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Water fluoridation as a marker for sociodental inequalities

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Abstract – *Objectives:* The aim of this study was to investigate the associations between the Human Development Index at city level (HDI-M) in the state of Paraná, Brazil, and the length of time of population exposure to water fluoridation (time span) with the respective mean decayed, missing and filled teeth (DMF-T) of schoolchildren in the state, looking at possible inequalities in these associations. *Methods:* The HDI–M of 323 cities in the state of Paraná, Brazil, was correlated to the duration of exposure to water fluoridation, calculated in number of days. Correlation between the HDI-M and the DMF-T indexes for 12-year-old children was also performed. *Results:* Correlations were statistically significant, showing that in the cities with a better HDI-M, water fluoridation had been implemented earlier (squared coefficient correlation of 22%). The fluoridation time span accounted for around 11% of the variance in the DMF-T indexes of the cities. The correlation indicated that locations with a better HDI-M had a better DMF-T, owing to the probable mediating effect of receiving fluoridation earlier. Furthermore, the cost of water fluoridation to benefit the population that has access to this public health measure has been estimated at USD 0.15 per capita/year. *Conclusions:* It is possible to conclude that this low-cost measure is able to improve oral health status in general. Nevertheless, in the Brazilian areas studied, fluoridation seems to reflect existing social development inequalities, as it was first made available in more socially developed areas, thus bearing an influence on their higher DMF-T performance to date.

Key words: disparities; fluoridation; public health

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Drinking water supply fluoridation stands out as one of the 10 most important public health initiatives in the last century (1). Water fluoridation has been approved and recommended by international organizations under the label of a suitable, efficient, safe, practical, and cost-cutting measure (2). Many studies show that this public approach to dental health reduces the prevalence of caries, saves money by decreasing the need for dental treatment, and reduces social inequalities among groups with different socioeconomic status (3–6).

However, the beneficial effects of water fluoridation on dental caries should not be taken for granted, regardless of the time since fluoridation was introduced (time span influence), and the social features of places where fluoridation occurs, as they may play an important role. When these factors are taken into account, a different picture would appear to emerge (7).

At present, the discussion has become focused on how differences in the social context of populations affect not only caries prevalence, but also other oral diseases (8–10) as well. Parallel to this, another important issue relates to the potential impact of fluoridation on tackling sociodental inequalities (11, 12). The literature shows some evidence that children living in socially deprived areas, but who have access to fluoridated water, have better oral health conditions than those from a similar social condition and no access to water fluoridation (5, 6, 13). Thus, water fluoridation should favor a deprived population with no access to other oral health policies (1, 14, 15).

Nevertheless, in some Brazilian regions, the above situation does not seem to be the case.

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Although it is known that dental caries experience runs parallel to the social inequalities in a given population (8), it appears that socially deprived regions, as reflected by the lowest human development indexes (HDI), also have the poorest water fluoridation levels. This happens regardless of the measure being imposed in the country by federal law (16), with an irregular distribution, concentrated on wealthier areas located in the South and Southeast.

Peres et al. (7) found that at city level, there was delay in providing water fluoridation in less developed areas. This finding corroborates the ''inverse care law'' first postulated by Hart (17), and recently updated as the ''inverse equity hypothesis'' by Victora et al. (18).

Inequalities in health systematically put groups of people who are already socially disadvantaged at a further disadvantage in the major social determinants of health (19). Reduced opportunities of access to and the use of fluoridated water are central to the discussion in this article. They refer to differences in oral health status that occur among population groups as a result of public policies, and they are consistently associated with large variations in oral health status, which could be avoided and successfully addressed.

Presenting some of the facts about water fluoridation and oral health inequalities in Brazilian cities may allow policy directives and actions for the health sector to be suggested, thereby leading to a reduction in oral health inequalities, both by means of direct control through partnerships and health promotion, and also through knowledge development and exchange. The aim of this study was, therefore, to verify possible inequalities in the association among HDI-M, time of population exposure to water fluoridation and mean of DMF-T in cities of Paraná, Brazil.

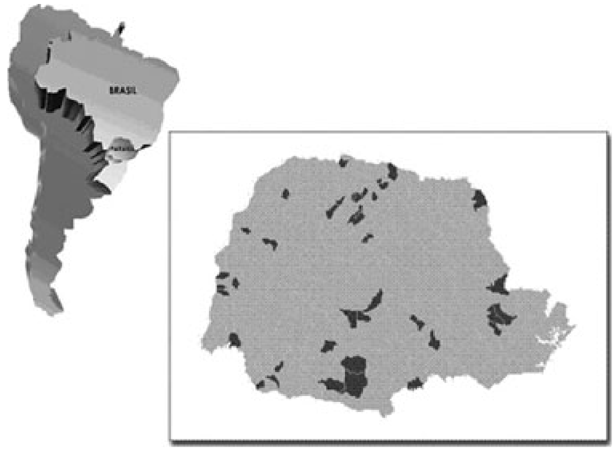

Fig. 1. The maps show the geographical position of the state of Paraná in South America, Brazil, and areas in the state as regards water fluoridation, in the year 2000. The light gray sites represent water fluoridated areas and the dark gray sites mean there is no access to this oral health measure (21).

