[1] *Department of Public Health, Federal University of Santa Catarina, Florianópolis, Brazil*
[2] *Department of Social Dentistry, University of São Paulo, Brazil*

Is water fluoridation effective in reducing inequalities in dental caries distribution in developing countries? Recent findings from Brazil

Submitted: 19 May 2005
Accepted: 26 March 2006
Published Online First 13 July 2006

Summary

Objectives: To assess socioeconomic differences between towns with and without water fluoridation, and to compare dental caries levels among socioeconomic strata in fluoridated and non-fluoridated areas.
Methods: A countrywide survey of oral health performed in 2002–03 and comprising 34,550 children aged 12 years provided information about dental caries levels in 249 Brazilian towns. Socioeconomic indices, the coverage and the fluoride status of the water supply network of participating towns were also appraised. Multivariate regression models fitted the adjustment of dental caries levels and covariates to socioeconomic status and water supply. Inequalities in dental outcomes were compared in towns with and without fluoridated tap water.
Results: Better-off towns tended to present a higher coverage by the water supply network, and were more inclined to add fluoride. Fluoridated tap water was associated with an overall improved profile of caries, concurrent with an expressively larger inequality in the distribution of dental disease.
Conclusion: Suppressing inequalities in the distribution of dental caries requires an expanded access to fluoridated tap water; a strategy that can be effective to foster further reductions in caries indices.

Key words: **Water Fluoridation – Socioeconomic factors – Dental caries – Health policy – Epidemiology – Brazil**

Dental caries – the most prevalent childhood chronic disease in many countries (US Department of Health 2000) – is a major public health problem and is associated with preventable pain (Reisine 1985) and high treatment costs (Yee & Sheiham 2002).

During the last decades, an important decrease in the prevalence and severity of dental caries was observed both in developed (Petersen 2003) and developing countries such as Brazil (Narvai et al. 1999). Nevertheless, its distribution continues to affect children unequally. In Brazil, previous studies addressing inequalities in oral health reported that girls (Antunes et al. 2003), black people (Antunes et al. 2003), children enrolled in public schools (Freire et al. 1996), those living in deprived areas (Projeto SB Brasil 2003), those living in towns presenting a lower Human Developed Index (Peres et al. 2003), and those living in rural areas (Mello & Antunes 2004) presented higher levels of dental caries than their counterparts.

The most effective mass intervention to prevent dental caries is water fluoridation; in 1999, it was considered one of the ten most important achievements in public health during the twentieth century (Centers for Disease Control and Prevention 1999). In 1986, the World Health Organization (WHO) and the International Dental Federation (FDI) sponsored a Conference entitled "Appropriate use of fluorides", which concluded that water fluoridation is an effective, safe, and inexpensive preventive measure, which has the virtue of requiring no active compliance on the part of the persons benefited. This Conference recommended that community water fluoridation be introduced and maintained wherever possible (Murray 2003). Recently, a systematic review of water fluoridation commissioned by the Chief Medical Officer of the Department of Health for England reinforced WHO and FDI recommendations and confirmed a significantly higher decrease in dental caries levels for fluoridated areas than for non-fluoridated areas (NHS Centre for Reviews and Dissemination 2000). Moreover, the report of the absence of scientific evidence for the association between water fluoridation and mortality from any cancers or fracture incidence confirmed the safety of this health policy (NHS Centre for Reviews and Dissemination 2000).

Soz Praventiv Med. 51 (2006) 302–310
0303-8408/06/050302–09
DOI 10.1007/s00038-006-5057-y
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Based upon scientific evidence related to the effectiveness of water fluoridation for caries prevention, some countries have approved legislation instituting the measure as mandatory. In 1974, a Brazilian law required the fluoridation of water supplies in the whole country.[1] Later, the Federal Constitution promulgated in 1988[2] and the law that implemented the National Health System[3] in 1990 expanded this determination. Nowadays, nearly one hundred million people in Brazil, more than 50% of its whole population, drink fluoridated water (Narvai 2000), a health policy supported by the majority of academic and professional groups of public health dentistry (Centro de Documentação do Ministério de Saúde 1993).

In spite of this legal and scientific basis, a previous study conducted in a Southern Brazilian state showed that less developed towns delayed the provision of water fluoridation (Peres et al. 2004), following standards anticipated both by Hart's "inverse care law" (Hart 1971) and by the "inverse equity hypothesis" formulated by Victora et al. (2000). The former postulated that "the availability of good medical care tends to vary inversely with the need of the population served"; while the latter reported that "inequities only improve when the rich have achieved new minimum achievable levels of morbidity and mortality and the poor gain greater access to the interventions".

