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National Pathfinder Survey on Children's Oral Health in Italy: Pattern and Severity of Caries Disease in 4-Year-Olds

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Key Words
dmfs index · Early childhood caries · Preschool children, caries disease · Primary dentition

Abstract
This paper describes the dental health status of Italian 4-year-olds in 2004/2005 and analyzes the association between caries in preschool children and some background characteristics in children and parents. Caries was recorded according to WHO criteria. 5,538 subjects were examined. Information on the children's and their parents' social, behavioral, ethnic and demographic status was obtained through a series of closed questions. Bivariate analysis was performed to investigate the association between caries and background characteristics. The probability of being an extra zero for the dmfs index was estimated via the zero-inflated negative binomial regression model (ZINB). 78.4% (95% CI = 77.2–79.6) of the children were caries-free. The national mean dmfs index was 1.36 (95% CI = 1.15–1.57), ranging from 1.22 (95% CI = 1.03–1.42) in the Italian North-East to 1.73 (95% CI = 0.83–2.63) in the South section. Significant bivariate associations between caries experience and risk factors were observed for parents' nationality (not Italian vs. Italian: $p < 0.001$), parents' educational levels (low vs. high: $p < 0.001$), preterm birth (yes vs. no: $p = 0.011$), prolonged breastfeeding (≤13 months vs. >13 months: $p = 0.038$) and early tooth eruption (<6 months as reference: $p = 0.004$). Multivariable analysis (ZINB) showed that children with a low caries risk level had a higher probability of being an extra zero; in particular, children from fathers with a high educational level showed a probability of being an extra zero of 0.22. The results suggest a need to plan preventive programs to reduce oral health disparities among Italian preschool children, based on educational intervention with parents and children concerning oral health and caries prevention.

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Caries development is related to lifestyle and to several behavioral factors like poor oral hygiene and poor dietary habits. However, the pattern of caries disease reflects distinct risk profiles related to living conditions, lifestyles and environmental factors and the implementation of preventive oral health schemes [Petersen, 2005].

Findings of relationships between socioeconomic status and health outcomes are quite ubiquitous across the health literature. People with lower educational attainment and lower income usually have a lower life expectancy; thus, children from families with a low income are more likely to have a low birthweight and to suffer from childhood illnesses [Armfield, 2007]. Breastfeeding is recommended by pediatricians to be continued for at least the first year of life and beyond for as long as mutually desired by mother and child [Gartner et al., 2005]. Prolonged and unrestricted breastfeeding, however, has been reported to be a potential risk factor for caries [Hallett and O'Rourke., 2006; Iida et al., 2007].

Caries disease in preschool children has a complex multifactorial etiology: it has also been associated with improper feeding practice [Ismail, 2003; Hallett and O'Rourke, 2006; Campus et al., 2007a; Kramer et al., 2007] and low socioeconomic background [Ismail, 2003; Muirhead and Marcenes, 2004; Hallett and O'Rourke, 2006]. Nowadays, increasing attention is being paid to differences in population subgroups in characterizing the distribution and correlation of dental disease [Seppä et al., 2000; Muirhead et al., 2004; Bankel et al., 2006]. A link between preterm birth or low birthweight and caries was proposed [Seow, 1997; Burt and Pai, 2001; Eastman, 2003; Shulman, 2005; Saraiva et al., 2007], but no conclusive evidence has been found.

In all developed countries, dental health status in preschool children has significantly improved during the last decade [Al-Mohammadi et al., 1997; Radford et al., 2001; Stecksén-Blicks et al., 2004; Henkuzena et al., 2004; Olak et al., 2007]. No national data on caries prevalence in Italian preschool children exist, although local data show a high level of caries disease still now [Campus et al., 2004, 2007a; Ferro et al., 2006].

