Received: 27 February 2020 | Revised: 25 June 2021 | Accepted: 28 June 2021

DOI: 10.1111/cdoe.12676

ORIGINAL ARTICLE

Community Dentistry and Oral Epidemiology WILEY

Does water fluoridation influence ethnic inequalities in caries in Brazilian children and adolescents?

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Funding information
Conselho Nacional de Desenvolvimento Científico e Tecnológico, Grant/Award Number: 153623/2018-7

Abstract

Objectives: This study aimed to investigate the influence of community water fluoridation on ethnic inequalities in untreated dental caries among children and adolescents in Brazil while taking the human development context into account.

Methods: Data from a nationwide Brazilian epidemiological population oral health survey were used (SB Brazil 2010). Outcomes were caries prevalence measured by the proportion of individuals with one or more untreated decayed teeth and caries severity defined by the mean number of untreated decayed teeth (DT). Three different contexts were considered: 1—cities with no water fluoridation; 2—cities with water fluoridation and low Human Development Index (HDI); and 3—cities with water fluoridation and high HDI. The exposure was ethnic/racial group (White, Pardo, Black) and covariates were age, sex and household income. Multilevel logistic and negative binomial regressions were performed with 6696 children (aged 5 years) and 11 585 adolescents (aged 12 and 15-19 years).

Results: For both children and adolescents, ethnic differences in caries prevalence and mean DT were found in the nonfluoridated cities with low HDI and also in cities with high HDI, most of which were fluoridated. For example in nonfluoridated cities with low HDI, 5-year-old Pardo children were more likely to have untreated decay (OR = 1.22; 95% CI: 1.02, 1.46) and had more decayed teeth (RR = 1.18; 95% CI: 1.04, 1.34) than their White counterparts after adjusting for sex and household income. No statistically significant differences were observed in fluoridated cities with low HDI.

Conclusion: Water fluoridation appears to be associated with reduced ethnic inequalities in dental caries prevalence and mean DT among children and adolescents in more disadvantaged settings.

KEYWORDS

dental caries, ethnic inequality, Human Development Index, water fluoridation

1 | INTRODUCTION

Ethnic/racial inequalities in oral health are a major challenge globally.[1-6] Most studies suggest that ethnic differences in health result from social, cultural and economic characteristics rather than from increased biological susceptibility.[7,8] Poorer outcomes in oral health among disadvantaged ethnic groups have been linked to a number of structural factors, among others, living in poorer areas, lack of culturally sensitive models of oral health care and insufficient exposure to fluoridated water.[8] Increasing evidence indicates that racial discrimination is a risk factor for disease and contributes to inequalities in health.[7]

Among countries on the American continent, Brazil has the largest population of individuals with African ancestry.[9] According to the Brazilian census bureau, the skin colour composition of the population in 2010 was 47.7% Whites, 43.0% Pardos (Brazilians of mixed ethnic ancestries), 7.8% Blacks, 1.1% of Asian ancestry and 0.4% Indigenous.[10] Previous research has documented racial inequalities in oral health with higher caries levels among Pardos and Blacks than among Whites in 2000.[6]

Dental caries is the most prevalent condition globally, affecting 35% of the worldwide population (2.4 billion people). Caries have substantial impacts on individuals, families and societies, causing pain, considerable social and economic burdens and reduced quality of life.[11] In Brazil, dental caries levels have declined in the overall population, but these improvements have not occurred equally across socioeconomic groups.[12,13] Improvements have been attributed to better living conditions and oral health policies, including improved access to fluoridated water and the use of fluoride toothpaste.[12-15] The decline in dental caries in Brazil coincided with major social and economic development in the country. From 1991 to 2010, life expectancy at birth increased by 9.2 years, and the per capita monthly income grew 14.2%. The establishment of the universal health care system in 1988 improved the availability of publicly funded dental services and the percentage of Brazilian children that never had a dental appointment decreased from 20.9% in 1998 to 12.8% in 2008.[16] However, oral health inequalities persist affecting Blacks and Pardos, as well as rural, poorer, less educated and otherwise disadvantaged populations.[14]

