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Multilevel modeling for dental caries among adolescents in a Brazilian large city

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Abstract

Dental caries is a complex disease, which needs an approach that considers caries influencing factors at different levels and their integration. Multilevel Modeling is a clustered analysis of variables from the individual to the community level. The aim of this study was to investigate the association of social and biological factors grouped into hierarchical levels, in students with caries. A sample of 687 students was evaluated from public and private schools of Curitiba. The parameters evaluated were: individual level, school level and district level. Individual variables had a highly significant association with caries experience, also in the presence of school and district levels. Male sex negatively associated with caries experience. However, the interaction between male sex and no fluoride use was positively associated with caries. Lower socioeconomic status, dental biofilm, and fluorosis were associated with caries. Nevertheless, the interaction between dental biofilm and fluorosis was negatively associated with caries experience. The interaction between no flossing and use of public dental services were also associated with caries outcome. Individual factors were associated with caries experience even with the inclusion of contextual variables in the study population.

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Introduction

Dental caries is an infectious and multifactorial disease. The prevalence of caries has reduced significantly, including in Latin America and Brazil (DMFT=2.07 for 12 years-old) [1,2] possibly due to the increased availability of fluoride and oral health programs [3,2].

Nevertheless, groups of children have still been showing high caries activity. It is estimated that 20 to 25% of children and adolescents in Brazil concentrate 60 to 80% of caries prevalence [2]. The phenomenon of disease concentration in small groups is termed polarization and represents one of the epidemiological disease aspects, where a population portion focuses most needs for treatment [2,4]. Thus, the early identification of caries risk indicators is fundamental for measures of prevention, control and reduction of damage, with obvious epidemiological, human and economical consequences [5].

Socioeconomic status [6], oral health behavior, including diet [7], gender, ethnicity [3] and biological factors, such as biofilm formation and saliva properties [8,9], have been considered the main risk factors influencing individual susceptibility to caries. However, there has been a shift from individual to population–level approach when researching the risk indicators for chronic diseases [10]. As previously published, individual factors are usually influenced by the population context [7,10]. Also, a higher caries experience and a lower dental care index (the ratio between the number of filled teeth and DMFT) were observed in children attending public schools than for those enrolled in private schools [3] and in areas with lower levels of empowerment and income [11, 12]. There has been seen significant

variation in the severity of caries between low-income neighborhood clusters. Indeed, neighborhood features were seen to be associated with self-reported oral health [13].

Caries is a complex disease and an approach that can evaluate the factors influencing the disease at different levels and their integration is suitable. To date there are only few studies evaluating caries in a multilevel approach, and they do not analyze all factors that may be contributing to its complex development [7]. Multilevel Analysis is a model that considers factors related to the individual together with the community level, organized in hierarchical levels. Thus, the aim of this study was to investigate the association of individual and community factors, grouped into hierarchical levels by Multilevel Modeling.

Methods

Six districts in Curitiba- PR, Brazil with similar socioeconomic aspects were assessed in this study (Table 1). In Brazil, the socioeconomic status generally implies in the type of school, public (lower income) or private (higher income). Then, two larger schools from each district, one public and one private, with a minimum of 1500 students, were chosen using a table of random numbers totalizing twelve schools. All 12-year-old students or those which would complete this age in the year of the study were invited to participate on each school. An informed consent form was given to every student caregiver in each school. Adolescents whose caregivers/parents did not return the consent form were not included for study along with smokers, orthodontic appliances users, and

Table 1. Districts demographic and socioeconomic aspects.

		DISTRICTS					
		1	2	3	4	5	6
	DEMOGRAPHIC ASPECTS	248,698 inhabitants or 14.2% of the total Municipality	155,794 inhabitants or 8.9% of total Municipality	215 503 inhabitants or 12.3% of the total Municipality	197 346 inhabitants or 11.3% of the total Municipality	168,425 inhabitants or 9.6% of total Municipality	243 506 inhabitants or 13.9% of the total Municipality
		47427 children 0-14 years old (19.1% of the regional population)	42125 children 0-14 years old (40.4% of the regional population)	45711 children 0-14 years old (21.2% of the regional population)	41297 - children 0-14 years (20.9% of the regional population)	42087 children 0-14 years old (25.0% of the regional population)	42125 children 0-14 years (17.3% of the regional population)
	INCOME PER CAPITA – 2010* (*1 minimum wage, MW= $130)	45.9% received over 1 to 3 MW	42.5% received over 1 to 3 MW	44.3% received over 1 to 3 MW	50.4% received over 1 to 3 MW	44.9% received over 1 to 3 MW	40.0% received over 1 to 3 MW
SOCIOECONOMIC ASPECTS	WATER SUPPLY	99.2% of households connected to the water network	98.8% of households connected to the water network	99.4% of households connected to the water network	99.7% of households connected to the water network	99.0% of households connected to the water network	98.9% of households connected to the water network
	SEWAGE NETWORK	82.7% of households connected to sewage network	86.6% of households connected to sewage network	94.8% of households connected to sewage network	93.9% of households connected to sewage network	89.4% of households connected to sewage network	95.8% of households connected to sewage network