In 2004, an epidemiological survey called 'National Pathfinder among Children's Oral Health in Italy' was promoted by the Collaboration Centre for Epidemiology and Community Dentistry of Milan in collaboration with the Italian Society of Hygiene and Preventive Medicine. The main aim of the project was to gain epidemiological data on caries prevalence and severity among Italian children in two definite age groups (4- and 12-year-olds) [Castiglia et al., 2007; Campus et al., 2007b]. The secondary aim was to associate clinical data with background factors recorded by a self-administered questionnaire. In this paper, the oral status of Italian 4-year-olds was assessed and the dependence between caries in preschool children and some background characteristics of the children and parents was investigated.

Subjects and Methods

The present study was carried out as a cross-sectional survey from March 2004 to April 2005. The design of the study was approved by the Research Ethics Committee of the University of Milan in December 2003.

A multistage cluster sampling was performed as previously reported [Campus et al., 2007b], considering the Italian sections as strata: North-West, North-East, Central, South and Insular Italy (fig. 1). In the second stage the counties of the sections and then the schools (kindergartens) were chosen at cluster level with proportional random selection of participants. A sample size for each stratum was calculated based on an assumed prevalence of dental caries (dmfs >0) of 20%, a standard error of 0.05 and a design effect of 2.5 [Lwanga and Lemeshow, 1991]. The number of 5,100 Italian children aged 4 years was increased by 10%. This strategy provided a sample that was self-weighting. In total, 5,667 children were recruited and 5,538 were examined; 88 children with no parental consent and 41 not present in the classroom at the moment of the examination were excluded. The study sample represented 1.04% of the total Italian population aged 4 years attending kindergartens (534,447 children) [National Italian Institute of Statistics, 2003]. The frequency of 4-year-old children attending this kind of school is 59.7%.

The tap water fluoride content in the different areas selected for the survey varied from 0.02 to 0.4 ppm [Italian Territory Office, 2001]. Caries disease data (dmfs) were collected in the schools by means of clinical examinations and decay was recorded at the dentinal lesion level [Pitts and Longbottom, 1995], using a plane mirror (Hahnenkratt, Königsbach, Germany) and the WHO CPI ballpoint probe (Asa-Dental, Milan, Italy), under artificial light (LED Head-Lite Cap; Taipei, Taiwan).

Because of the high number of children under examination, the number of examiners was set at 7. In order to avoid intercluster variability attributable to interexaminer variability, each selected school was visited by all 7 raters at the same time and each examiner visited an equal number of subjects. The team received training, and intra- and interexaminer reliability was assessed before the beginning of the survey. Every rater evaluated the same 30 subjects twice and the records were compared with those of the benchmark examiner. Sensitivity, specificity, percentage agreement and kappa statistics [Jamieson et al., 2004] were recorded through tooth-by-tooth examination [Castiglia et al., 2007].

Consent forms and explanatory letters were sent to parents with a self-submitted questionnaire that parents or guardians had to complete at home. After a previous validation through a pilot study, the items in the questionnaire were methodically formulated to avoid confusion and misunderstanding. Table 1 reports the variables derived from the questionnaire. The aim of the questionnaire was to assess the potential risk factors through informa-