Evidence from Brazil has highlighted the relevance of human development levels for dental caries.[12,17] The Human Development Index (HDI) assesses well-being from the geometric mean of three dimensions: income, education and health. It is a continuous measure that can take on any value between 0 and 1 (the higher the value, the better the social conditions). In Brazil, the HDI increased from 0.49 to 0.72 between 1991 and 2010, denoting significant improvements in overall living conditions.[18]

While clearly not the only means of caries prevention, the use of fluoride as a caries preventive measure is well established and the World Health Assembly resolution has confirmed the importance of water fluoridation as a public health measure to promote population oral health.[19] The British Fluoridation Society estimated that about 25 countries provided water fluoridation in 2012 including the USA and Brazil, where more than half of their populations were covered.[20]

About 80% of the Brazilian population have access to treated water at least by filtration and disinfection, while nearly 15% have access to water provided by wells inside or outside the property.[21] As an effective public health intervention, fluoridation of public water supplies is mandatory since 1974 according to Federal Law, and the Ministry of Health recommends the fluoride concentration in tap water to be around 0.7 ppm.[22] Despite this, and although the fluoridation of public water supplies has increased between 2000 and 2008,[21] it has been estimated that 25% of the population distributed across 40% of all cities did not have access to fluoridated water supplies in 2008.[21]

Studies from other countries have shown that water fluoridation can reduce but not eliminate oral health inequalities.[4,23-26] A Brazilian study investigated the correlation between municipal HDI values and DMFT amongst 12-year-olds living in fluoridated and nonfluoridated cities. Exposure to fluoridated water attenuated the magnitude of the correlation between these variables, with lower DMFT in fluoridated cities.[27] Other research found that access to fluoridated water only slightly reduced the ethnic inequalities in dental caries in Brazil, however, the HDI was not considered in these analyses.[6]

This study aimed to investigate the influence of community water fluoridation on ethnic inequalities in untreated dental caries among children and adolescents in Brazil while taking the human development context into account.

2 | METHODS

Data came from the SB Brazil 2010 Project,[28] a nationwide representative epidemiological oral health survey of the urban Brazilian population conducted in 177 cities and using probability cluster sampling. These were the capital cities of each of the 27 Brazilian states (including the country capital, Brasília), and 30 cities randomly selected in each of the five main regions of Brazil (North, Northeast, Central-West, Southeast and South). In each city, urban census tracts and households were randomly selected and eligible individuals were interviewed and examined. More than 70% of the selected residences agreed to participate. The final survey sample included 37 519 individuals and was representative for each of the five surveyed age groups (5, 12, 15-19, 35-44, 65-74 years).[29] Interviews and clinical examinations followed WHO criteria[30] and were carried out in respondents' homes by teams consisting of a general dentist and an assistant. Approximately 570 dentists and 570 assistants were trained and calibrated for the survey. Depending on the field characteristics, two to five teams per district were selected and trained. Examiners with Kappa values above 0.65 were approved for data collection.[29] Ethical approval for the SB Brazil 2010 was granted by the Ethics Commission, Resolution CNS 15498, on 1 July 2010. All participants provided their informed consent.

To enable the assessment of associations for both deciduous and permanent dentitions, the current study included three age groups: children aged 5 years (deciduous dentition) and adolescents aged 12 and 15-19 years (permanent dentition). Outcome measures were the prevalence of any untreated caries and the mean number of untreated decayed teeth (mean DT). Caries prevalence was a binary variable, distinguishing between those without untreated caries (D = 0) and those with one or more untreated decayed teeth (D ≥ 1). Mean DT was a count variable defined as the number of untreated decayed teeth (D). In line with WHO criteria, untreated dental caries was recorded at the clinical examination if a lesion in the pit and fissure or on a smooth tooth surface had an unmistakable cavity, undermined enamel, or a detectably softened floor or wall; or where a temporary restoration (except glass ionomer) was present.[30] The CPI probe was used to confirm visual evidence of caries on the occlusal, buccal and lingual surfaces.