Table 2. Individual and contextual characteristics of students (n=687) and caries status.

Variables	n	Frequency (%)	Proportion of DMFT≥1 (%)
	687	100.0	
Level 1: Student			
Sociodemografic			
Ethnic group			
White	606	88.2	48.5[a]
Light- and dark-skinned black	62	9.0	69.3[b]
Yellow	19	2.8	63.2[a,b]
Sex			
Female	377	54.9	52.2[a]
Male	310	45.1	49.0[a]
Behavioural			
Toothbrushing frequency			
2 or more/day	644	93.7	49.8[a]
Until once/day	43	6.3	65.1[a]
Flossing			
Yes	443	64.5	47.2[a]
No	244	35.5	57.4[b]
Fluoride use (solution,varnish,gel)			
Yes	405	59.0	47.4[a]
No	282	41.0	55.7[b]
Dental visits frequency			
2 times or more/year	304	44.2	48.7[a]
Once/year	315	45.9	50.8[a]
No	68	9.9	60.3[a]
Sugar consumption between meals			
No	69	10.0	50.7[a]
Yes	618	90.0	50.8[a]
Socioeconomic			
Dental access			
Private	427	62.2	41.4[a]
Public	260	37.8	66.1[b]
Individual socieconomic status			
A1/A2 (highest)	175	25.5	32.6[a]
B1/B2	310	45.1	51.9[b]
C	166	24.2	65.1[c]
D/E (lowest)	36	5.2	63.9[b,c]
Clinical			
Plaque Index (modified)			
0	95	13.8	38.9[a]
>0 and <1	475	69.2	50.1[a]
≥1	117	17.0	63.2[b]
Gengivitis			
No	404	58.8	47.0[a]
Yes	283	41.2	56.2[b]
Fluorosis			
No	497	72.3	52.3[a]
Yes	190	27.7	46.8[a]
Stimulated salivary flow rate			
>0.5 mL/min	522	76.0	51.0[a]
≤0.5 mL/min	165	24.0	50.3[a]
Salivary buffering capacity			
pH>3.9	670	97.5	50.9[a]
pH≤3.9	17	2.5	47.1[a]
Level 2: School			
Type of school			
Private	334	48.6	41.3[a]
Public	353	51.4	59.8[b]
Oral health education			
Yes	240	34.9	52.5[a]
No	447	65.1	49.9[a]
Permission for sweet consumption			
Non permitted	228	33.2	37.3[a]
Permitted	459	66.8	57.5[b]
Level 3: District			
Fluoride concentration in water supply			
≥0.7 mL/L	333	48.5	49.2[a]
<0.7 mL/L	354	51.5	52.3[a]
Socioeconomic position			
better living conditions	447	65.1	47.2[a]
worse living conditions	240	34.9	57.5[b]

Fisher's exact or chi-square test. Distinct lower-case superscript letters indicate statistical significance (p<0.05).

individuals taking antibiotics in the last three months. The study was approved by the Ethical Committee on Research of Pontifical Catholic University of Paraná (PUCPR) under register n° 487.

They were distributed about 1100 consent forms, and 687 12-year-old unrelated adolescents agreed to participate, approximately 55 students from each school, both sexes.

The 687 students were diagnosed according to the decayed, missing and filled teeth index (DMFT). White spot lesions in dental surfaces were considered decayed according to clinical criteria described by Assaf et al. [14].

Examinations were conducted in schoolrooms in accordance with international standards established by World Health Organization (WHO) [15]. All evaluations were performed by two calibrated examiners. Inter- and intra-examiner reproducibility was taken on 10% of the sample and the Kappa test was used to measure reliability. The obtained values for Kappa test were 0.93 for inter- and 0.99 for intra-examiner.

A multilevel study was designed to assess the individual and contextual effects on caries experience (DMFT=0 or DMFT≥1). Data were hierarchically structured in three levels: individuals (level 1), schools (level 2), and districts (level 3). The choice of variables was based in caries multifactorial model proposed by Fejerskov & Manji [16].