Methods

In the state of Paraná, Brazil, 7.786.084 inhabitants live in urban areas (20). After nearly five decades since it was first introduced, fluoridation now reaches approximately 97% of this urban population (Fig. 1), which makes this state one of the largest areas in Brazil covered by this public health policy (21).

This study of the above setting uses a quantitative ecological approach. There are some relevant additional comments to be made about the methods used in this study. First, the ecological design that was adopted appears to be more appropriate when there is an interest in studying the ecological effects, such as those that result from the water fluoridation policy. Ecological effects are particularly relevant when evaluating the impact of population intervention, such as new programs, policies, or legislation (22). Secondly, the relationship between social development indicators and oral health policies, programs and outcomes can be directly investigated using correlations.

Data regarding the independent variable HDI for the years 1991 and 2000 was obtained from the Human Development Atlas (23). When it refers to the municipal level, an ''M'' is added, and this index (HDI-M) is also widely used in studies on the quality of life and socioeconomic conditions of populations. The dependent variables were both the period of time between the introduction of water fluoridation at city level until the year 2006 (time span expressed in number of days the city has been exposed to water fluoridation) and the mean DMF-T for the 12-year-old schoolchildren in the corresponding cities. These data came from a survey using random samples, carried out by the Health Department of Paraná in 1996 (24).

When the relation between the social determinants of quality of life and general and oral health outcomes is analyzed, it is necessary to consider the determining factors of inequalities in health. The HDI is a powerful instrument created by the United Nations at the beginning of the 1990s (25), which takes into account the multidimensionality of differences in living conditions. The HDI relates to: (i) population longevity, expressed by life expectancy; (ii) adult literacy rate, composed of two variables: the adult literacy rate and the combined rate of enrollment in three different levels of education; and (iii) income or gross national product per capita, expressed in USD and adjusted to reflect purchasing power parity among citizens from several countries. This index ranges from 0 to 1, ranking cities according to the following levels: low human development ($0 \leq HDI < 0.5$), medium ($0.5 = HDI < 0.8$), and high ($0.8 = HDI \leq 1$).

Data on fluoridation in a total of 399 cities in the state were retrieved from the Water and Sanitation Company of the state of Paraná. From this total, 12 cities were excluded because they present natural, above optimal, water fluoridation levels. A further 64 cities were excluded because information was unavailable. Thus, 323 cities were included in the sample.

All the data were analyzed using SPSS version 13.0 software. Data were first checked for normality, using the Kolmogorov–Smirnov test and variance homogeneity, using the Levene test. After this, the HDI-M data (ranging from 0 to 1), water fluoridation time span (in days), and the mean DMF-T were correlated using the Rho Spearman test.

Furthermore, the cost of water fluoridation to benefit a population of 7.552.502 habitants in Paraná in the year 2000 was also estimated (21).

Results

Table 1 shows some descriptive statistics obtained from an initial exploratory analysis of the data. It is already possible to observe that by adopting a cutoff of 0.8 for the HDI-M 2000, a small number of cities with significantly better ranking present more days exposed to fluoridated water than cities with a lower HDI-M. It is important to observe that there were no cities with an HDI of lower than 0.5. These characteristics seem to reflect favorably on their mean DMF-T, in comparison with those cities with an HDI-M equal to or lower than 0.8.

The correlation between the HDI-M/2000 indexes and the time span of implementing water fluoridation in the included cities in the state of Paraná is shown in Table 2. The Rho Spearman correlation statistical test was chosen for ordinal variables and also because of the asymmetric distribution of the time span data.

A positive and statistically significant correlation was found between the HDI-M and the fluoridation time span ($r = 0.48$; 99%, $P < 0.00$), with the HDI-M accounting for about 22% of the variation in this correlation (Fig. 2).