For the 15- to 19-year-old participants, determination of ethnic group was based on self-assessment, whereby respondents identified themselves according to the categories of ethnic classifications based on skin colour that are used by the Brazilian Institute for Geography and Statistics: White, Asian, Pardo (skin colour between white and black), Black and Indigenous ethnic groups.[10] For 5- and 12-year-old participants, ethnic category was reported by one of the parents.

Brazilian cities were divided into three different groups: (a) cities without water fluoridation; (b) cities with water fluoridation and a low HDI and (c) cities with water fluoridation and a high HDI. Information on water fluoridation was obtained from three different sources, including assessment of the fluoridation status of Brazilian municipalities with more than 50 000 inhabitants between 2012 and 2015,[22] the National Survey of Basic Sanitation (PNSB) in 2000 and 2008,[31,32] and the National System of Sanitary Information (SNIS) in 2010 and 2014.[33] The provision of water fluoridation was determined based on at least two of the above data sources. The municipal Human Development Index (HDI) for Brazilian cities was calculated from 2010 data on income, education and health. The cut-off point to distinguish between cities with low and high HDI was the median HDI of all cities that were part of the survey (0.73). Using this HDI cut-off point, 53 cities were classified as having water fluoridation and lower HDI, while 51 cities were classified as having water fluoridation and higher HDI. Because the vast majority of nonfluoridated cities (63 out of 73) had low HDI values, cities that were not fluoridated were not further subdivided into low and high HDI. The geographical distribution of the three groups of cities is shown in (Appendix 1).

Dental caries in young people has been found to vary with age[6] and thus, age was used as a covariate to adjust models pertaining to adolescents. Sex (male; female) and household income were also included as covariates. Income was measured using equivalized monthly household income[34] and dichotomized to distinguish between households living below the Brazilian minimum wage (<1 MW) and those at or above the minimum wage (≥1 MW). In December 2010, the Brazilian minimum wage was 510.00 BRL (Brazilian Reais) or 301.70 USD (US Dollars).

Analyses were carried out using Stata Version 14.[35] Qgis software version 3.8.2 was used to create Appendix 1.[36] Sampling weights were employed throughout to account for the geographical clustering of the data. All analyses were based on complete cases as the rate of missingness was less than 10% (8.9% among 5-year-olds and 9.3% among 12-year-olds and 15- to 19-year-olds). Characteristics of initial and analysis samples were compared (Appendix 2). Descriptive analyses included cross-tabulations of outcome variables by ethnic group, covariates, and by city group. We then undertook multilevel regression analyses, with individual respondents at level 1 and cities at level 2. Associations between ethnic group and caries prevalence were estimated using multilevel logistic regression and expressed as Odds Ratios (OR). Mean decayed teeth were analysed using multilevel negative binomial regression and rate ratio estimation (RR), due to overdispersion of the outcome variable (variance at least three times higher than the mean in all contexts). All models were adjusted for sex and monthly household income and satisfied the goodness-of-fit criteria (AIC and BIC). Preliminary analyses showed that water fluoridation and HDI-moderated associations between ethnic group and caries outcomes (interaction terms statistically significant), therefore analyses were stratified by city group. Data for children (5-year-olds) and adolescents (12- and 15-year-olds) were analysed separately. The proportions of children belonging to Indigenous and Asian ethnic groups were very small (0.8% and 2.3%, respectively, among 5-year-olds; and 0.6% and 1.9%, respectively, among 12 and 15-to-19-year-olds). Therefore, these ethnic groups were not included in the analyses.