Individual level (level 1)

Individual demographic variables included sex (male/female) and ethnicity: white/ light- and dark-

skinned/black and yellow (Asian descent).The parent/caregiver answered self-completed questionnaires about oral health behavior: tooth brushing frequency, dental flossing, topical fluoride (solution, varnish, gel), dental attendance pattern (frequency of dental check-ups and public/private access) and sugar consumption between meals [12,6].

A standard Brazilian socioeconomic classification based on household items and on the level of education of the head of household was adopted [12]. A set of points is assigned to these indicators and a final score defines the socioeconomic groups; A (highest), B, C, D, and E (lowest). Because of the small number of observations in class E, data were categorized into four groups: high social class (class A), high-middle social class (class B), middle social class (class C) and low social class (classes D and E).

The biofilm accumulation was verified by the Plaque Index (PI) [17] modified, which adopted the same criteria, but evaluating 6 teeth surfaces: 16 [buccal (B)], 12 B, 26 [lingual (L)], 36 B, 32 L, and 46 L. The PI was categorized as: no plaque accumulation (PI=0), regular plaque accumulation (PI>0 and <1, up to a third of the surface with accumulated biofilm) and high plaque accumulation (PI≥1, more than a third of the surface with accumulated biofilm). Individuals were considered positive for gingivitis when all teeth from at least one sextant were affected, with bleeding and inflammation. The presence or not of any degree of fluorosis was established according to Dean's index (WHO) [15] .

The stimulated salivary flow rate (SSFR) was measured as previously described [18]. To classify the SSFR the following numerical scores were attributed: 0 for low caries risk >0.5 mL/min and 1 for high caries risk ≤0.5 mL/min, because the cut line for dichotomization was based on the data distribution. The buffering capacity (BC) was performed as described previously [19]. Final pH of the mixture was determined using a pH-meter and BC was considered good if the final pH was >3.9 and deficient for pH≤3.9.

School level (level 2)

Twelve large schools were randomly chosen, being 1 public and 1 private from each of the 6 health districts studied. Besides the type of school, it was also verified permission or not for sweeties' consumption in the classroom and other areas in the institution and the presence or not of oral health education programs.

District level (level 3)

Means of fluoride concentration in water supply in 2006 were obtained for 6 Health Districts from the Municipal Health Secretary of Curitiba and dichotomized into <0.7 and ≥0.7 mL/L, because it is the minimum concentration allowed in the city.

The classification of the socioeconomic conditions in the health districts was described by Moraes & Ribeiro [20], and considered income and education of the household head. The score was then organized in descending order and grouped into 5 socioeconomic categories. The first category was A (best living conditions) and the last category was E (worst living conditions). Because of data distribution in this study, it was chosen to join B/C (better living conditions), and D/E (worse living conditions). None of the evaluated districts obtained score A.

Table 3. Multilevel modeling of 12-yr-old students, considering individual, school and district hierarchical levels in relation to caries experience

	Model 1 (null model)			Model 2			Model 3			Model 4			Model 5		
Variables	***p* value**	**OR**	**CI 95%**	***p* value**	**OR**	**CI 95%**	***p* value**	**OR**	**CI 95%**	***p* value**	**OR**	**CI 95%**	***p* value**	**OR**	**CI 95%**
LEVEL 1: INDIVIDUAL															
Sociodemografic															
Ethnic group															
White (ref)															
Light- and dark-skinned				0.096	1.66	(0.91-3.02)	0.080	1.71	(0.94 – 3.11)	0.060	1.82	(0.98-3.38)			
black															
Yellow				0.129	2.21	(0.79-6.17)	0.109	2.32	(0.83 – 6.49)	0.137	2.24	(0.77-6.52)			
Sex															
Female (ref)															
Male				0.133	0.77	(0.54 - 1.08)	0.107	0.75	(0.53 – 1.06)	0.002*	0.49	(0.31-0.77)	0.003*	0.51	(0.33 – 0.79)
Behavioural															
Toothbrushing frequency															
2 or more/day (ref)															
Until once/day				0.859	1.07	(0.52-2.21)	0.929	1.03	(0.50 – 2.14)	0.685	0.85	(0.40-1.83)			
Flossing															
Yes (ref)															
No				0.161	1.30	(0.90-1.87)	0.215	1.26	(0.87 – 1.82)	0.189	0.59	(0.26-1.30)	0.635	0.89	(0.56 – 1.42)
Fluoride use (solution, varnish, gel)															
Yes (ref)															
No				0.652	1.09	(0.76-1.55)	0.698	1.07	(0.75 – 1.54)	0.087	0.66	(0.40-1.06)	0.082	0.66	(0.41 – 1.05)
Dental visits frequency															
2 times or more/year (ref)															
Once/year				0.441	0.87	(0.61-1.24)	0.510	0.87	(0.63 – 1.26)	0.922	0.98	(0.68-1.41)			
No				0.614	0.85	(0.46-1.59)	0.736	0.90	(0.48 – 1.68)	0.285	0.70	(0.36-1.35)			
Sugar consumption between meals															
No (ref)															
Yes				0.481	1.22	(0.70-2.11)	0.474	1.22	(0.70 – 2.13)	0.425	1.27	(0.71-2.26)			