A systematic review of water fluoridation reported that few studies have been performed to assess if water fluoridation reduces social inequalities among groups of different socioeconomic status, and that all of them have failed to control for confounding on intervening factors, and none of them was conducted in developing countries, where social and health inequalities are particularly relevant (NHS Centre for Research and Dissemination 2000).

This study aimed to answer two main questions: i) Are there socioeconomic differences in Brazilian towns associated with water fluoridation supply? ii) Are there differences in dental caries levels among socioeconomic strata in fluoridated and non-fluoridated areas?

Methods

Data source

From May 2002 to October 2003, official agencies of the Brazilian health authority performed a major epidemiological survey of oral health. The multi-stage sampling design consisted of a random selection of 250 towns according to population size and their insertion in Brazilian states, with schools representing the sampling collection units for the oral examination of children (Projeto SB Brazil 2004). When sponsoring institutions made the survey data available for public consultation, we reviewed all oral-examination records, for a total of 34,550 twelve-year-old schoolchildren.

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 (Projeto SB Brazil 2004) 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.

Previous nationwide dental caries epidemiologic data such as the prevalence of dental caries and its standard deviation guided the sample calculation. A non-replacement scheme for the sample size calculation used 20% as the estimated rate of losses. The actual rate of losses was lower than this estimate in all Brazilian regions. The study was conducted in 250 municipalities of the 5 macroregions of the country, with a mean of 130 children examined per municipality. The exams were performed on schoolchildren from public and private schools in urban and rural areas. The rate of enrollment in school at this age reaches 94.6% of all children. The exams were performed under natural illumination using wood spatulas for better visualization and periodontal probes (CPI probes). About 900 examiners participated in the study, accompanied by about 1200 assistants. The examiners were trained in two stages. Each regional coordinator of the research trained about 25 calibrators, professors of Dentistry and dentists with previous experience in epidemiological studies. Each calibrator, in turn, was responsible for the training of the team of 2 municipalities. Approximately 5% of the exams were carried out in duplicate in order to measure intra-observer reliability; the lowest Kappa value observed was 0.7 which indicates an adequate intra-observer agreement.

The present study resulted from the analysis of secondary data originating from a nationwide Brazilian epidemiological study conducted by the Health Ministry. Further methodological information is described in the original report of the survey (Projeto SB Brazil 2004).

The World Health Organization provides a clinical definition of dental caries in order to standardise the observation of different dental examiners in the survey. A tooth is considered to be decayed when "a lesion in a pit or fissure, or on a smooth tooth surface, has an unmistakable cavity, undermined enamel, or a detectably softened floor or wall" (WHO 1997). This category includes filled or sealed teeth that are also de-

[1] Brasil. Congresso Nacional. Lei Federal no 6050, de 24/05/1974
[2] Brasil. Constituição da República Federativa do Brasil. Brasília: Senado Federal, 1988
[3] Brasil. Congresso Nacional. Lei Federal no 8080 de 19/09/1990

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cayed. The index measuring caries prevalence also records teeth with previous experience of decay, even after receiving restorative treatment or being extracted because of caries. A tooth is considered to be filled when one or more restorations are present, and the caries has already been treated; a tooth that has been extracted because of caries is considered to be missing. These specifications allow the estimate of the DMFT index, a traditional measurement assessing caries prevalence and severity, which refers to the average number of permanent teeth somehow affected by caries, i.e. decayed (D), missing (M) or filled (F) teeth (T).

The oral-examination record also gathered information about the socio-demographic characteristics of the children examined, i.e., localization and type of school. Type of school refers to the differentiation of students enrolled in public and private schools. Since public schools do not charge tuition fees, dental studies have assumed that children attending private schools in the Brazilian context present higher socioeconomic status than those enrolled in public schools (Freire et al. 1996). Localisation refers to the classification of schools in the urban or rural areas of participating towns.

The Regional Office for the United Nations Development Programme in Brazil (PNUD 2003) provided information about the human development index (HDI) in each town, a composite measurement summarizing information on income, educational level and longevity. Additional information obtained at the town level was provided by the local health authority regarding the proportion of households linked to the water supply network and the fluoride status of tap water. A dummy variable discriminated towns with fluoridated water supplies for at least five years after the time of the survey from those that did not; thus allowing an optimal benefit of fluoridated drinking water on caries prevention during the whole estimated chronology of permanent tooth eruption at the age of 12. This information, added to the proportion of households linked to the network of water supply, allowed appraising differential levels of access to fluoride in these towns.