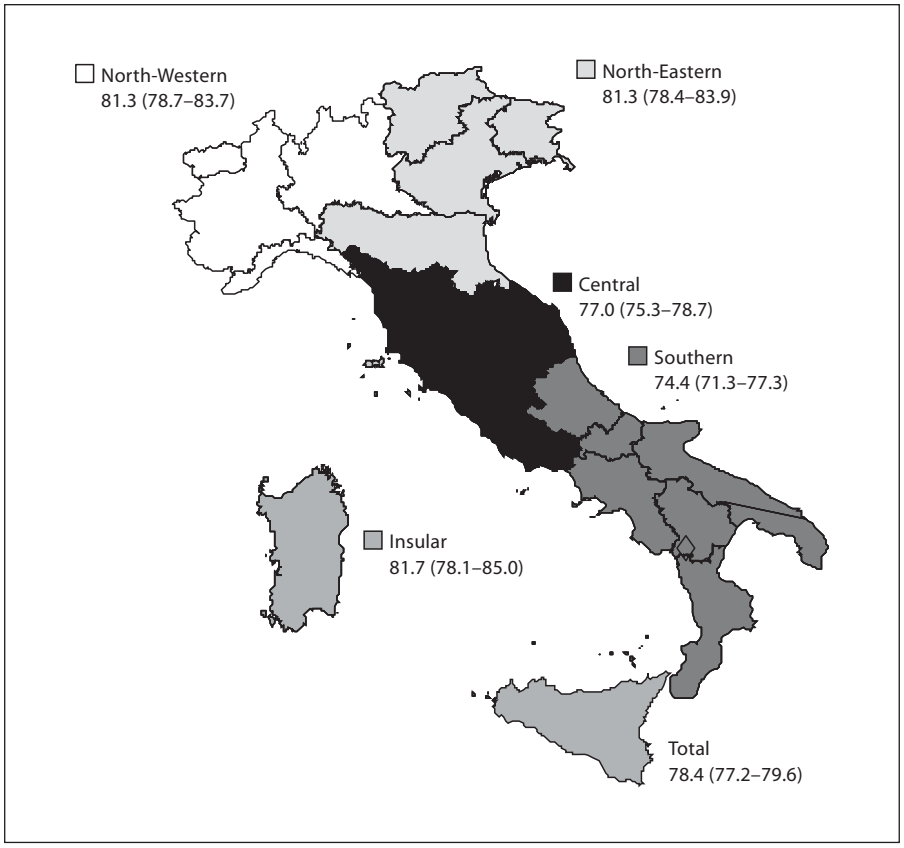

Fig. 1. Caries-free (%) by Italian sections and gender (95% CIs in parentheses).

tion on infant feeding practice, medical events, sociodemographic factors (parents' educational level was considered as a proxy variable of socioeconomic status; high school level was used as threshold corresponding to the 10th year of schooling after reception) and dental behavior in early childhood that may have affected the pattern and severity of current caries experience.

Clinical and background data were coded and entered into an ad hoc database performed on Microsoft Access. Data were analyzed using Stata 9.0 [Stata Corporation, 2005]. The statistical significance level for all analyses was set at 0.05.

The z test was applied to evaluate the significance of caries-free prevalence between genders and the homogeneity test was applied to check the null hypothesis that the Italian section samples were homogeneous with respect to caries-free prevalence. 95% confidence intervals (95% CIs) were also calculated according to the z distribution.

A nonparametric Cuzick trend test across ordered dmfs groups [Mwalii, 2005], i.e. across Italian geographical sections by severity of disease, was performed. The test is an extension of the Wilcoxon rank-sum test [Cuzick, 1985]. The associations between caries experience (dmfs >0) and potential risk factors were investigated by the χ^2 test and the significant background variables were considered as predictors for dmfs in regression models.

The Shapiro-Wilk test was employed to evaluate whether the dmfs index satisfied the assumption of normality in the regression models. Since the dmfs index was not normally distributed ($z = 19.03$, $p < 0.001$), some regression models not requiring the

Table 1. Variables derived from the questionnaire

(a) Infant feeding
Duration of breastfeeding (>13 months)
(b) Infancy and mother illness during pregnancy
Medical illness during pregnancy (>1 month = yes and <1 month = no)
Taken prescription medication during pregnancy (>1 month = yes and <1 month = no)
Preterm birth (<36 weeks)
(c) Social demographics
Gender
Immigrant (Italian vs. not Italian)
Parents' educational level (high = high school or higher vs. low = lower than high school)
(d) Dental health behaviors
Age of first tooth eruption (<6 months)
Toothbrushing habits (yes and no)

assumption of normality, such as the negative binomial suggested by Grainger and Reid [1954] and the Poisson model [Fabien et al., 1999], were performed. Moreover, these models have been compared to the zero-inflated regression models [zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB)] [Bohning et al., 1999; Lewsey and Thomson, 2004]. These models are used to count data with an excess of observed zeroes that can cause overdispersion, as previously presented [Solinas et al., 2008].