Firstly, an exploratory study was performed using Fisher and chi-square test. The multilevel software MLwiN version 2.01 (Centre for Multilevel Modeling, Bristol, UK) was used to estimate the effects of individual, school and district variables on DMFT. The multilevel analyzes were used to determine the relative size of the variance at each level [21]. As the outcome was binary, a multilevel logistic model was used. Both the Marginal Quasi Likelihood (MQL) first-order approximation procedures and Predictive Quasi Likelihood (PQL) second-order approximation procedures were used. However, because they produced similar results, only the results based on PQL second-order procedures are reported and discussed [12]. Five models were specified for the outcome. First, a null model (Model 1), which took into account the structure from levels 1, 2 and 3. The null model was followed by Model 2 in which variables from level 1 were included. In Model 3, it was included variables from levels 1, 2 and 3. There were adjustments in Models 4 considering: i) all the school and district variables; ii) all the variables at the individual level, which presented statistically significant

Table 3 (Continued). Multilevel modeling of 12-yr-old students, considering individual, school and district hierarchical levels in relation to caries experience

Socioeconomic												
Dental access												
Private (ref)												
Public	0.003*	1.91	(1.25-2.92)	0.014*	1.75	(1.12 – 2.75)	0.401	1.26	(0.73-2.19)	0.139	1.47	(0.88 – 2.46)
Individual socieconomic status												
A1/A2 (ref) highest												
B1/B2	0.002*	1.92	(1.27-2.92)	0.009*	1.80	(1.16 – 2.78)	0.099	1.54	(0.92-2.57)	0.009*	1.79	(1.15 – 2.77)
C	0.013*	2.05	(1.17-3.61)	0.038*	1.88	(1.03 – 3.41)	0.045*	2.13	(1.02-4.44)	0.047*	1.83	(1.01 – 3.32)
D/E lowest	0.368	1.50	(0.62-3.60)	0.458	0.40	(0.57 – 3.45)	0.155	2.47	(0.71-8.59)	0.402	1.47	(0.60 – 3.63)
Clinical												
Plaque Index (modified)												
0 (ref)												
>0 and <1	0.151	1.43	(0.88-2.34)	0.130	1.46	(0.89 – 2.38)	0.016*	2.11	(1.15-3.88)	0.008*	2.21	(1.23 – 3.96)
≥1	0.014*	2.28	(1.18-4.40)	0.011*	2.35	(1.22 – 4.56)	0.000*	4.42	(1.97-9.91)	0.000*	4.94	(2.36 – 10.37)
Gengivitis												
No (ref)												
Yes	0.482	1.14	(0.79-1.65)	0.442	1.16	(0.80 – 1.68)	0.397	1.18	(0.80-1.73)			
Fluorosis												
No (ref)												
Yes	0.554	0.90	(0.62-1.29)	0.565	0.90	(0.62 – 1.29)	0.026*	3.03	(1.14-8.01)	0.019*	3.12	(1.21 – 8.08)
Stimulated salivary flow rate												
>0.5 mL/min (ref)												
≤0.5 mL/min	0.732	0.94	(0.64-1.37)	0.729	0.93	(0.64 – 1.37)	0.753	0.94	(0.63-1.40)			
Salivary buffering capacity												
pH>3.9 (ref)												
pH≤3.9	0.484	0.69	(0.25-1.94)	0.543	0.72	(0.25 – 2.05)	0.459	0.65	(0.21-2.03)			

association (*SSA*) with the outcome, and iii) interactions at level 1, which have made sense as hypotheses and also demonstrated *SSA*. Interactions at second and third levels did not reach statistical significance and thus were not included in this model. In Model 5, it was included i) all variables at level 1 which showed significance in Model 4 ii) all variables at level 2 and 3, and iii) all individual interactions that have made sense as hypotheses and showed significance in Model 4. The results were presented as odds ratios (OR) and their 95% confidence intervals (CI). For each logistic model the intraclass correlation (ICC) was calculated using an approach described by Hox [21].