Census information allowed gathering additional information on income and educational level for participating towns (Fundação IBGE 2001). The rate of illiteracy refers to people older than 10 years; completion of high school (proportion) refers to the head of households; per capita income refers to the Brazilian Minimum Wage (BMW), a unit of measurement whose value has varied during the last years around 100 US dollars; and the proportion of low income population refers to those with a per capita income lower than half the BMW.

Data analysis

DMFT information allowed exploring two further oral health outcomes: caries- free children, i.e., those presenting DMFT = 0, and high-caries children, i.e. those presenting at least four permanent teeth affected by caries (DMFT ≥ 4). For the assessment at the aggregate level, the prevalence of these conditions was estimated.

Statistical analysis was carried out using the SPSS. At first, we described socioeconomic variables and dental outcomes according to the quartile distribution of households linked to the water supply network, and assessed the Spearman correlation coefficient for the town-level figures of these variables. Next, we compared socioeconomic characteristics and indices of dental caries in towns with and without fluoridated water using the Mann-Whitney U test.

Ordinary least squares regression models were fitted for adjusting the three outcome variables (DMFT, caries free and high caries proportions) with explanatory variables related to town-level characteristics (HDI, illiteracy rate, completion of high school, per capita income, proportion of low income subjects), fluoride status of the water supply and the proportion of households linked to the water network. Explanatory variables were selected for the multivariate models only if they presented a p value lower than 0.05 after the adjustment for the remaining variables comprised in the analysis.

Finally, we appraised inequalities in oral health outcomes between categories of localization (rural/urban) and type of school (public/private) in towns with and without water fluoridation.

The project was submitted to and approved by the National Ethics in Research Committee, approval document no. 581/2000 of July 21, 2000. A term of informed consent was distributed to all children and only those who returned it properly signed by their parents or legal representatives participated in the study.

Results

Table 1 summarizes the distribution of several variables by quartile of the proportion of households linked to the water supply network in the towns participating in the 2002-3 Brazilian Oral Health Survey. Inequalities in water supply coverage were prominent. The proportion of households linked to the water supply network ranked from 27.75 % (average for the first quartile) to 92.20 % (average for the fourth quartile). There was a significant correlation ($p < 0.001$) between all socioeconomic indices and the proportion of households linked to the water supply network. Towns presenting higher water supply coverage had increased HDI values (as indicated by their averages in each quartile: 0.666, 0.698, 0.737 and 0.801) a higher proportion of individuals who completed high school, which ranked from 7.68 % (average for the first quartile) to 23.49 % (average for the fourth quartile) and

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higher per capita income (ranking from 0.98 to 1.76 Brazilian Minimum Wages), and decreased illiteracy rates (from 23.13 % to 15.41 %) and proportion of low income subjects (51.14 % to 32.99 %). A better profile of dental caries indices was significantly associated ($p < 0.001$) with an increased water supply coverage. The proportions of caries-free individuals (38.96 %), the DMFT index (2.21) and the proportion of high-caries children (29.29 %) presented prominently improved figures in towns with the most elevated coverage of pipe water, when compared to those estimated for the towns with the most limited water supply network (respectively 20.09 %, 3.53 and 40.27 %).

Participating towns were classified into two sets: 100 with and 149 without fluoridated water supplies (one town was excluded of the study because its sample did not comprise 12-year-old schoolchildren). Towns in the former set presented

Table 1 Proportion of households linked to the water supply network in 249 towns : association with town-level socioeconomic characteristics and indices of dental caries in 12-year-old schoolchildren (Brazilian Oral Health Survey, 2003)

% of households linked to the water supply network	1st quartile	2nd quartile	3rd quartile	4th quartile		
Average	27.75 %	55.51 %	74.61 %	92.20 %		
Standard deviation	13.92 %	6.33 %	.70 %	4.03 %		
Socioeconomic characteristics	**1st quartile**	**2nd quartile**	**3rd quartile**	**4th quartile**	**Spearman**	**Significance**
Human development index	0.666	0.698	0.737	0.801	0.625	P <0.001
Illiteracy rate (>10 yrs old)	23.13 %	19.00 %	15.41 %	7.67 %	–0.586	P <0.001
% completed high school	7.68 %	10.24 %	13.59 %	23.49 %	0.454	P <0.001
Per capita income (BMW*)	0.98	1.04	1.25	1.76	0.345	P <0.001
% low income **	51.14 %	49.15 %	44.49 %	32.99 %	–0.314	P <0.001
Indicators of dental caries	**1st quartile**	**2nd quartile**	**3rd quartile**	**4th quartile**	**Spearman**	**Significance**
% caries free	20.09 %	24.52 %	28.54 %	38.96 %	0.508	P <0.001
DMFT***	3.53	3.38	2.93	2.21	–0.432	P <0.001
% high caries	40.27 %	40.05 %	36.40 %	29.29 %	–0.271	P <0.001

* BMW = Brazilian minimum wage
** Low income refers to the proportion with a per capita income lower than half the BMW.
*** DMFT index = a traditional measurement assessing caries prevalence and severity, which refers to the average number of permanent teeth somehow affected by caries, i.e. decayed (D), missing (M) or filled (F) teeth (T).