The ZINB model expresses the dmfs index as a function of various explanatory variables (gender, parent nationality and educational level, preterm birth, prolonged breastfeeding, age of tooth eruption, toothbrushing habits and disease or medication during pregnancy). Regarding nondichotomous covariates, each child was put into two groups according to the educational level of both mother and father: high (high school or higher), or low (lower than high school). Children were also categorized according to the immigration status of their mother and father (Italian vs. not Italian). Finally, regarding age of tooth eruption, children were categorized into four age groups: younger than 6 months; between 6 and 9 months; between 9 and 12 months; older than 12 months.

The zero-inflated regression model is a mixing specification that adds extra weight to the probability of observing a zero [Mullahy, 1986]. This can be interpreted as a splitting device that divides individuals into two groups: subjects not at risk, so they have zero counts with probability p and potential subjects at risk with probability $1- p$. The influence of covariates may move subjects from the first to the second group and the effect of the extra zero component in the ZINB model is estimated by a logit regression. The results of the ZINB model with the covariates were related to the modeling of the extra zeroes (in the logit scale) and the negative binomial process in the natural log scale. The probability of being an extra zero was calculated from the coefficient in the logit part of the table, while the adjusted mean dmfs values were calculated from the coefficients in the negative binomial part. A covariate may have or not the same direction of impact in the two groups. The goodness of fit of the regression models was determined by Akaike information criterion values [Akaike, 1974]. To assess the existence of multicollinearity across independent variables with high correlation coefficients a collinearity test was performed.

Results

The sample consisted of 5,538 children (aged 47.2 ± 3.5 months; 2,518 males and 2,665 females, gender was unspecified in 6.4% of the self-submitted questionnaires). In the interexaminer reliability training, sensitivity and specificity were 95 and 100%, respectively, while kappa statistics ranged from 0.92 to 0.97. As regards intraexaminer reliability, the mean sensitivity was 94% (ranging from 91.3 to 96.5%), significantly increasing between the two calibration sessions (Student's paired t test: $p = 0.003$).

The percentages of caries-free subjects in the Italian geographical sections are reported in figure 1. The percentage of caries-free subjects is not homogeneous among Italian sections (χ^2 test; $p < 0.05$): from 81.3% in the North-West to 74.4% in the South. Overall, 78.4% (95% CI = 77.2–79.6%) of the children were caries-free, 78.7% males and 78.9% females ($p > 0.05$).

Table 2 reports, adjusted for design effect, the survey estimation results of the national dmfs index and its components. Overall, the national mean dmfs index was 1.36 (95% CI = 1.15–1.57) and differences among the geographical areas were not significant ($p = 0.85$). However, a significant increase in dmfs index from North to South (p for trend = 0.016) was observed.

Statistically significant differences were found for the fs component ($p = 0.002$); the lowest mean value was in Insular Italy (fs = 0.01, 95% CI = 0.00–0.02) and the highest in the Central section (fs = 0.09, 95% CI = 0.04–0.14). Regarding the ds component, which ranged from 1.18 (95% CI = 0.95–1.41) in the North-West to 1.67 (95% CI = 0.82–2.52) in the South, the mean national value was 1.29 (95% CI = 1.11–1.48), accounting for about 95% of the dmfs index. As regards gender, males showed higher dmfs values than females (mean dmfs index 1.48 vs. 1.21), but a significant difference between genders was observed only in the South (2.03 vs. 1.37; $p = 0.03$). Significant differences in the mean fs component between males and females were observed both in Central (0.13 vs. 0.05; $p = 0.002$) and in Insular Italy (0.00 vs. 0.01; $p < 0.001$). A significant difference between genders in the ds component was observed in the South (2.00 vs. 1.29; $p = 0.03$), where males showed the highest value in the country.

Background characteristics of children split up by caries experience are reported in table 3. Significant associations between caries experience and potential risk factors were observed for parent nationality (not Italian vs. Italian), parent educational level (low vs. high level), preterm birth, prolonged breastfeeding and early tooth eruption (<6 months as reference). The study variables produced a condition number of 2.05, indicating that collinearity will not have a major influence on results of regression models.