Furthermore, the drinking water fluoridation time span showed a negative correlation to the DMF-T index, this correlation being significant at the 0.01 level ($r = -0.33$; 99%; $P < 0.00$). In the context of the studied areas, this correlation shows

Table 1. Time of exposure to water fluoridation and the DMF-T in 12-year-old schoolchildren, according to a cutoff of 0.8 for the HDI-M of the analyzed cities

	n (cities)	Fluoridation exposure (time span in days)	DMF-T
HDI-M			
Lower than 0.8	304	6231 ± 1652	5.18 ± 1.8
Higher than or equal to 0.8	19	8952 ± 3401	3.62 ± 1.3

Table 2. Correlation coefficient of analyzed variables

Spearman's rho	HDI-M	Fluoridation exposure (time span in days)	DMF-T
HDI-M			
Correlation coefficient	1.000	0.476	−0.287
Sig. (two-tailed)		0.000	0.000
Fluoridation exposure (time span in days)			
Correlation coefficient	0.476	1.000	−0.311
Sig. (two-tailed)	0.000		0.000

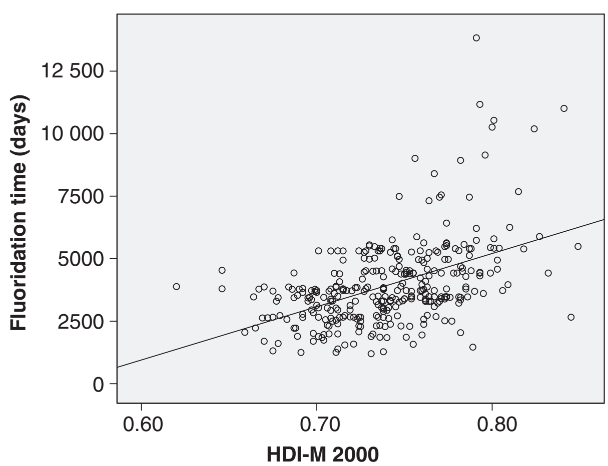

Fig. 2. Correlation between the start of water fluoridation and the classification of the respective cities, ranked by the HDI-M.

the importance of the fluoridation time span, accounting for about 11% of the variance in caries reduction, as shown in Table 2. Finally, the HDI-M is also inversely correlated to the DMF-T indexes of the areas ($r = -0.29$; 99%, $P < 0.00$) rendering a squared coefficient of 8%, confirming that areas with better HDI had lower dental caries levels.

Although it is not shown here, the partial correlation between the DMF-T and fluoridation time, controlled by the HDI-M, was also statistically significant ($r = -0.16$; $P < 0.00$).

The above correlations are important, but the temporal consistency of the HDI-M, taken here as an independent variable, still remains an issue. Would the HDI-M have been similar in these places in past periods? Moreover, for the contextual effect of the HDI-M to be more plausible, it should be stable for a certain length of time. A way of evaluating this question is by looking at the correlation between the HDI-M available for the years 1991 and 2000. The high correlation found between the 2 years ($r = 0.9$; $P < 0.00$) strengthens the hypothesis, as this index remains stable for the cities, at least in the period covering the decade considered above.

At a total cost of USD 1.089.062 for water supply fluoridation in the state of Paraná for the year 2002, the estimated cost per capita in USD was 0.15 per year. The family cost (5 persons) is about USD 0.75 per year.

Discussion

A positive and statistically significant correlation was found between the HDI-M and the fluoridation time span; the drinking water fluoridation time span also showed a negative correlation to the DMFT index. These results are in agreement with the findings of some authors (3, 7, 26, 27). The HDI-M is also inversely correlated to the DMF-T indexes of the cities, confirming that areas with better HDI-M indexes had lower dental caries levels.

The findings suggest that in certain regions of Brazil, fluoridation has historically followed the economic development of society with no regard for its contextual needs, indicating that the inverse care law also can apply to public health programs. This should certainly be considered with attention, in terms of formulating public policies and decision-making, because cities with lower development, measured by the HDI-M, also showed worse caries indicators or prevalence.

Water fluoridation is an important public health measure capable of attending a large population, particularly persons who have bad oral health and limited access to health systems. Because water fluoridation is directly associated with the reduction of dental caries, in a country like Brazil, where there are many huge inequalities, political efforts should be made to address this unequal implementation of water fluoridation and provide it to populations that do not yet have access to it.

Special attention must be paid when analyzing these significant findings, as correlation is not causation. Statistically significant results can easily be found without evident etiological pathways.

There is another point with regard to the direction of the potential association, namely, the nature of the relationship between the independent and dependent variables. The theoretical rationale in this study assumes that such correlations occur, probably because water fluoridation is a consequence of access to basic conditions for promoting health, such as basic sanitation, implementation of treated water and other public health measures. On the contrary, measures like these would appear to have been implemented at an early stage, thus privileging those with better socioeconomic conditions.

As regards the cost–benefit of water fluoridation, with the per capita cost of fluoridation being around USD 0.15, it is shown to be an economic measure, as also revealed by another study (28). Thus, future policies on implementing water fluoridation in Brazil's states, such as Paraná, could be better formulated to address the needs of hundreds of cities that still do not have this oral health benefit.

Conclusion

Considering the limitations of this study, it is concluded that in the studied areas, water fluoridation seems to reflect the inequalities of social development, as it first became available in the more socially developed areas, thus affecting their better DMF-T performance to date. However, other studies using longitudinal designs are necessary to confirm such hypothesis.

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