are exposed to ETS are at increased risk for developing dental caries in primary teeth (15–17). As far as we know, it is the first time that the association between exposure to ETS on the one hand and sociodemographic factors, dietary and oral hygiene habits on the other are also evaluated in relation to the prevalence of dental caries in primary teeth.

Table 4. Bivariate association between parental smoking behaviour and other evaluated independent variables in 5-year olds

Variable	*P*-value	Parental smoking behavior[a] (n)			
		Never	Not anymore	Yes	Total
Educational level mother	<0.001				
Primary & secondary school		140	24	122	286
College or higher education		216	38	65	319
University		48	11	15	74
Educational level father	<0.001				
Primary & secondary school		238	49	195	482
College or higher education		219	30	58	307
University		93	17	16	126
Home situation	<0.001				
Both parents		398	71	189	658
Other		37	6	45	88
Help with brushing	0.021				
Daily		154	22	56	232
More than once a week		146	29	82	257
Less than once a week		131	26	94	251
Brushing frequency	0.009				
More than once a day		94	15	46	155
Daily		248	49	113	410
Less than once a day		84	13	72	169
Application of sweetener on a pacifier	<0.001				
Never		385	69	170	624
Sometimes or always		37	3	49	89
Cleaning a pacifier in the own mouth	0.023				
Never		235	32	103	370
Sometimes or always		155	36	101	292
In between meals	0.042				
Less than once a day		83	16	39	138
Daily		196	26	85	307
More than once a day		151	35	106	292
In between drinks	<0.001				
Less than once a day		183	37	51	271
Daily		127	16	64	207
More than once a day		123	24	118	265
In between drinks by parents	<0.001				
Less than once a day		280	46	112	438
Daily		80	16	32	128
More than once a day		74	14	90	178
Last visit to the dentist by parents	0.001				
<1 year		347	55	156	558
1–5 years		74	19	57	150
>5 years		14	2	20	36

[a]Totals less than 1283 are due to missing observations; only significant results presented.

A limitation of the set-up of this study is the lack of radiographic documentation. Caries experience was assessed only clinically as dental examinations were not performed in combination with routine dental check-ups or treatment appointments. Exposing the children to roentgen rays only for scientific purposes was considered unethical. Hence, the prevalence of caries was probably underscored. Further research is indicated to reveal if the influence of evaluated factors is altered when caries is diagnosed based on clinical as well as radiographic judgements.

Caries experience data at the d_3 level were utilized as this is the level where preventive action is no longer sufficient and operative intervention is indicated. However, this approach results in an underestimation of caries prevalence rates. Further research is needed to study the effect of exposure to ETS and other evaluated variables on visible caries prevalence scored at d_1 and d_2 level in both age groups.

In the present study ETS exposure was assessed based on questionnaires completed by the parents. It could be argued that this approach is subjective and

Table 5. Multivariable logistic regression models for visible caries experience in 3- and 5-year olds