The inappropriateness of the Poisson regression model, evaluated by significance of the dispersion parameter alpha into the negative binomial model ($p < 0.001$), and the inappropriateness of the negative binomial model, considering the Akaike information criterion values for the regression models (Poisson = 5.84; negative binomial = 2.09; ZIP = 3.18, and ZINB = 2.08), indicated that the ZINB regression model fitted data significantly better than the others ($p < 0.001$). ZINB adjusted estimates for caries severity (dmfs index) and the probability of being

Table 2. Survey estimation of means and 95% CI of dmfs index by gender and Italian sections, adjusted for design effect

Italian sections	ds	fs	dmfs
North-West	1.18 (0.95–1.41)	0.06 (0.04–0.10)	1.25 (1.00–1.49)
Males	1.32 (1.00–1.64)	0.06 (0.02–0.10)	1.38 (1.04–1.72)
Females	1.06 (0.68–1.44)	0.06 (0.03–0.10)	1.12 (0.74–1.51)
p value[1]	0.31	0.95	0.32
North-East	1.19 (1.00–1.39)	0.03 (0.00–0.04)	1.22 (1.03–1.42)
Males	1.38 (1.09–1.67)	0.04 (0.00–0.08)	1.42 (1.11–1.73)
Females	0.84 (0.47–1.22)	0.02 (0.00–0.03)	0.86 (0.48–1.25)
p value[1]	0.07	0.36	0.07
Central	1.25 (0.93–1.57)	0.09 (0.04–0.14)	1.34 (0.97–1.70)
Males	1.19 (0.96–1.42)	0.13 (0.06–0.21)	1.33 (1.03–1.62)
Females	1.29 (0.86–1.71)	0.05 (0.02–0.08)	1.34 (0.89–1.78)
p value[1]	0.48	0.002	0.92
South	1.67 (0.82–2.52)	0.06 (0.02–0.10)	1.73 (0.83–2.63)
Males	2.00 (0.97–3.03)	0.03 (0.01–0.05)	2.03 (0.99–3.07)
Females	1.29 (0.70–1.88)	0.07 (0.00–0.16)	1.37 (0.69–2.04)
p value[1]	0.03	0.21	0.03
Insular Italy	1.27 (0.92–1.62)	0.01 (0.00–0.02)	1.28 (0.92–1.64)
Males	1.56 (1.30–1.83)	0.00 (0.00–0.00)	1.56 (1.29–1.83)
Females	1.05 (0.08–2.03)	0.01 (0.01–0.01)	1.07 (0.09–2.04)
p value[1]	0.40	0.00001	0.41
Total Italy	1.29 (1.11–1.48)	0.06 (0.03–0.09)	1.36 (1.15–1.57)
Males	1.40 (1.22–1.59)	0.08 (0.02–0.13)	1.48 (1.29–1.67)
Females	1.16 (0.88–1.44)	0.05 (0.03–0.07)	1.21 (0.92–1.50)
p value[1]	0.13	0.15	0.068
p value for mean differences among all sections[1]	0.86	0.0019	0.85

Figures in parentheses indicate 95% CIs. [1] Adjusted Wald test.

an extra zero by significant background risk factors for caries experience are reported in table 4. Children with a low caries risk level showed higher probability of being an extra zero. In particular, an increasing probability of being an extra zero was observed in relation to tooth eruption age ranging from 0.17 in children with tooth eruption at 6–9 months to 0.28 in children with tooth eruption at over 12 months. Children of fathers with a high educational level showed a probability of being an extra zero of 0.22. The lowest adjusted dmfs index (4.4) was observed in children with an Italian father.

Discussion

Literature concerning caries of the primary dentition is not widely documented, i.e. few papers report dmfs values [Carvalho et al., 1998; Campus et al., 2004; Henkuzena et al., 2004; Stecksén-Blicks et al., 2004, 2006]. To the best of the authors' knowledge this is the first paper describing a representative dmfs index of the entire national preschool population of one European country.