Two sensitivity analyses were performed. First, comparisons of untreated caries prevalence and mean DT were carried out with the high HDI cities (>0.73) excluded from the nonfluoridated group of cities (Appendix 3). Second, we compared differences between the three contexts using caries experience as the basis for the outcomes (any caries experience, ie dmft/DMFT > 0, and mean dmft/DMFT) (Appendix 3).

3 | RESULTS

Initial sample sizes were 7348 (5-year-olds) and 12 773 (12- and 15- to 19-year-olds). Data were missing for 8.9% of the child and 9.3% of the adolescent sample, respectively, therefore analysis samples included 6696 children (aged 5 years) and 11 585 adolescents (aged 12 and 15-19 years). There were no important differences between the initial and analysis samples for the variables included in regression models (Appendix 2).

The median HDI was 0.66 in nonfluoridated cities and 0.67 in cities with water fluoridation and low HDI. In the fluoridated cities with high-HDI the median HDI was 0.77.

Table 1 shows the distribution of the sample characteristics as a whole, and separately for each context (city group). For both samples, overall levels of untreated caries were lowest in cities with water fluoridation and high HDI. Ethnic inequalities were evident across the three contexts, with White children and adolescents

generally having considerably lower levels of untreated decay than Pardo and Black children and adolescents. The pattern of inequalities was not the same across contexts, with more pronounced ethnic inequalities in nonfluoridated cities and fluoridated cities with high development, while in cities with fluoridation and low development differences were evident between White and Black (but not equally between White and Pardo) children.

Tables 2and Appendix 4 show the ethnic inequalities in untreated caries prevalence and mean DT in unadjusted and adjusted multilevel regression models. Among 5-year-old children, there were ethnic differences in caries prevalence and mean DT after adjustment for sex and household income in the nonfluoridated context. Pardo children were 22% more likely to have untreated decay and had a higher number of decayed teeth (RR = 1.18; 95% CI: 1.04, 1.34) than their White counterparts. Black children in cities without water fluoridation had more decayed teeth than White children (RR = 1.27; 95%CI: 1.01, 1.61) though there was no difference in the overall prevalence of any untreated decay between these ethnic groups. In cities with fluoridation and high HDI, Black children were 42% and Pardo children 20% more likely to have untreated caries than White children, and the same pattern was observed for mean DT. However, no differences between any of the three ethnic groups were observed in the areas with fluoridation and low HDI.

In the nonfluoridated cities, Black adolescents were 67% and Pardos 38% more likely to have untreated caries and also had a higher mean DT (RR = 1.25; 95% CI: 1.07, 1.46 for Black, and RR = 1.18; 95%CI: 1.08, 1.30 for Pardo) than their White counterparts. Clear ethnic inequalities also existed for adolescents in fluoridated cities with high HDI: Black adolescents were 56% and Pardo adolescents were 48% more likely to have untreated caries, and had more carious teeth, than Whites. Differences between ethnic groups were smaller and not statistically significant in the fluoridated areas with low HDI after adjustment for covariates, however, the point estimates suggest that some inequalities existed. After adjustment, Black adolescents in nonfluoridated cities with low HDI had 37% higher risk for untreated caries and a higher number of untreated decayed teeth (RR = 1.20; CI: 0.93-1.56) than White adolescents.

In the first sensitivity analysis, excluding cities with high HDI from the group of nonfluoridated cities yielded very similar results and did not substantially change our conclusions (results shown in Appendix 3). In the second sensitivity analysis, using dmft/DMFT as outcome measures resulted in similar findings, that is no or smaller ethnic differences in cities with water fluoridation and low HDI than in cities without water fluoridation (Appendix 3).

4 | DISCUSSION

This study explored ethnic inequalities in untreated caries between Brazilian Black/Pardo than White children and adolescents. Inequalities were evident in nonfluoridated cities and in cities with water fluoridation and high levels of human development. However, in fluoridated cities with low HDI levels no inequalities in untreated caries levels were found among children, and smaller ethnic differences among adolescents, than in cities without water fluoridation.