	3-year olds			5-year olds		
Variable	Number of subjects[a]	OR	95% CI	Number of subjects[a]	OR	95% CI
Gender						
Boys (ref.)	658			652		
Girls	592	1.48	0.48–4.59	631	**0.31**	**0.16–0.62**
Home situation						
Both parents (ref.)	921			658		
Other	84	1.15	0.20–6.63	88	0.41	0.13–1.31
Educational level mother						
Primary & secondary school (ref.)	402			286		
College of higher education	425	1.15	0.36–3.64	319	0.69	0.31–1.54
University	92	1.07	0.13–8.46	74	0.31	0.07–1.41
Educational level father[b]						
Primary & secondary school (ref.)	482			344		
College of higher education	307	0.49	0.14–1.76	240	0.77	0.35–1.71
University	126	0.20	0.02–1.71	96	0.74	0.22–2.54
Presence of dental plaque						
No (ref.)	736			753		
Yes	326	**8.79**	**2.71–28.52**	447	**3.07**	**1.50–6.30**
Age at start brushing						
1 year or younger (ref.)	360			271		
More than 1 year	455	3.07	0.93–10.16	134	1.58	0.60–4.19
More than 2 years	194	1.18	0.21–6.56	35	1.41	0.31–6.34
Help with brushing						
Daily (ref.)	524			367		
More than once a week	370	1.58	0.45–5.51	394	1.07	0.44–2.61
Less than once a week	151	3.84	0.82–17.89	342	1.23	0.54–2.80
Brushing frequency						
More than once a day (ref.)	184			252		
Daily	556	4.94	0.37–65.42	620	1.51	0.67–3.40
Less than once a day	306	2.25	0.15–34.88	222	0.84	0.26–2.74
Use of a nursing bottle						
No (ref.)	581			931		
Yes	396	0.52	0.18–1.48	127	1.35	0.37–4.91
Application of sweetener on a pacifier						
Never (ref.)	912			937		
Sometimes or always	133	0.33	0.09–1.23	135	1.51	0.57–4.04
Cleaning a pacifier in the own mouth						
Never (ref.)	504			541		
Sometimes or always	471	0.39	0.14–1.08	453	1.12	0.58–2.14
In between meals						
Less than once a day (ref.)	200			190		
Daily	479	0.79	0.18–3.47	474	0.43	0.16–1.13
More than once a day	370	0.62	0.12–3.07	442	0.64	0.23–1.74
In between drinks						
Less than once a day (ref.)	326			394		
Daily	306	1.52	0.36–6.41	316	2.16	0.94–4.96
More than once a day	419	1.96	0.55–7.01	399	**2.43**	**1.04–5.68**
Drinks at night						
None (ref.)	934			980		
Daily or more	116	**8.75**	**1.61–47.68**	116	1.37	0.17–11.31
Snacks at night						
Less than once a week (ref.)	794			849		
Once a week	137	1.06	0.26–4.40	118	2.70	0.89–8.15
Daily	114	0.40	0.06–2.50	127	1.73	0.60–4.95
Family smoking status						
Never (ref.)	615			654		
Not anymore	102	1.71	0.30–9.65	109	0.55	0.19–1.65
Yes	321	1.98	0.68–5.76	330	**3.36**	**1.49–7.58**

[a]Totals less than 1250 (in 3-year olds) or 1283 (in 5-year olds) are because of missing observations.
OR: odds ratio; ref: reference; were also considered in the multivariable analyses: age (as continuous variable) and region; significant results presented in bold.

may result in information bias. However, the question regarding the smoking behavior of the household where the child is raised was posed in a questionnaire in which all other questions were related to oral health. It is believed that only few parents would link their smoking behavior with the oral health of their offspring. Moreover, the reported prevalence of parental smoking in both age groups (about 30%) was within the range of prevalence data for Flemish men (35%) and women (21%) in 2001 (http://www.vlaanderen.be/vrind/welzijn).

Exposure to ETS can also be estimated through cotinine levels, which mirror one's exposure during the preceding few days. However, it has been found that cotinine measures do not offer an advantage over exposure data based on parental smoking histories (21). Moreover, one should realize that exposure to ETS may vary from season tot season, day to day, or even hour to hour. As for now, the optimal time frame for the assessment of exposure is unknown (14).

The effect of exposure to ETS was more pronounced in 5-year olds: when comparing the regression estimates, one can see that the estimates in the 5-year olds are almost double the estimates observed in the 3-year olds (Table 5). This difference may be related to a greater cumulative exposure to ETS in the 5-year olds. Furthermore, the difference in effect of exposure to ETS between age groups could be attributed to the difference in caries prevalence: in 3-year-old children only 7% presented with visible caries experience, compared with 30% in the 5-year olds. Hence, the lower prevalence in the 3-year olds may result in less statistical power.

In the present study the socioeconomic status of the examined children was estimated from the reported highest educational level of both parents. It has been argued that the level of parental education is useful for this purpose as it can be applied to both sexes, is applicable to persons not in labor force, and is a stable parameter over lifespan (22). It has been suggested that a higher educational level is predictive for better jobs, higher incomes, better housing, and socioeconomic status (23, 24).

The results confirmed the association between smoking behavior and parental educational level (25). The prevalence of parental smoking was significantly lower in two-parent households compared with other family structures, a finding that is in agreement with other reports.

