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Multilevel assessment of determinants of dental caries experience in Brazil

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Abstract – *Objective:* To examine contextual and individual determinants of dental caries experience, documenting levels of the disease in Brazil. *Methods:* The dental status of 34 550 12-year-old schoolchildren was informed by a country-wide survey of oral health comprising 250 towns and performed in 2002–2003. Indices assessing dental caries experience were compared by sociodemographic characteristics of examined children (gender, ethnic group, localization and type of school), and geographic characteristics of participating towns [the human development index (HDI), and access to fluoridated tap water]. A multilevel model fitted the adjustment of untreated caries to individual and contextual covariates. *Results:* Better-off Brazilian regions presented an improved profile of dental health, besides having a less unequal distribution of restorative dental treatments between blacks and whites, rural and urban areas, and public and private schools. Girls [odds ratio (OR) = 1.1; 95% confidence interval (CI): 1.0–1.1], blacks (OR = 1.6; 95% CI: 1.5–1.7), and children studying in rural areas (OR = 1.9; 95% CI: 1.7–2.0) and public schools (OR = 1.7; 95% CI: 1.6–1.9) presented higher odds of having untreated decayed teeth. The multilevel model identified the fluoride status of tap water ($\beta = -0.3$), the proportion of households linked to the water network ($\beta = -0.3$), and the HDI ($\beta = -0.2$), as town-level variables associated with caries levels. *Conclusion:* Dental caries experience is prone to socio-demographic and geographic inequalities. The monitoring of contrasts in dental health outcomes is relevant for programming socially appropriate interventions aimed both at overall improvements and at the targeting of resources for groups of population presenting higher levels of needs.

Key words: dental caries; dental health services; fluoride; socioeconomic factors

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Pathfinder national surveys of oral health meeting international standards set up by the World Health Organization (WHO) (1) have been performed in Brazil after the return of the country to democracy during the mid-1980s. The comparison of these surveys' results indicated an impressive reduction of caries indices, which have been attributed to the fluoridation of tap water and major-selling tooth-paste brands, besides an extensive reform of the health system (2). The fluoridation of water supplies has been mandatory in Brazil since 1974, but its implementation was progressive mainly after the mid-1980s. Its current population coverage exceeds 50%. Major dentifrice brands began selling fluoride toothpaste in 1988 (3); the market share of fluoride dentifrice in Brazil corresponds to almost 100% since 1990, but its optimal benefit demands the adherence to a regular dental hygiene. A noticeable increase in the dental public service followed the reform of the Brazilian health system in 1990, with an extended promotion of initiatives on oral health education, and the provision of preventive and restorative dental treatment to children.

Notwithstanding the overall reduction in caries measures, differential levels of access to fluoridated

tap water, toothbrushing with fluoride toothpaste, and dental health promotion are problems which continue to affect much of the population (4). Resembling the changing pattern of caries distribution in developed countries (5, 6), this overall improvement was concurrent with an increasingly unequal distribution of the disease, with higher levels affecting deprived areas (7). Lalloo et al. (8) used international data to assess the association between dental disease and human development, and concluded that caries levels were correlated with socioeconomic status. In the Brazilian context, several studies (2, 4, 7) report a complex causal pathway involving the access to dental services, the provision of fluoride and sociodemographic characteristics as determinants of children's caries experience.

The present study assessed information gathered by an extensive survey of oral health, with the objective of documenting the extent of dental disease in the country. We also aimed at gauging the association of caries experience with sociodemographic characteristics of examined children and with geographic standings of participating towns, as a strategy to appraise inequalities in dental health.

Methods

Data source

From May 2002 to October 2003, official agencies of the Brazilian health authority performed a major epidemiological survey of oral health (9), comprising 108 921 dental examinations performed in accordance with international standards established by the WHO (1). Nearly 2000 professionals participated as dental examiners, and as recorders and coordinators. In each state of the Brazilian federation, instructors with previous experience in oral health surveys following WHO's guidelines directed the training and calibration of all dentists and clerks. The original report (9) of the survey presented comprehensive information on data reproducibility, i.e. the assessment of kappa statistics for the inter- and intra-observer agreement of all dental conditions considered in each age group.

The multistage sampling design consisted of a random selection of 250 towns from all Brazilian states, as stratified by population size, with schools representing the sampling collection units for the oral examination of children. The resulting sample was considered representative for the estimation of caries prevalence among 12-year-old schoolchildren in the whole country (9). When sponsoring institutions made the survey data available for public consultation, we reviewed all oral-examination records, totalling 34 550 12-year-old schoolchildren.