Table 2 Socioeconomic characteristics and dental caries indices. Comparison of towns with (n = 100) and without (n = 149) fluoridated tap water for at least 5 years (Brazilian Oral Health Survey, 2003)

	Towns with fluoridated tap water for at least 5 years (n = 100)		Towns without fluoridated tap water for at least 5 years (n = 149)		
Socioeconomic characteristics	**Average**	**Std dev**	**Average**	**Std dev**	**Significance**
Human development index	0.775	0.061	0.691	0.081	P <0.001
Illiteracy rate (>10 yrs old)	10.20 %	5.94 %	20.49 %	10.99 %	P <0.001
% completed high school	18.16 %	8.56 %	10.82 %	6.94 %	P <0.001
Per capita income (BMW*)	1.56	0.89	1.05	0.62	P <0.001
% low income **	36.19 %	21.40 %	50.32 %	22.03 %	P <0.001
Indicators of dental caries	**Average**	**Std dev**	**Average**	**Std dev**	**Significance**
% caries free	35.57 %	13.56 %	22.88 %	12.05 %	P <0.001
DMFT***	2.37	0.99	3.45	1.49	P <0.001
% high caries	30.79 %	14.21 %	40.47 %	18.17 %	P <0.001

* BMW = Brazilian minimum wage
** Low income refers to the proportion with a per capita income lower than half the BMW.
*** DMFT index = a traditional measurement assessing caries prevalence and severity, which refers to the average number of permanent teeth somehow affected by caries, i.e. decayed (D), missing (M) or filled (F) teeth (T).

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Table 3 Simple and multiple linear regression analysis of town-level socioeconomic characteristics and dental caries indices in 249 towns (Brazilian Oral Health Survey, 2003)

Models	Unadjusted coefficient (95 % CI)			P	R	Adjusted coefficient (95 % CI)	p	R
DMFT*								
Human Development index	–5.259	(–7.269;	–3.249)	<0.001	–0.312			
Illiteracy rate (>10 yrs old)	0.039	(0.023;	0.055)	<0.001	0.294			
% completed high school	–0.062	(–0.081;	–0.042)	<0.001	–0.368			
Per capita income (BMW**)	–0.002	(–0.003;	0.000)	0.011	–0.161			
% low income***	0.009	(0.001;	0.016)	0.029	0.138			
Fluoridated tap water	–1.083	(–1.418;	–0.748)	<0.001	–0.375	–0.840 (–1.195; –0.485)	<0.001	–0.292
% households linked to the water supply network	–0.019	(–0.026;	–0.012)	<0.001	–0.340	–0.013 (–0.020; –0.006)	<0.001	–0.227
Caries free								
Human Development index	63.546	(44.155;	82.937)	<0.001	0.381			
Illiteracy rate (>10 yrs old)	–0.465	(–0.622;	–0.309)	<0.001	–0.349			
% completed high school	0.805	(0.621;	0.989)	<0.001	0.481	0.325 (0.085; 0.565)	0.008	0.196
Per capita income (BMW**)	0.027	(0.013;	0.042)	<0.001	0.228			
% low income***	–0.107	(–0.183;	–0.031)	0.006	–0.173			
Fluoridated tap water	12.687	(9.460;	15.915)	<0.001	0.442	7.664 (4.390; 10.938)	<0.001	0.268
% households linked to the water supply network	0.271	(0.210;	0.332)	<0.001	0.487	0.140 (0.062; 0.218)	<0.001	0.254
High caries								
Human Development index	–47.350	(–72.513;	–22.187)	<0.001	–0.230			
Illiteracy rate (>10 yrs old)	0.321	(0.119;	0.522)	0.002	0.196			
% completed high school	–0.532	(–0.781;	–0.283)	<0.001	–0.259			
Per capita income (BMW**)	–2.995	(–5.746;	–0.243)	0.033	–0.135			
% low income***	0.069	(–0.026;	0.164)	0.152	0.091			
Fluoridated tap water	–9.679	(–13.931;	–5.428)	<0.001	–0.274	–7.699 (–12.269; –3.128)	0.001	–0.219
% households linked to the water supply network	–0.164	(–0.247;	–0.081)	<0.001	–0.240	–0.106 (–0.195; –0.018)	0.019	–0.156