Our study has a number of strengths. The analysis utilized data from a national epidemiological survey (SB Brazil 2010), which is probably the best available Brazilian data on oral health that accurately reflects the country's characteristics as a whole, also considering the complexity involved in ethnic/racial classification in Brazil.[6] Water fluoridation levels were determined using different data sources, thereby improving their reliability. Multilevel analysis took the clustered nature of the data into account and stratification by water fluoridation status and Human Development Index allowed us to examine the influence of contextual factors on ethnic inequalities. On the other hand, the study had several limitations. As these were observational data, no causal inferences can be made. Because the vast majority of cities with high levels of human development were fluoridated, it was not possible to examine the role of water fluoridation on ethnic inequalities in caries levels in a high HDI context. Furthermore, we did not have data on sugar intake or other oral health behaviours from participants, including other sources of individual fluoride exposure. However, as the selected households were located in urban areas covered by the public water supply network, we can infer that participants had access to fluoridated water in cities with water fluoridation. Also, participants in all three contexts were likely to be exposed to fluoridated toothpaste.[37] Other unobserved factors potentially influencing levels of untreated caries include the availability and accessibility of dental services.

Among the three contexts considered in this study, two had similarly low levels of development but contrasting exposure to water fluoridation. Our findings showed clear and extensive ethnic inequalities in cities with low HDI and without fluoridated water; however, much more modest (if any at all) inequalities were found in cities with similarly low HDI but with fluoridated water supply. This suggests that water fluoridation may help to reduce ethnic inequalities in levels of untreated caries among children and adolescents living in more disadvantaged areas in Brazil. However, for more affluent cities the role of water fluoridation on oral health inequalities could not be ascertained.

Caries prevalence and mean DT were lower for all ethnic groups in the areas with water fluoridation and high HDI, endorsing the important role of fluoridation and favourable socioeconomic area-level conditions as structural determinants of dental caries.[13-15,23-26] At the same time, clear and extensive ethnic inequalities in caries were evident in this context. Potential explanations could relate to a wider variation in affluence and higher levels of racial discrimination in more affluent cities. For example it is possible that within cities with higher HDI, ethnic differences in levels of affluence are more excessive, with more Blacks and Pardos living in extreme poverty and Whites living in more affluent neighbourhoods. However, this could not be investigated in this study due to the lack of available relevant data at neighbourhood level. Although we did adjust for self-reported income, this is not sufficient to support or refute the aforementioned explanation.

TABLE 1 Caries prevalence and severity (weighted proportions) in Brazilian children and adolescents, by explanatory variables and by context. SB Brazil 2010