Data on dental examinations allowed estimating the DMFT index, a traditional descriptor of caries experience, its components (FT, MT and DT), and the dental care index, defined by the ratio FT/DMFT (10). DMFT information also allowed exploring the prevalence of untreated caries for assessments at the individual level, and by the proportion of children presenting this condition in each area, for assessments at the aggregate level (11).

Oral examination records also included information on sociodemographic characteristics, such as gender, ethnic group (comparing whites with blacks and mixed children), localization (rural and urban) and type of school (public and private). The Regional Office for the United Nations Development Programme in Brazil (12) provided information for the human development index (HDI) in each town, a composite measurement summarizing information on income, instructional attainment and longevity. Access to fluoride in the previous 5 years was described for each town in terms of the presence or absence of fluoridated water supply and the proportion of households with pipe water supply.

Data analysis

Geographic inequalities in caries experience were assessed by comparing the DMFT, the dental care index and the prevalence of untreated caries in each Brazilian area. The appraisal of inequalities used the ratio of outcomes between categories of gender (girls/boys), ethnic group (blacks/whites), localization (rural/urban) and type of school (public/private). The assessment of association between the ratios thus calculated and the HDI used the Spearman correlation coefficient.

Multivariate analysis fitted the adjustment of individual and contextual determinants of having untreated caries. The assessment of goodness-of-fit for multilevel modelling used the −2-loglikelihood test as a measure of deviance.

Multilevel modelling

Multilevel analysis used the scheme of fixed effects/random intercept (13), to fit the adjustment of untreated caries with covariates referring to examined schoolchildren (first level) and participating towns (second level).

At the first level, a conventional multivariate logistic regression analysis (14) comprising all

schoolchildren allowed assessing the effect of sociodemographic characteristics on untreated caries, using dummy variables for gender (girls), ethnic group (black), localization (rural) and type (public) of school as first-level covariates. At the second level, a conventional multivariate logistic regression analysis was run for each town, totalling 250 new regression equations. These equations had their slopes fixed to coincide with those predetermined by the equation comprising the whole data set, because this model does not allow for second-level variations on the effect of first-level covariates. Therefore, all second-level variation was attributed to the intercept, and an ordinary least squares regression analysis fitted the adjustment of the intercept to the town-level covariates: the proportion of households with tap water, the fluoride status of water supplies and the HDI.

Results

Extreme geographic contrasts were observed for the distribution of dental caries in Brazilian regions. The South and the Southeast had markedly lower DMFT levels and proportion of children with untreated caries, and higher dental care index and proportion of caries free children, than the remaining Brazilian regions (Table 1).

The study of sociodemographic inequalities in the distribution of dental caries indicated a higher DMFT (Table 2) and a lower dental care index (Table 3) for children attending rural and public schools than for those enrolled in urban and private schools. The unequal profile of access to dental services affecting children in rural and public schools was even more discrepant in deprived regions of the country. Furthermore, black children presented a lower proportion of decayed teeth already treated than their white counterparts, a discrepancy which was also more intense in the North and Northeast regions (Table 3).

Significant positive correlation coefficients indicated the contextual association between the ratios of the dental care index assessed for each sociodemographic covariate and the HDI: 0.46 ($P = 0.007$) for the ethnic ratio; 0.57 ($P = 0.004$) for the localization ratio; and 0.67 ($P < 0.001$) for the type of school ratio. These figures indicate that Brazilian states with higher human development had higher ratios comparing the dental care index;

Table 1. Dental caries indices, human development index (HDI) and number of examined 12-year-old schoolchildren in Brazilian regions, 2003

Indices	Centre-West	Northeast	North	Southeast	South	Brazil
Caries free (DMFT = 0)	27%	28%	24%	38%	37%	31%
Dental care index	41%	19%	14%	52%	45%	33%
Untreated caries	53%	61%	66%	37%	42%	51%
Decayed teeth	1.8	2.3	2.3	1.0	1.2	1.7
Missing teeth	0.1	0.3	0.4	0.1	0.1	0.2
Filled teeth	1.3	0.6	0.5	1.2	1.0	0.9
DMFT	3.2	3.2	3.1	2.3	2.3	2.8
HDI	0.74	0.61	0.66	0.75	0.77	0.70
Number of examined children	5849	7322	6208	8052	7119	34 550

Table 2. DMFT index by sociodemographic characteristics of 12-year-old schoolchildren in Brazilian regions, 2003