* DMFT = proportions of caries-free and high caries children
** BMW = Brazilian minimum wage
*** Low income refers to the proportion with a per capita income lower than half the BMW.

a better profile of socioeconomic characteristics than those in the latter. The average illiteracy rate for towns without the benefit was more than twofold the corresponding figure for those performing the fluoridation; a discrepancy almost as high as this was observed for the proportion which completed high school. Low income people were about 40 % more prevalent in non-fluoridated towns, while the HDI was about 12 % higher in those regularly adding fluoride. The effectiveness of fluoride on caries prevention was indicated by significant differences between caries indices between the two sets of towns (Tab. 2).

Table 3 shows simple and multiple linear regression analyses for the DMFT index, the proportion of caries-free and high-caries children, considering as explanatory variables measures of water supply and socioeconomic status of participating towns. In the unadjusted assessment, most socioeconomic characteristics were associated with the three dental caries indices. However, almost all of them were excluded from the multivariate models comprising the adjustment for characteristics of water supply. For the DMFT and the high caries indices, only the fluoride status of tap water and the proportion of households linked to the water network remained in the final model. These observations indicate that the fluoride status of tap water and the coverage of the water network are significantly associated with levels of dental caries prevalence and severity. For the proportion of caries-free children, the final model included both covariates, besides the proportion of heads of households that completed high school.

The comparison of socio-demographic characteristics of children between towns with and without fluoridated water indicated a consistently higher inequality among children living in fluoridated towns. The ratio of dental caries indices comparing children enrolled in public and private schools, and in rural and urban areas, indicated that the gap between socio-demographic strata was expressively larger in towns presenting fluoridated water, even though these towns presented an improved overall profile of caries indices (Tab. 4).

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Table 4 Dental caries indices stratified by socio-demographic characteristics of 12-year-old schoolchildren in 100 towns with and 149 towns without fluoridation of the water supply (Brazilian Oral Health Survey, 2003).

Dental caries indicators	Towns with water fluoridation (n = 100)	Towns without water fluoridation (n = 149)
DMFT*		
Localization		
Rural	3.49	3.84
Urban	2.08	3.33
Localization Ratio	1.68	1.16
Type of school		
Public	2.19	3.37
Private	1.53	3.31
Type of school Ratio	1.43	1.02
% Caries free		
Localization		
Rural	20.1 %	23.6 %
Urban	39.7 %	24.2 %
Localization Ratio	0.59	0.83
Type of school		
Public	38.3 %	23.4 %
Private	50.9 %	30.8 %
Type of school Ratio	0.75	0.76
% High caries		
Localization		
Rural	44.1 %	44.4 %
Urban	25.3 %	39.9 %
Localization Ratio	1.74	1.11
Type of school		
Public	26.7 %	40.1 %
Private	17.5 %	40.1 %
Type of school Ratio	1.53	1.00

* DMFT index = a traditional measurement assessing caries prevalence and severity, which refers to the average number of permanent teeth somehow affected by caries, i.e. decayed (D), missing (M) or filled (F) teeth (T).

Discussion

Towns which added fluoride to their water supplies presented an expressively better profile of dental caries indices than those that did not; an observation that corroborates a plethora of previous studies (NHS Centre for Research and Dissemination 2000). This study demonstrated that better-off Brazilian towns were more likely to add fluoride to their water supplies. This study also demonstrated that the coverage of the water supply network was dependent on the socioeconomic status of participating towns. These observations indicate that the beneficial effect of fluoride on caries prevention is not homogeneously distributed in the population but rather reflect a health inequity, because deprived areas, with higher levels of need, receive less preventive resources.

The unequal distribution of water fluoridation found in the nationwide oral health survey corroborates a previous study (Peres et al. 2004), which, despite being circumscribed to a single Brazilian state, also showed that the distribution of fluoridated water mostly favored towns with better socioeconomic profiles. In addition, among towns with fluoridated water, richer ones implemented the benefit earlier. A lack of technical and political support to add fluoride to tap water in poor communities may be another hypothesis explaining why poor communities presented lower coverage of water fluoridation than better-off communities.