Results

Individuals from level 1 (n=687), schools from level 2 (n=12) and districts from level 3 (n=6) were evaluated in this study. Caries status according to individual and contextual aspects is shown in Table 2.

Out of the students, 338 subjects (49.2%) were caries-free (DMFT=0) and 349 (50.8%) had caries experience (DMFT≥1). The mean DMFT for students with caries experience was 2.88±1.79 and the general mean DMFT was 1.46±1.92, being 1.82±2.05 for public and 1.08±1.70 for private schools.

In the exploratory study, it was observed an association of caries experience with the variables i) ethnic group (light- and dark-skinned black), no flossing, no fluoride use (solution, varnish, gel), public dental access, lower individual socioeconomic status, higher plaque index, presence of gingivitis (level 1), ii) public school, permission for candy or gum consumption (level 2), and iii) worse living conditions in the district socioeconomic condition (level 3). 3 presents the findings of a multilevel logistic regression with the variable outcome DMFT=0⁄DMFT≥1.

Model 1 (Null Model) showed that the variation be-

Table 3 (Continued). Multilevel modeling of 12-yr-old students, considering individual, school and district hierarchical levels in relation to caries experience

LEVEL 2: SCHOOL									
Type of school									
Private (ref)									
Public	0.894	0.96	(0.54 – 1.70)	0.796	0.92	(0.50-1.69)	0.948	1.02	(0.56 – 1.85)
Oral health education									
Yes (ref)									
No	0.517	0.85	(0.53 – 1.38)	0.850	0.95	(0.56-1.61)	0.676	0.90	(0.54 – 1.50)
Permission for candy or gum consumption									
Non permitted (ref)									
Permitted	0.136	1.51	(0.88 – 2.61)	0.193	1.48	(0.82-2.68)	0.228	1.43	(0.80 – 2.56)
LEVEL 3: DISTRICT									
Fluoride concentration in water supply									
≥0.7 mL/L (ref)									
<0.7 mL/L	0.789	1.06	(0.69 – 1.64)	0.609	1.14	(0.69-1.89)	0.624	1.13	(0.69 – 1.88)
Socioeconomic position									
Better living conditions (ref)									
Worse living conditions	0.623	1.14	(0.68 – 1.89)	0.575	1.16	(0.69-1.97)	0.562	1.17	(0.69 – 1.98)
Interactions									
Male sex and no fluoride use				0.002*			0.003*		
PI score 1 and fluorosis				0.020*			0.018*		
PI score 2 and fluorosis				0.003*			0.002*		
Class B and no flossing use				0.112					
Class C and no flossing use				0.826					
Classes D/E and no flossing				0.269					
No flossing and public access				0.007*			0.028*		
σ^2 District	0.020	0.075	0.020	0.043			0.045		
σ^2 School	0.238	0	0	0			0		
ρ District	0.006	0.022	0.006	0.013			0.013		
ρ School	0.073	0.022	0.006	0.013			0.013		

** Association with dental caries outcome.*

tween districts (7.8%) was much smaller than the variation at the school level (92.3%). The intraclass correlation coefficient for schools was 0.073 and for districts was 0.006.

In Model 2, it was observed that socioeconomic status (class B, p=0.002 and class C, p=0.013), public dental access (p=0.003), and high PI (p=0.014) were associated with caries experience.

In Model 3, it was verified that the characteristics of schools and districts have not affected caries experience. Significant findings remained similar to those from Model 2.

In Model 4, the lack of association between community-level variables (schools and districts) and caries experience was still maintained. Socioeconomic class C (p=0.045), dental plaque accumulation (regular PI, p=0.016 and high PI, p=0.000), and fluorosis (p=0.026) were significantly associated with caries experience. The interaction between fluorosis and dental biofilm accumulation was negatively associated with caries experience [regular PI (β=-1.265, p=0.020) and high PI (β=-2.032, p=0.003)]. In addition, the interactions between no flossing and use of public dental services were associated with caries experience [β=+0.809; p=0.007; OR=3.79; 95% CI:1.45-9.92] (Table 3).

All these findings remained significant even after statistical adjustment in the final model (Model 5).

Discussion

Multilevel Modeling is appropriate for analyzing hierarchical data and provides an efficient way to link the conventionally distinct community and individual-level approaches [21]. Moreover, it could avoid a loss of statistical power in the use of variables from different levels, and the risk of ecological fallacy, which is a kind of error when only the population level is considered [22].