Categories	Centre-West	Northeast	North	Southeast	South	Brazil
Girls	3.3	3.3	3.1	2.5	2.4	2.9
Boys	3.0	3.1	3.1	2.1	2.2	2.7
Girls/boys ratio	1.1	1.1	1.0	1.2	1.1	1.1
Blacks	3.2	3.1	3.1	2.2	2.6	2.9
Whites	3.2	3.3	3.2	2.4	2.3	2.6
Black/white ratio	1.0	0.9	1.0	0.9	1.2	1.1
Rural	4.0	4.6	3.3	2.9	3.8	3.7
Urban	3.1	3.0	3.1	2.3	2.2	2.7
Rural/urban ratio	1.9	1.5	1.1	1.3	1.8	1.4
Public school	3.1	3.2	3.1	2.3	2.4	2.8
Private school	3.4	2.5	2.9	1.9	1.6	2.5
Public/private ratio	0.9	1.3	1.1	1.2	1.5	1.1

Table 3. Dental care index by sociodemographic characteristics of 12-year-old schoolchildren in Brazilian regions, 2003

Categories	Centre-West	Northeast	North	Southeast	South	Brazil
Girls	42%	20%	15%	54%	46%	34%
Boys	40%	17%	13%	50%	43%	32%
Girls/boys ratio	1.1	1.2	1.1	1.1	1.1	1.1
Blacks	36%	16%	13%	45%	41%	25%
Whites	46%	27%	19%	58%	45%	44%
Black/white ratio	0.8	0.6	0.7	0.8	0.9	0.6
Rural	30%	7%	3%	45%	40%	23%
Urban	41%	21%	15%	53%	45%	34%
Rural/urban ratio	0.7	0.3	0.2	0.9	0.9	0.7
Public school	39%	18%	15%	50%	45%	33%
Private school	57%	42%	19%	64%	54%	48%
Public/private ratio	0.7	0.4	0.8	0.8	0.8	0.7

Table 4. Multilevel model of logistic regression analysis for untreated caries in 12-year-old schoolchildren, Brazil, 2003

	Estimate	SE	Adjusted OR	95% CI
First level: subjects				
Gender: girls	0.058	0.023	1.1	1.0–1.1
Ethnic group: blacks	0.476	0.023	1.6	1.5–1.7
Area: rural	0.618	0.043	1.9	1.7–2.0
Enrolment in public school	0.530	0.048	1.7	1.6–1.9
−2-loglikelihood (first level)	44 200.355			
			β	Significance (P-value)
Second level: towns				
Constant (fixed part)	1.310	0.098		<0.01
% Households with tap water	−0.002	0.000	−0.3	<0.01
Town with fluoridated water supply	−0.104	0.023	−0.3	<0.01
Human development index	−0.350	0.155	−0.2	0.03
−2-loglikelihood (full model)	41 892.863			

i.e. better-off regions had ratios approaching the unity, indicating dental treatments more equally distributed among children of different sociodemographic categories (blacks/whites, rural/urban schools, public/private schools).

Logistic regression analysis fitted a multilevel model adjusting covariates for the prevalence of untreated caries (Table 4). Being a girl [adjusted odds ratio (OR) = 1.1; 95% confidence interval (CI): 1.0–1.1], or black (adjusted OR = 1.6; 95% CI: 1.5–1.7), studying in rural areas (adjusted OR = 1.9; 95% CI: 1.7–2.0), or in public schools (adjusted OR = 1.7; 95% CI: 1.6–1.9) were all factors identified as individual determinants of the odds of having one or more untreated decayed permanent teeth. Negative slopes at the second level indicated that the town's oral health profile benefited from having fluoridated tap water ($\beta = -0.3$), an increased proportion of households linked to the water network ($\beta = -0.3$), and higher values for the HDI ($\beta = -0.2$). These conditions were thus identified as the contextual determinants of untreated caries. As the full model presented a significantly lower deviance than the first-level model, the multilevel model comprising the whole set of covariates was considered the most effective for explaining the outcome variable.

Discussion

Health inequalities and their relation to living conditions are in the mainstream of public health thinking. Gwatkin (15) reported the ethnic and gender dimensions of inequalities, as well as economic standings, as those that matter most for the assessment of health inequalities in developing countries. The Pan American Health Organization (16) stated the growing impact on health and overall well-being of inequalities associated with socioeconomic, gender and ethnic macro-determinants. The extent of contemporary health inequalities led Farmer (17) to define this condition as a plague of our era.