Furthermore, the current study showed that inequalities in the experience of dental caries among socio-demographic strata increased in the presence of fluoridated water, as indicated by the ratio of figures comparing indices for public and private schools, and for schools in rural and urban areas, due to a non-homogeneous coverage by the water supply network. In fluoridated towns, the improvement of caries indices was less effective for poorer children (those attending public schools), indicating that they may have a lower access to fluoridated tap water. This observation is indeed more flagrant when considering the localization of the schools, because the water supply network seldom reaches rural areas.

Our findings suggest that water fluoridation, a State-funded health policy, benefited more, or earlier, towns presenting better socioeconomic indicators. Paradoxically, one of the

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main goals of the Brazilian state and an express principle of its health system is to implement health policies specifically aimed at reducing inequalities among socioeconomic strata.[4]

It is known that some overall effective interventions in health may contribute to increasing inequalities in health; as to water fluoridation, this concern has already been raised (Nuttall 2003). However, Jones et al. (1997) verified that the more socially deprived areas benefit more from fluoridation in the British context. Burt (2002) reviewed evidence from dental studies in the U.S., Britain, Australia and New Zealand, and also indicated that water fluoridation not only reduces the overall prevalence and severity of caries, but also reduces the disparities between socioeconomic groups.

Nevertheless, differential levels of access to the water supply network in the Brazilian context limit this evaluation. Although contributing to reducing DMFT levels, fluoridated tap water has been reported to be associated with higher inequalities in the distribution of dental caries (Antunes et al. 2004). Our findings are consistent with this earlier observation, and partially agree with results from a systematic review of water fluoridation performed by the NHS Centre for Reviews and Dissemination, which refrained from more optimistic interpretations, while assessing the effectiveness of water fluoridation to reduce social inequalities (NHS Centre for Research and Dissemination 2000).

The question of whether inequities can be reduced by public-health interventions has been previously addressed in public health research assessing different Brazilian datasets. While studying inequalities in child health and service coverage, Victora *et al*. (Victora et al. 2000) observed that the introduction of new public health interventions affects unequally the population, mostly benefiting higher socioeconomic strata. When health initiatives take place before the removal of social inequalities, they can thus worsen the relative position of the underprivileged with respect to disease prevalence. Even public subsidies for health frequently benefit more the rich than the poor.

A recent study reviewing potential approaches for improving equity in child health outcomes highlighted the importance of an improved access to water and sanitation for poor communities (Victora et al. 2003). This observation also applies to the current study, in which the potential reduction of inequalities in caries indices was reported as dependent on fostering the expansion of access to fluoridated water.

Antunes et al. (2005) showed that the recent reduction of AIDS mortality in Sao Paulo was concurrent with a shrinking inner-city inequality of this outcome. As this decrease was not associated with area-level indices of socioeconomic status, the authors concluded that an effective universal access to antiretroviral medicines contributed to the reduction of inequalities in health. Before the onset of this program, the AIDS epidemic (as dental caries in the overall Brazilian context) took its heaviest toll on the less affluent and politically influent social strata. While providing the perspective that health programs with universal coverage may be effective for the reduction of health inequalities, these findings also comprise a promising perspective for the expansion of access to fluoridated tap water as a strategy to further reduce caries levels and the inequality of its distribution.

Causing inequalities in the disease distribution may be an undesirable but, at the same time, 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 resides in the need to prevent what Whitehead (Whitehead 1992) called "health inequities", i.e. inequalities associated with avoidable, unnecessary and unjust differences in health.

We analyzed a large dataset of a nationwide oral health survey comprising almost 35 thousand 12 year-old schoolchildren, an age indicated by the World Health Organization (WHO 1997) for inter- and within-country comparison. These children lived in 249 towns with different socioeconomic characteristics, population size, and location in the different regions of the country. The analytic criteria considered towns to have a fluoridated water supply when they had been presenting this resource for at least five years prior to the oral health examination. The main interest of the study was the assessment of association between socioeconomic characteristics, caries levels, the fluoride status of water, and the extension of the water network; all inferences were made at the aggregate level. Moreover, we used multivariate statistical models in order to control for confounding variables, a methodology whose importance was addressed in the appraisal of studies of the same issue (NHS Centre for Research and Dissemination 2000).

In conclusion, we observed that richer towns were more inclined to add fluoride, and to present a higher coverage of the water supply network. Although having an improved profile of caries indices, towns with fluoridated water showed higher inequalities in the experience of dental disease. Social determinants of poor health can only be addressed by societal solutions. Ingredients for developing successful programs include understanding the problem, developing policy responses and building political support (Heymann 2000). Based on the findings of this study, recommendations aimed at reducing dental health inequalities can be made to deci-

[4] Brasil. Congresso Nacional. Lei Federal no 8080 de 19/09/1990

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sion makers in health policy, i.e., the expansion of the water supply, network an expanded access to pipe water supply and the expansion of water fluoridation, preferably according to a chronological order first benefiting poorer communities.