The dmfs index of 4-year-old children was statistically dissimilar among Italian geographical sections: in particular, dmfs progressively increased from Northern to Southern sections. The observed mean dmfs value was lower than that recorded at different times in Latvia [Henkuzena et al., 2004], Sweden [Stecksén-Blicks et al., 2006], Brazil [Carvalho et al., 1998] as well as in Italy [Campus et al., 2004]. The different dmfs values reported in the literature are probably due to geographic variations, but also to the different periods of data collection; more recent data could probably show a more restricted range of dmfs among these countries. Caries experience rates among 4-year-olds range from 13.3% [Ferro et al., 2006] to more than 50% [Henkuzena et al., 2004].

Table 3. Background characteristics of children (n = 5,538) by levels of dmfs

	dmfs = 0	dmfs >0	p value[1]
Gender			>0.05
Females	2,096 (78.6)	569 (21.4)	
Males	1,987 (78.9)	531 (21.1)	
Mother's nationality			<0.01
Italian	3,827 (80.7)	917 (19.3)	
Not Italian	376 (63.8)	213 (36.2)	
Father's nationality			<0.01
Italian	3,877 (80.9)	918 (19.1)	
Not Italian	281 (58.9)	196 (41.1)	
Mother's education			<0.01
High	2,945 (81.8)	657 (18.2)	
Low	1,240 (72.1)	480 (27.9)	
Father's education			<0.01
High	2,642 (82.4)	565 (17.6)	
Low	1,516 (73.2)	554 (26.8)	
Preterm birth			<0.05
Yes	397 (74.5)	136 (25.5)	
No	3,757 (79.2)	985 (20.8)	
Breastfeeding			<0.05
>13 months	3,415 (79.3)	891 (20.7)	
≤13 months	768 (76.3)	238 (23.7)	
Age at first tooth eruption			<0.01
<6 months	1,226 (75.6)	395 (24.4)	
6–8 months	2,013 (79.5)	518 (20.5)	
9–12 months	697 (80.7)	167 (19.3)	
>12 months	163 (81.9)	36 (18.1)	
Toothbrushing			>0.05
Yes	4,016 (78.9)	1,077 (21.1)	
No	151 (73.3)	55 (26.7)	
Illness during pregnancy			>0.05
Yes	137 (77.8)	39 (22.2)	
No	3,990 (78.7)	1,078 (21.3)	
Prescription medicines taken during pregnancy			>0.05
Yes	751 (80.0)	188 (20.0)	
No	3,398 (78.5)	929 (21.5)	

The total number of children in each characteristic may differ because of missing data. Figures are numbers with percentages in parentheses. [1] χ^2 test.

In the Italian preschool population, the ds component was dominant in all geographical areas, indicating a need for dental care and a lack of control over the disease. Nevertheless, the disease pattern could probably be associated with the socioeconomic status of the population: children living in South Italy, where the GNP per capita is significantly lower than in other parts of the country, showed a higher caries prevalence (ds component) [Campus et al., 2007b]. This supports the results of other studies examining the dental status of 4-year-old children [Al-Mohammadi et al., 1997; Radford et al., 2001]. The well-known association between deprivation and caries may hide other associated or causative factors, such as infant feeding practice and toothbrushing habits.

Caries prevalence significantly differed among geographical sections although it was low throughout the country (78% approximately caries-free), evidencing that caries disease affects particularly small groups of population nowadays. The Italian results seem to overlap with those described in other European studies [Stecksén-Blicks et al., 2004; Henkuzena et al., 2004; Olak et al., 2007], where health care systems and dental caries prevention programs are rather dissimilar. In Nordic countries, caries preventive programs have been established since the 1970s and the number of children with caries was reduced by half in a span of 15 years [Stecksén-Blicks et al., 2004]. In Italy, primary dental health service is based on private health care providers; thus, oral care is mainly financed by direct payment or, to a lesser extent, through public or private insurance schemes. The low level of caries experience described in this paper supports the hypothesis that public dental services play a minor role in the caries experience decrease observed in all developed countries.