Dental caries experience is prone to sociodemographic and geographic inequalities. The current report of poorer dental health outcomes in the most deprived Brazilian regions (Table 1) agrees with previous studies indicating the longstanding contextual effect of deprivation on caries experience. Peres et al. (18) and Antunes et al. (2) assessed the negative association between children's caries levels and indices of social development, respectively, for the deciduous and the permanent dentition. Pattussi et al. (19) identified social deprivation, income inequality and social cohesion as relevant dimensions explaining differentials of caries distribution.

Besides documenting current levels of dental disease, this study assessed the inequality of its distribution among Brazilian regions and among children with different sociodemographic characteristics. Consistent with comparisons indicated in Tables 2 and 3, significantly higher levels of caries and lower access to dental treatment had already been reported in a Brazilian rural setting than in its adjacent urban area (20).

A different chronology of permanent tooth eruption determines a higher risk of tooth decay for girls than for boys in the Brazilian context; thus the importance of controlling the explanatory model for gender. As to gender differences of dental treatment, this is a longstanding condition in Brazil, and an earlier study appraised it as indicative of the differential commitment of parents and of society to the functional and aesthetic dimensions of girls' and boys' oral health (21).

The unequal access to dental treatment between black and white children is a further indication of sociodemographic disparities affecting the experience of dental caries. Previous studies attributed ethnic differentials of dental health to discrepant socioeconomic status and access to services and goods between ethnic groups in Brazil, with no further biological fundament (2, 22).

On account of the high number of children examined (34 550 children), individual determinants of untreated caries are subject to overestimated goodness-of-fit indicators, and even a mild association, as that indicated for gender, resulted in a small *P*-value and 95% CI (Table 4). However, the remaining first-level determinants presented higher figures for the OR, and the contextual assessment (250 towns) is not subject to this statistical effect.

The final model identified geographic standings and sociodemographic characteristics significantly associated with the dental health profile. Increasing evidence associates low-income individuals and communities in Brazil with the intake of high levels of carbohydrates, including sweets (23), and with limited use of fluoride toothpaste and inadequate access to dental service (7, 21, 22). In addition, harmful socioeconomic environments during childhood such as those associated with low levels of maternal education, malnutrition and poor access to preschool were described as having contributed for high levels of dental caries in the primary dentition (24), the most effective predictor of the risk of caries in permanent teeth.

As to fluoridated tap water, Jones et al. (25) verified that poorer areas benefit more from fluoridation in the British context. According to their study, fluoride addition to the public water supply is an effective initiative for the reduction of caries prevalence concurrent with a reduction in the 'dental health divide'. Burt (26) reviewed evidence from dental studies in the US, Britain, Australia and New Zealand, and also indicated that water fluoridation contributes not only for an improved profile of caries measures, but also for reducing health disparities between socioeconomic strata. Notwithstanding these observations, inequalities in the provision of fluoridated water and different levels of access to the network of water supply in Brazil limit this evaluation. Even such a 'passive' mechanism for the prevention of caries (i.e. non-dependent on dental interventions) did not benefit the population evenly (4, 7). This observation suggests that there is room for a further reduction of caries experience in Brazil by targeting the provision of fluoridated tap water to towns without it, and to households not linked to the system of water supply.

While studying inequalities in service coverage and child health in Brazil, Victora et al. (27) observed that the introduction of new medical technologies does not benefit all social strata of the population evenly, but rather confers most benefit on the higher socioeconomic strata. When health initiatives take place before the removal of social gaps and inequalities, they can thus worsen the relative position of the underprivileged in respect to disease prevalence. Nugent et al. (28) anticipated such a condition for the assessment of dental caries, and proposed that overall effective health interventions might be more effective in that part of a population with less dental disease.

The discussion of inequalities in caries experience should thus consider differentials in recently implemented health technologies and procedures,

which have been appraised as effective for the control of caries, such as fluoridation of water supplies. Causing inequalities in the disease distribution may be an undesirable but unavoidable consequence of preventive interventions associated with the decline of a widespread disease such as caries. However, the importance of monitoring inequalities in the distribution of dental caries relies on the need of preventing what Whitehead (29) called 'health inequities', i.e. inequalities associated with avoidable, unnecessary and unjust differences in health.

Health programmes demand selective information for exploring inequalities in the experience of disease, so that their proposals do not inadvertently damage health or reinforce inequalities. A continuous monitoring of oral health may contribute to improved initiatives aimed at reducing levels of caries without enlarging the gap in the burden of disease. This information may also instruct health programmes aimed at targeting resources to areas with higher levels of needs, thus contributing for socially appropriate interventions in oral health. Equity must be a priority in the planning of health actions, and the challenge of measuring this dimension should help promote further studies in this sometimes complex field.

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