Acknowledgments

Marco Aurélio Peres was supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico - Brasil (National Council for Scientific and Technological Development-Brazil), CNPq, Grant N. 382889/2004.3.

Zusammenfassung

Ist Trinkwasserfluoridierung wirksam, um Ungleichheiten bei Zahnkrankheiten zu reduzieren?

Untersuchungsziel: Erfassung von sozioökonomischen Unterschieden zwischen Städten mit und ohne Trinkwasserfluoridierung und Vergleich der Zahnkaries-Prävalenz innerhalb verschiedener sozioökokonomischen Schichten in fluoridierten und nicht-fluoridierten Gebieten.

Methoden: Eine landesweite Studie über Zahngesundheit aus den Jahren 2002-03, die 34 550 12-jährige Kinder umfasst, liefert Informationen über den Zahnkariesstatus in 249 brasilianischen Städten. Sozioökonomische Indices, die Abdeckung und der Fluoridstatus des Wasserversorgungssystems der teilnehmenden Städte wurden ebenfalls erfasst. In multivariate Regressionsmodelle wurden die Zusammenhänge von Zahnkaries und Kovariaten mit sozioökonomischem Status und Wassserversorgung untersucht. Ungleichheiten bei der Zahngesundheit in Städten mit und ohne fluoridiertem Leitungswasser wurden verglichen.

Ergebnisse: Wohlhabendere Städte weisen ein tendenziell flächendeckenderes Wasserversorgungssystem auf und neigen eher zur Fluoridierung. Die Fluoridierung des Leitungswassers ist assoziiert mit einem allgemein besseren Kariesstatus und einer entsprechend deutlicheren Ungleichverteilung von Zahnkrankheiten.

Schlussfolgerung: Ein verbesserter Zugang zu fluoridiertem Leitungswasser kann als eine Strategie zur Reduktion sozialer Ungleichheit in der Verteilung von Zahnkrankheiten angesehen werden.

Résumé

La fluoration de l'eau est-elle efficace pour réduire les inégalités en santé dentaire?

Objectifs: Identifier les différences socio-économiques entre les villes avec et sans fluoration de l'eau. Comparer les taux de carie dentaire des différents niveaux socio-économiques dans des régions avec eau fluorée et non fluorée.

Méthodes: En 2002–03, une étude nationale portant sur la santé dentaire de 34 550 enfants âgés de 12 ans a fourni les taux de carie dentaire dans 249 villes brésiliennes. Les indices *(?)* socio-économiques, la qualité du réseau d'approvisionnement en eau potable et sa fluoration ont été également été mesurés. Les inégalités en matière de santé dentaire ont été analysées dans les villes avec et sans eau du robinet fluorée.

Résultats: Les villes les plus prospères présentent un meilleur réseau d'approvisionnement en eau potable et ajoutent plus fréquemment du fluor à l'eau. L'eau du robinet fluorée est associée à une amélioration du taux de caries, mais aussi à une augmentation des inégalités de distribution de la carie dentaire.

Conclusion: La suppression des inégalités en matière de caries dentaires requiert un accès universel à une eau du robinet fluorée. Une telle stratégie peut être efficace pour réduire les taux de caries.

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References

Antunes JLF, Waldman EA, Borrell C (2005). Is it possible to reduce AIDS deaths without reinforcing socioeconomic inequality in health? Int J Epidemiol Advance Access published on February 28, 2005.

Antunes JLF, Junqueira SR, Frazao P, Bispo CM, Pegoretti T, Narvai PC (2003). City-level gender differentials in the prevalence of dental caries and restorative dental treatment. Health Place *9(3)*: 231–9.

Antunes JLF, Narvai PC, Nugent ZJ (2004). Measuring inequalities in the distribution of dental caries in the Brazilian context. Community Dent Oral Epidemiology *32(1)*: 41–8.

Antunes JLF, Pegoretti T, de Andrade FP, Junqueira SR, Frazao P, Narvai PC (2003) Ethnic disparities in the prevalence of dental caries and restorative dental treatment in Brazilian children. Int Dent J *53(1)*:7–12.

Burt BA (2002). Fluoridation and social equity. J Public Health Dent *62*: 195–200.

Centers for Diseases Control and Prevention (1999). Achievements in public health, 1900–1999. Fluoridation of drinking water to prevent dental caries. Morb Mortal Wkly Rep *44(RR-13)*: 1–40.