It has been suggested that exposure to ETS at home could be an indicator of poor oral hygiene among children (patterned after parental habits) or could be associated with poor dietary habits or low fluoride exposure (17). Indeed, the association between exposure to ETS and these factors was confirmed: children raised by parents who smoked brushed less frequently, received less help with brushing, and consumed more in between meals and nightly beverages. Their parents tended more to 'clean' the pacifier in the mouth and apply sweetener on it. Therefore, these and other possible confounding factors were adopted in the multivariable analyses (Table 5). Unexpectedly, however, even after adjustment for parental educational level, dietary and oral hygiene habits, a more than threefold elevated risk for caries associated with parental smoking was revealed in 5-year olds.

The results of the present study raise questions regarding the underlying biological mechanisms of the observed associations. First of all, tobacco smoke is composed of thousands of chemicals, of which the individual contributions to the pathophysiologic processes are still unknown (14). Moreover, a prospective study design is needed to identify exposure to ETS as a direct risk factor for caries development in young children and to prove causality of the association. Based on the literature, a number of possible causal pathways might be considered to explain the results obtained in the present study.

One *in vitro* study concluded that tobacco may have a promoting effect on the growth of oral cariogenic streptococci, resulting in a more likely transmission of streptococcus mutans from smoking mothers to their children (26). Yet, Billings et al. remarked that this *in vitro* study only involved smokeless tobacco products and, as the original authors noted, growth of cariogenic organisms may have been entirely attributable to the manufacturer's added sugar and not to natural tobacco sugar (27).

It has already been reported in 1957 that maternal smoking during pregnancy is associated with increased risks for low birth weight and prematurity (28). In later dental studies, low birth weight as well as prematurity have both been linked with developmental defects (enamel hypoplasia) and increased caries experience (29, 30). As a consequence, Williams et al. suggested this as a possible pathway of causality (15). As the present dataset did not contain any data regarding pregnancy or delivery of the examined children, this hypothesis could not be confirmed. On the other hand, Shulman recently failed to find any association between low birth weight and caries of the primary dentition (31).

Two systematic reviews confirmed that children's exposure to environmental tobacco smoke is associated with enhanced rates of asthma, other respiratory illnesses and middle ear infections (9, 13). It can be hypothesized that the increased caries susceptibility observed in children exposed to ETS may also be explained by these conditions and their treatment. Rhinitis, for instance, may cause mouth breathing, resulting in dry mouth and increased caries susceptibility (16). On the other hand, as ETS has immunosuppressive properties and is a known risk factor for infections of the 'cranial organs', it is not surprising that children exposed to ETS are at increased risk for dental caries, which is also an oral infectious disease (16).

Active as well as passive smokers are exposed to free radicals, generated in cigarette smoke. Because free radicals cause oxidative damage to macromolecules such as lipids, proteins and DNA, they are believed to be involved in the pathogenesis of cardiovascular diseases and cancer (32). Vitamin C is an important plasma antioxidant; it scavenges free radicals efficiently. It has been well established that cigarette use compromises vitamin C status in active smokers (32). Recently, it was reported that ETS can also reduce concentrations of ascorbate in children, even when the amount of exposure to ETS is minimal (33). Even though it is – to our knowledge – not known whether oxidant damage has a causative role in the increased caries susceptibility in children exposed to ETS, it is important to note that decreased vitamin C levels have been associated with growth of cariogenic bacteria (34).

In conclusion, the present study confirms the bivariate association between exposure to environmental tobacco smoke and caries experience in preschool children. Even after adjusting for parental educational level, reported dietary and oral hygiene habits, the association between exposure to ETS and caries experience was still significant in 5-year olds. As the pathophysiologic pathways behind these results are not yet fully understood, the present report may suggest the necessity to further explore the causal relationship between exposure to ETS and caries experience in young children.

Acknowledgements

The following partners collaborated in the 'Smile for Life Project': Dominique Declerck (Project coordinator) and Roos Leroy (both from the Department of Dentistry, Catholic University Leuven); Karel Hoppenbrouwers (Youth Health Care at the Catholic University Leuven, and the Flemish Society for Youth Health Care); Emmanuel Lesaffre (Centre for Biostatistics, Catholic University Leuven); Stephan Vanden Broucke (Research Group for Stress, Health and Well-being at the Catholic University Leuven); Luc Martens (Dental School, Ghent University); Erwin Van Kerschaver and Martine Debyser (Child and Family). The study was supported financially by GABA Benelux and GABA International.

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