	Children (n = 6696)				Adolescents (n = 11 585)			
			Caries Prevalence	Decayed Teeth			Caries Prevalence	Decayed Teeth
Individual variables	n	%	% (95%CI)	Mean (95%CI)	n	%	% (95%CI)	Mean (95%CI)
Ethnic group								
Whites	3073	49.1	45.2 (37.0-53.5)	1.70 (1.22-2.17)	4780	46.8	39.5 (32.9-53.5)	1.28 (0.84-1.73)
Pardos	3064	41.6	53.7 (47.4-59.8)	2.33 (1.77-2.96)	5576	41.9	53.3 (42.7-62.7)	1.90 (1.20-2.59)
Blacks	559	9.3	55.8 (43.8-67.2)	2.73 (2.20-3.27)	1229	11.3	51.2 (42.5-59.9)	1.92 (1.22-2.61)
Sex								
Female	3368	48.9	48.9 (41.4-56.4)	1.96 (1.49-2.43)	5578	51.5	48.6 (42.0-52.2)	1.65 (1.24-2.06)
Male	3328	51.1	50.5 (45.5-56.5)	2.18 (1.69-2.67)	6007	48.5	44.5 (34.4-55.2)	1.57 (0.81-2.32)
Income								
Below minimum wage	4271	61.9	56.6 (49.6-63.4)	2.53 (2.02-3.05)	6967	56.2	55.3 (47.1-63.2)	2.08 (1.41-2.74)
At or above minimum wage	2425	38.1	38.3 (33.7-43.4)	1.31 (1.01-1.62)	4618	43.8	35.5 (28.6-43.1)	1.01 (0.62-1.41)
Context: No WF	2607	23.8	61.5 (51.6-70.6)	3.00 (2.32-3.68)	4250	19.4	62.2 (52.7-70.2)	2.83 (2.24-3.40)
Ethnic group								
Whites	1008	44.4	55.6 (40.9-69.5)	2.27 (1.39-3.14)	1355	38.8	54.6 (44.6-64.3)	2.45 (1.74-3.16)
Pardos	1481	45.9	65.8 (58.5-72.3)	3.43 (2.66-4.20)	2528	53.3	67.1 (57.7-75.3)	3.04 (2.49-3.60)
Blacks	118	9.6	68.6 (63.8-73.0)	4.33 (3.58-5.09)	367	7.8	66.5 (51.1-79.0)	3.19 (1.54-4.85)
Context: WF and Low HDI	571	17.6	58.2 (47.2-68.5)	2.50 (1.73-3.27)	1003	18.9	58.0 (51.1-64.7)	2.11 (1.39-2.83)
Ethnic group								
Whites	265	42.7	57.9 (42.5-72.0)	2.52 (1.67-3.36)	386	34.9	52.4 (44.0-60.7)	1.91 (1.18-2.64)
Pardos	270	45.1	55.6 (44.9-65.8)	2.34 (1.28-3.39)	470	46.6	57.6 (50.4-64.6)	2.00 (1.28-3.39)
Blacks	70	12.2	68.9 (65.3-72.3)	3.06 (2.56-3.56)	147	18.5	69.7 (55.8-80.8)	2.79 (1.73-3.83)
Context: WF and High HDI	3518	58.6	42.3 (38.3-46.3)	1.57 (1.44-1.70)	6332	61.7	38.2 (31.8-44.6)	1.08 (0.81-1.35)
Ethnic group								
Whites	1800	53.0	38.5 (35.9-41.1)	1.31 (1.20-1.42)	3039	53.0	33.4 (27.1-40.4)	0.89 (0.59-1.19)
Pardos	1410	38.7	47.2 (42.2-52.0)	1.86 (1.63-2.08)	2578	36.9	45.4 (40.4-50.4)	1.34 (1.08-1.60)
Blacks	308	8.3	44.1 (26.9-59.7)	1.83 (1.44-2.22)	715	10.1	37.2 (21.1-56.7)	1.12 (0.57-1.68)

TABLE 2 Results of multilevel logistic regression models predicting odds of having untreated dental caries in the three contexts. SB Brazil 2010

	No Fluoridation		WF and low-HDI		WF and high-HDI	
	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Children						
Ethnic group						
White	1	1	1	1	1	1
Pardos	1.36 (1.14-1.62)	1.22 (1.02-1.46)	0.94 (0.63-1.41)	0.85 (0.56-1.29)	1.33 (1.14-1.55)	1.20 (1.02-1.40)
Blacks	1.13 (0.80-1.59)	1.02 (0.72-1.44)	1.21 (0.65-2.27)	1.08 (0.57-2.05)	1.61 (1.25-2.07)	1.42 (1.10-1.84)
Per capita income						
<1 MW	1	1	1	1	1	1
≥1 MW	0.43 (0.36-0.52)	0.44 (0.37-0.53)	0.57 (0.38-0.83)	0.54 (0.36-0.81)	0.44 (0.38-0.51)	0.47 (0.41-0.55)
VPC	14.80%	11.60%	8.40%	9.80%	3.20%	2.90%
Adolescents						
Ethnic group						
White	1	1	1	1	1	1
Pardos	1.49 (1.29-1.72)	1.38 (1.19-1.60)	1.20 (0.88-1.64)	1.15 (0.84-1.59)	1.57 (1.40-1.77)	1.48 (1.31-1.67)
Blacks	1.81 (1.41-2.34)	1.67 (1.29-2.15)	1.61 (1.03-2.52)	1.37 (0.87-2.16)	1.77 (1.49-2.11)	1.56 (1.31-1.87)
Per capita income						
<1 MW	1	1	1	1	1	1
≥1 MW	0.52 (0.46-0.60)	0.52 (0.45-0.60)	0.57 (0.43-0.76)	0.54 (0.40-0.73)	0.54 (0.48-0.60)	0.51 (0.46-0.57)
VPC	12.70%	11.10%	11.60%	8.40%	5.50%	5.20%