Centro de Documentação do Ministério da Saúde (1993). Conferência Nacional de Saúde Bucal, 2a. Relatório Final. Brasília.

Freire MCM, Melo RB, Silva SA (1996). Dental caries prevalence in relation to socioeconomic status of nursery schoolchildren in Goiânia, Go, Brazil. Community Dent Oral Epidemiol *24*: 357–61.

Fundação IBGE (2001). Censo demográfico 2000. Características da população e dos domicílios. Resultados do universo. Rio de Janeiro.

Hart JT (1971). The inverse care law. Lancet *1*: 405–12.

Heymann SJ. (2000). Health and Social Policy. In: Berkman L, Kawachi I. Social Epidemiology. Oxford: OUP: 368–82.

Jones CM, Taylor GO, Whittle J G, Evans D, Trotter DP (1997). Water fluoridation, tooth decay in 5 year olds and social deprivation measured by the Jarman score: analysis of data from British dental surveys. BMJ *315:* 514–7.

Mello TR, Antunes JLF (2004). [Prevalence of dental caries in schoolchildren in the rural area of Itapetininga, Sao Paulo State, Brazil]. Cad Saúde Pública *20(3)*: 829–35.

Murray JJ (2003). Fluoride and dental caries. In: Murray JJ, Nunn JH, Steele J. Prevention of Oral Disease. 4th ed. Oxford: OUP: 35–60.

Narvai PC (2000). [Dental caries and fluorine: a twentieth century relation]. Ciência & Saúde Coletiva *5*: 381–92.

Narvai PC, Frazão P, Castellanos RA (1999). [Dental caries experience decline in permanent teeth of the Brazilian schoolchildren at the end the XXth century]. Odontologia e Sociedade *1*: 25–9.

NHS Centre for Reviews and Dissemination (2000). A Systematic Review of Water Fluoridation. York: University of York Report.

Nuttall N (2003). Preventions of social inequalities in oral health. In: Murray JJ, Nunn JN, Steele JG. Prevention of oral disease. 4th ed. Oxford: OUP: 221–40.

Peres MA, Fernandes LS, Peres KG (2004). Inequality of water fluoridation in Southern Brazil – the inverse equity hypothesis revisited. Soc Sci Med *58*: 1181–9.

Peres MA, Peres KG, Antunes JL, Junqueira SR, Frazao P, Narvai PC (2003). The association between socioeconomic development at the town level and the distribution of dental caries in Brazilian children. Rev Panam Salud Publica *14(3)*: 19–57.

Petersen PE (2003). The World Oral Health Report 2003: continuous improvement of oral health in the 21st century – the approach of the WHO Global Oral Health Programme. Community Dent Oral Epidemiol *31(Suppl 1)*: 3–23.

PNUD (2003). Programa das Nações Unidas para o Desenvolvimento, Instituto de Pesquisa Econômica Aplicada, Fundação João Pinheiro. Atlas do desenvolvimento humano no Brasil. Brasília.

Projeto SB Brasil 2003 (2004). Condições de saúde bucal da população brasileira 2002–2003, resultados principais. Brasília-DF: Ministério da Saúde, Secretaria de Atenção à Saúde, Departamento de Atenção Básica, Coordenação Nacional de Saúde Bucal.

Reisine ST (1985) Dental health and public policy: The social impact of dental disease. Am J Public Health *75*: 27.

US Department of Health and Human Services (2000). Oral Health in America: A report of the Surgeon General – Executive Summary. US Department of Health and Human Services, National Institute of Dental and Craniofacial Research, National Institutes of Health.

Victora CG, Vaughan JP, Barros FC, Silva AC, Tomasi E (2000). Explaning trends in inequities: Evidence from Brazilian child health studies. Lancet *356*: 1093–8.

Victora CG, Wagstaff A, Schellenberg JA, Gwatkin D, Claeson M, Habicht JP (2003). Applying an equity lens to child health and mortality: more of the same is not enough. Lancet *362*: 233–41.

Whitehead M (1992). The concepts and principles of equity and health. Int J Health Serv *22*: 429–45.

World Health Organization (1997). Oral health surveys: basic methods, 4th edition. Geneva: WHO.

Yee R, Sheiham A (2002). The burden of conservative dental treatment for children in Third World countries. Int Dent J *52(1)*: 1–9.

Address for correspondence

Marco Aurélio Peres
Departamento de Saúde Pública
Universidade Federal de Santa Catarina
Campus Universitário – Trindade
Florianópolis – SC – Brazil
88010-970
Tel.: (5548)33319046
Fax: (5548)33319542
e-mail: mperes@ccs.ufsc.br

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