Traditional statistical approaches might fail to describe caries data correctly, because a substantial fraction of the examined sample is clustered at value zero, as reported above. In fact, this proportion is greater than that predicted by the use of any basic probability model for count data. For these reasons the ZINB regression model was chosen and provided a reasonably acceptable fit. The sociodemographic pattern in the probability of being an extra zero was highly influenced by a high education level of the father, suggesting that this parameter should affect caries severity, as previously reported [Lewsey and Thomson, 2004]. An appealing speculation could be that parents with a high educational level could establish better oral health habits in their children.

The lowest adjusted dmfs index observed in children with an Italian father is a reflection of the higher caries experience in children with a non-Italian father.

The severe caries pattern in preschool children has long been attributed to improper feeding practice (prolonged bottle- or breastfeeding at bedtime particularly) [Hallett and O'Rourke, 2006; Kramer et al., 2007]. As reported above, prolonged breastfeeding might be a potential risk factor for caries [Hallett and O'Rourke, 2006; Iida et al., 2007] even if no scientifically based evidence can be provided [Kramer et al., 2007]. An association between

Table 4. Outcome of ZINB modeling for dmfs index

	Logit	p value	Probability of being an extra zero	Negative binomial	p value	Adjusted dmfs
Intercept	–2.05 (–3.08 to –1.03)	<0.001	0.13	2.29 (1.87 to –2.72)	<0.001	9.9
Mother of Italian nationality	0.55 (–0.34 to 1.44)	0.225	0.22	–0.14 (–0.83 to 0.56)	0.70	8.6
Father of Italian nationality	0.95 (–0.02 to 1.91)	0.054	0.33	–0.81 (–1.51 to –0.11)	0.02	4.4
Mother of high education	0.13 (–0.17 to 0.44)	0.391	0.15	–0.61 (–0.88 to –0.34)	<0.001	5.4
Father of high education	0.52 (0.20–0.85)	0.001	0.22	–0.33 (–0.59 to –0.06)	0.02	7.1
Preterm birth	–0.11 (–0.54 to 0.32)	0.613	0.12	0.07 (–0.27 to 0.41)	0.69	10.6
Breastfeeding	0.22 (–0.11 to 0.54)	0.191	0.16	–0.01 (–0.26 to 0.24)	0.92	9.8
Age of tooth eruption						
6–8 months vs. 6 months	0.26 (–0.04 to 0.56)	0.090	0.17	–0.02 (–0.26 to 0.21)	0.85	9.6
9–12 months vs. 6 months	0.57 (0.18–0.95)	0.004	0.23	0.05 (–0.28 to 0.38)	0.78	10.4
>12 months vs. 6 months	0.77 (0.15–1.38)	0.015	0.28	0.36 (–0.24 to 0.96)	0.24	14.2

Figures in parentheses indicate 95% CIs.

caries experience and prolonged breastfeeding was observed only in the bivariate analysis and no conclusion about harmful consequence of prolonged breastfeeding can be drawn as reported in the literature [Kramer et al., 2007].

This study fails to confirm the hypothesis of an association between preterm birth and caries disease. A possible reason might be the age of the examined sample (4 years). In fact, an association between preterm birth and dental caries was described in a sample aged 2 years [Saraiva et al., 2007]. Although contradictory results are reported in the literature [Seow, 1997; Eastman, 2003], there are few reasons to believe that the inclusion of 2-year-old children might produce an increase of significance [Saraiva et al., 2007]. When a sample of children, exposed to caries risk factors for a very short period of time, is studied, such as children with a recent tooth eruption, results should probably show a very low caries prevalence and should provide a statistically nonsignificant association.

This survey was carried out in large parts of Italian territory, so the results can be considered representative of the entire 4-year-old population. The results suggest a need to plan preventive programs in order to reduce oral health disparities among Italian preschool children, based on educational intervention with parents and children concerning oral health and tooth decay prevention.

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