Abbreviations: MW, minimum wage; VPC, Variance Partition Coefficient (% of variance due to differences at the municipality level).
[a]Adjusted for gender, income, age.

Comparing to the relevant literature, water fluoridation did not eliminate ethnic inequalities in caries-free levels between Māori and non-Māori children in New Zealand[4] or in untreated dental caries in Brazil,[6] but did reduce the gap in racial inequalities. However, unlike our investigation, these studies did not take the human development context into account, therefore direct comparisons are not straightforward even when referring to Brazilian data.

Overall, the same pattern of results was observed irrespective of whether the outcome was the prevalence of untreated decay or the number of decayed teeth. This indicates that ethnic inequalities affect the caries distribution in its totality, rather than being relevant only for different levels of caries severity. From a public health policy perspective, our results highlight the relevance of water fluoridation as one potential pathway to address ethnic inequalities among children and adolescents living in more deprived areas in Brazil. There are other important factors that can potentially influence ethnic inequalities that were not assessed here, such as oral health policies and access to dental services, but also health behaviours and broader neighbourhood conditions.

Furthermore, socioeconomic status (SES) do not directly address all the fundamental causes of ethnic inequalities and the interplay between socioeconomic position and racial discrimination. Higher SES was a protective factor for dental caries in all three contexts of this study, corroborating other findings.[1-3,6,15] Some disadvantaged Brazilian racial groups live in deprived neighbourhoods,[8] reflecting a complex and long-standing social process shaped by slavery, class and gender oppression.[38,39] While it is essential to focus on the social inequalities in oral health, ethnic inequalities may not be eliminated simply by addressing only the mechanisms that link SES to health.[40] Future research should use longitudinal approaches to further explore the conditions that contribute to ethnic inequalities in oral health, including but not limited to exposure to fluoridated water supplies.

In conclusion, ethnic inequalities in untreated caries among children and adolescents were evident in Brazilian cities with high development and also in those with low development that did not benefit from water fluoridation, while no inequality or reduced inequalities existed in low development cities that had water fluoridation. Water fluoridation could reduce inequalities related to dental caries in more disadvantaged settings.

ACKNOWLEDGEMENTS

The author (RAB) received a junior postdoc scholarship from CNPq Brazil process 153623/2018-7. This study was financed in part by the Fundação Universidade Federal de Mato Grosso do Sul—UFMS/MEC—Brazil. The author (PF) is a researcher of the Brazilian Council for Scientific and Technological Development (CNPq 305132/2019-9).

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Author 1 RAB: Contributed to conception, design, data interpretation, performed all st show the ethnic inequalities atistical analyses, drafted and critically revised the manuscript. Author 2 RGW: Contributed to conception, design, data interpretation, drafted and critically revised the manuscript. Author 3 GT: Contributed to conception, design, data interpretation, drafted and critically revised the manuscript. Author 4 AH: Contributed to conception, design, data interpretation, drafted and critically revised the manuscript. Author 5 PF: Contributed to conception, design, data interpretation, drafted and critically revised the manuscript. All authors gave their final approval and agreed to be accountable for all aspects of the work.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from [Brazilian Ministry of Health]. Restrictions apply to the availability of these data, which were used under license for this study. Data are available with the permission of [Brazilian Ministry of Health/ Oral Health Coordination].