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The mean DMFT in the study population was 1.46, considered low by WHO standards and similar to the levels observed in Europe [23], where the DMFT indexes among 12-year-old children range from 1.2 to 2.6. However, the mean DMFT for students with caries experience was 2.88, which demonstrates higher needs for treatment in this population, evidencing the dental caries polarization in the present study.

Regarding variables from the individual level, ethnicity seems to be less relevant than socioeconomic status to determine caries outcome [24]. In Brazil, ethnic differences in dental health may be further due to socioeconomic status and access to services than to biological background [25].

In this study, male sex was negatively associated with caries experience, differently from the findings by Aida et al. [7], who did not observe any association between gender and dental caries. Nevertheless, our results corroborate the study by Antunes et al. [3], who argued that an early chronology of permanent tooth eruption in women might determine the higher risk to tooth decay for girls among Brazilians. Higher access to dental care by girls may lead to an increase in DMFT index, especially regarding the number of filled teeth, as a result of overtreatment. The interaction between male sex and no use of fluoride was positively associated with caries experience. This is due to the fact that boys, in general, have a lower care index, which reflects their decreased concern about health and aesthetics [6]. In relation to caries-inhibiting effect of fluoride sources, Cochrane systematic reviews found that fluoride rinses are responsible for 26%, fluoride gel for 28%, and fluoride varnish for 46% of the reduction in the DMFS index [26], demonstrating the relevance of these topical methods. Lower individual socioeconomic status was associated with caries experience. Indeed, low social class has been associated with high DMFT [27,12]. The higher socioeconomic positions have shown the better health status measurements.

The present study also showed that higher degrees of plaque index were positively associated with caries outcome. Caries lesions develop where oral biofilms are allowed to mature and remain on teeth for long periods [9].

Fluorosis presence was also associated with caries experience, in accordance to other studies results [28, 29]. Severe fluorosis has been reported to increase susceptibility to dental caries by hypomineralization [30]. However, there has been some controversy on whether dental fluorosis increases, decreases, or has no effect on caries experience [31]. When plaque index and fluorosis were analyzed in interaction, fluorosis seemed to protect against caries only in the presence of dental biofilm. The interaction between fluorosis and dental biofilm with caries experience had never been carried out *in vivo*. One hypothesis is that fluorotic teeth could release some fluoride ions to the dental biofilm in a low pH condition which, consequently, reduce demineralization [32]. On the other hand, enamel changes in experimental teeth with signs of fluorosis that had been exposed to plaque accumulation were examined *in vitro* and specimens showed signs of surface demineralization [33].

Other significant interaction in the present study was shown between no flossing and use of public dental services, which means an increase in odds of caries experience if these two socioeconomic-dependent variables act together. This finding points at a role of health services on improvement's individual behavior, which has also been reported for other chronic diseases [33]. In relation to school level, it was not found a *SSA* between the type of school and oral health education with caries experience. The type of school has been considered a risk indicator of the disease in a Brazilian study [27] and not in another one [13]. However, public school enrollment was determinant in having one or more untreated decayed permanent teeth [3]. The lack of association between oral health education in schools and dental caries may be due to the fact that programs considering specific individual needs are similar in both types of school.

With regard to district level, an association between fluo-

ride concentration in water supply and caries experience was not found. Curitiba has a water fluoridation scheme which covers the whole population for decades. This homogeneity in the fluoride distribution could be the reason for the lack of association with caries experience. Besides, the 6 evaluated districts present a homogeneous income distribution, which might contribute for the lack of influence in caries experience.

The results from a few multilevel studies on dental caries, taking into account two levels, have been reported. Neighborhood aspects influenced oral health [34] and dental caries experience in Brazilians [12]. Moreover, contextual and individual sociodemographic characteristics influenced dental caries experience in 12-year-old schoolchildren from Brazil when using a conventional multivariate logistic regression (1). Otherwise, Aida [7] showed that 90.8% of variance in dmft index among Japanese 3-year-old children occurred at the individual level and 9.2% of the variance occurred at the community level.

The main findings of this study were that individual variables had a highly significant association with caries experience even in the presence of school and district levels (contextual variables).

The variables which determine the risk indicators for caries development varies significantly for different groups. The monitoring of contrasts in dental health outcomes is relevant for programming socially appropriate interventions. The analysis of different risk indicators, which influence dental caries, and its early identification, is relevant for planning suitable interventions for target population groups whom could present higher levels of disease, re-orienting attention on dental prevention and reducing costs in dental treatments offered by the health systems.

Overall effective health interventions might be more effective in that part of a population which concentrates disease [7]. On the other hand, groups of lower caries risk should not be underestimated, considering that risk indicators may not be easily recognized [35]. Maybe, a good tool to preserve equity and universality principles for dental caries should be the combination of both polarization and global attention approaches.

The Multilevel Analysis allows the evaluation of different risk indicators from distinct hierarchical levels, which makes this approach valuable for the integration of variables influencing the disease outcome, especially for complex diseases, such as dental caries. It was observed that individual factors, such as female sex, the interaction of male sex with no fluoride use, lower socioeconomic status, dental plaque accumulation, fluorosis, and the integration of no flossing with public health service use, even in the presence of contextual variables (schools and districts), were associated with caries experience in the study population.

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References

1. Brasil. Ministery of Health. Oral Health Brasil 2010 (SB Brasil 2010). National Oral Health Research: main results. 2012. available at: http://dab.saude.gov.br/CNSB/sbbrasil/ arquivos/ proje-je-to_sb2010_relatorio_final.pdf (last acess 12 February 2015).

2. Decline, polarization, inequality and social exclusion. Narvai PC, Frazao P, Roncalli AG, Antunes JL.

Dental caries in brazil: Rev Panam Salud Publica. 2006; 19:385-93. PMID: 16968593.

3. Ethnic disparities in the prevalence of dental caries and restorative dental treatment in brazilian children. Antunes JL, Pegoretti T, de Andrade FP, Junqueira SR, Frazao P, Narvai PC. Int Dent J. 2003; 53:7-12. PMID: 12653333.

4. Prevalence and polarization of dental caries among young, healthy adults: Cross-sectional epidemiological study. Tanner T1, Kämppi A, Päkkilä J, Patinen P, Rosberg J, Karjalainen K. Acta Odontol Scand. 2013; 71(6):1436-42. doi: 10.3109/00016357.2013.767932. Epub 2013 Apr 30. PMID: 23627898.

5. Factors associated with dental caries experience and oral health status among New South Wales adolescents. Skinner J1, Johnson G, Blinkhorn A, Byun R. Aust N Z J Public Health. 2014: Oct; 38(5):485-9. doi: 10.1111/1753-6405.12245. Epub 2014 Aug 28. PMID: 25169434.

6. The relation between family socioeconomic trajectories from childhood to adolescence and dental caries and associated oral behaviours. Peres MA, Peres KG, de Barros AJ, Victora CG. J Epidemiol Community Health. 2007; 61:141-5. PMID: 17234873.

7. Contributions of social context to inequality in dental caries: A multilevel analysis of japanese 3-year-old children. Aida J, Ando Y, Oosaka M, Niimi K, Morita M. Community Dent Oral Epidemiol. 2008; 36:149-56. PMID: 18333879.

8. Risk indicators of dental caries in 5-year-old brazilian children. Cortellazzi KL, Pereira SM, Tagliaferro EP, Tengan C, Ambrosano GM, Meneghim Mde C, et al. Community Dent Health. 2008; 25:253-6. PMID: 21367823.

9. Dental Caries. Selwitz RH, Ismail AI, Pitts NB. Lancet. 2007; 369:51-9. PMID: 17208642.

10. Area characteristics, individual-level socioeconomic indicators, and smoking in young adults: The coronary artery disease risk development in young adults study. Diez Roux AV, Merkin SS, Hannan P, Jacobs DR, Kiefe CI. Am J Epidemiol. 2003; 157:315-26. PMID: 12578802.

11. Measuring inequalities in the distribution of dental caries. Antunes JL, Narvai PC, Nugent ZJ. Community Dent Oral Epidemiol. 2004; 32:41-8. PMID: 14961839.

12. The potential impact of neighborhood empowerment on dental caries among adolescents. Pattussi MP, Hardy R, Sheiham A. Community Dent Oral Epidemiol. 2006; 34:344-50. PMID: 16948673.

13. Women's health: beyond reproductive years. Vibha, Laskar AR. Indian J Public Health. 2011; 55(4):247-51. PMID: 22298132.

14. Influence of initial carious lesions on oral health planning. Assaf AV, Tengan C, Tagliaferro EPS, Meneghim ZP, Meneghim MC, Pereira AC, Ambrosano GMB. Braz J Oral Sci. 2006; 5(19):1217-1222.

15. WHO. Oral health survey. Basic methods. Fourth edition. Geneva: World Health Organization. 1997;66.

16. Risk assessment in dental caries. In: Risk assessment in dentistry. Fejerskov O, Manji F. Bader JD. Chapel Hill: University of North Carolina Dental Ecology. 1990; 215–217.

17. The gingival index, the plaque index and the retention index systems. Loe H. J Periodontol. 1967; 38 suppl:610-6. PMID: 5237684.

18. Effects of antidepressants and benzodiazepines on stimulated salivary flow rate and biochemistry composition of the saliva. de Almeida Pdel V, Gregio AM, Brancher JA, Ignacio SA, Machado MA, de Lima AA, et al. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008; 106:58-65. PMID: 18329910.

19. Clinical investigations of the salivary buffering action. Ericsson Y. Acta Odontol Scand. 1959; 17:133-65.

20. Social inequalities and vaccination coverage: Utilization of household surveys. Moraes JCD, Ribeiro MCSdA. Braz J Epidemiol. 2008; 11:113-24.

21. Introduction to multilevel analysis. Hox J: Multilevel analysis, techniques and applications. Hox J. Mahwah: Lawrence Erlbaum Associates. 2002; 1-36.

22. The social determinants of oral health: New approaches to conceptualizing and researching complex causal networks. Newton JT, Bower EJ. Community Dent Oral Epidemiol. 2005; 33:25-34. PMID: 15642044.

23. The world oral health report 2003: Continuous improvement of oral health in the 21st century--the approach of the who global oral health programme. Petersen PE. Community Dent Oral Epidemiol. 2003 ; 31 suppl 1:3-23. PMID: 15015736.

24. Inequalities in oral health: A review of the evidence and recommendations for action. Watt R, Sheiham A. Br Dent J. 1999; 187:6-12. PMID: 10452185.

25. Multilevel assessment of determinants of dental caries experience in Brazil. Antunes JL, Peres MA, de Campos Mello TR, Waldman EA. Community Dent Oral Epidemiol. 2006; 34:146-52. PMID: 16515679.

26. Evidence-based effectiveness of topical fluorides. Marinho VC. Adv Dent Res. 2008; 20:3-7. PMID: 18694869.

27. Factors associated with dental caries in Brazilian children: a multilevel approach. Martins MT, Sardenberg F, Abreu MH, Vale MP, Paiva SM, Pordeus IA. Community Dent Oral Epidemiol. 2014; 42: 289–299. PMID: 24354434.

28. The relationship between dental caries and dental fluorosis in areas with moderate- and high-fluoride drinking water in ethiopia. Wondwossen F, Astrom AN, Bjorvatn K, Bardsen A. Community Dent Oral Epidemiol. 2004; 32:337-44. PMID: 15341618.

29. Prevalence and severity of dental caries in adolescents aged 12 and 15 living in communities with various fluoride concentrations. Pontigo-Loyola AP, Medina-Solis CE, Borges-Yanez SA, Patino-Marin N, Islas-Marquez A, Maupome G. J Public Health Dent. 2007; 67:8-13. PMID: 17436973.

30. Caries and dental fluorosis in a western saharan population of refugee children. Almerich-Silla JM, Montiel-Company JM, Ruiz-Miravet A. Eur J Oral Sci. 2008; 116:512-7. PMID: 19049520.

31. Dental fluorosis increases caries risk. Cunha-Cruz J, Nadanovsky P. J Evid Based Dent Pract. 2005; 5:170-1. PMID: 26092033.

32. Biochemical composition and cariogenicity of dental plaque formed in the presence of sucrose or glucose and fructose. Cury JA, Rebelo MA, Del Bel Cury AA, Derbyshire MT, Tabchoury CP. Caries Res. 2000; 34:491-7. PMID: 11093024.

33. A light and scanning electron microscopic study of enamel decalcification in children living in a water-fluoridated area. Thylstrup A, Boyar RM, Holmen L,

Bowden GH. J Dent Res. 1990; 69:1626-33. PMID: 2212207.

34. The independent contribution of neighborhood disadvantage and individual-level socioeconomic position to self-reported oral health: A multilevel analysis. Turrell G, Sanders AE, Slade GD, Spencer AJ, Marcenes W. Community Dent Oral Epidemiol. 2007; 35:195-206. PMID: 17518966.

35. Life course dental caries determinants and predictors in children aged 12 years: A population-based birth cohort. Peres MA, Barros AJ, Peres KG, Araujo CL, Menezes AM. Community Dent Oral Epidemiol. 2009; 37:123-33. PMID: 19250294.