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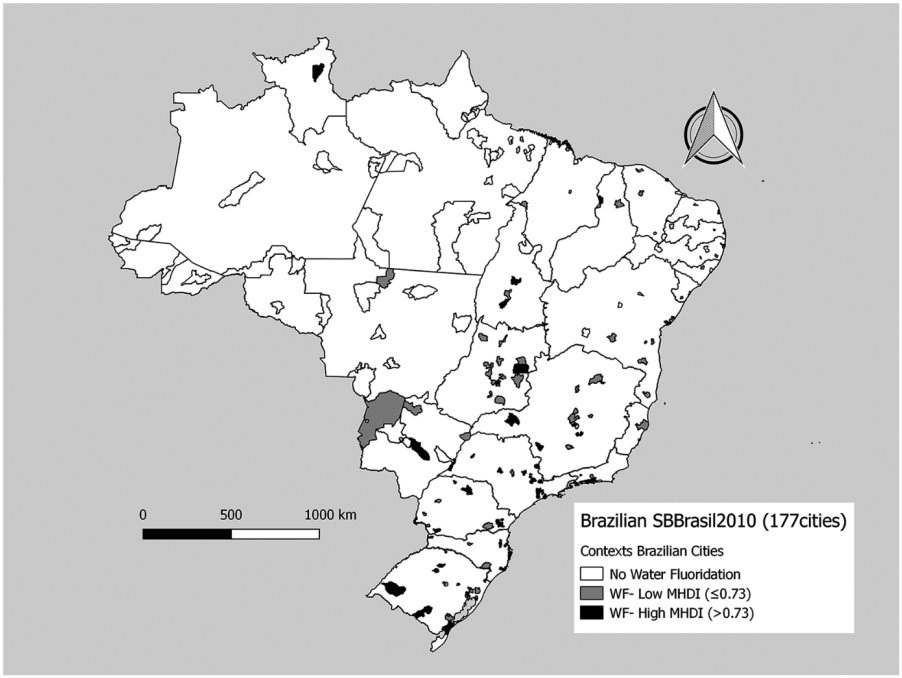
How to cite this article: Bomfim RA, Watt RG, Tsakos G, Heilmann A, Frazão P. Does water fluoridation influence ethnic inequalities in caries in Brazilian children and adolescents? *Community Dent Oral Epidemiol*. 2022;50:321–332. https://doi.org/10.1111/cdoe.12676

APPENDIX 1



APPENDIX 2

COMPARISON OF INITIAL SAMPLES AND FINAL ANALYSIS SAMPLES WITH COMPLETE CASES. SB BRAZIL 2010

TABLE A2.1. Comparison of initial samples and final analysis samples with complete cases (5-y-olds)

	Initial sample (n = 7348)		Complete cases (n = 6696)		
	n	% (95%CI)	n	% (95%CI)	*P*-value
Ethnic group					
Whites	3290	50.3 (43.2-57.3)	3073	49.1 (42.2-56.1)	0.06
Pardos	3274	40.5 (34.2-47.2)	3064	41.6 (35.2-48.2)	
Blacks	586	9.2 (7.3-11.5)	559	9.3 (7.5-11.5)	
Sex					
Female	3675	48.1 (44.1-52.1)	3368	48.9 (46.0-51.8)	0.18
Male	3673	51.9 (47.9-55.9)	3328	51.1 (48.2-54.0)	
Per capita income					
Below minimum wage	4480	61.9 (54.9-68.3)	4271	61.9 (55.5-67.9)	0.92
At or above minimum wage	2522	38.1 (31,7-45.0)	2425	38.1 (32.2-44.5)	
Untreated dental caries (D ≥ 1)	3695	49.8 (43.4-56.3)	3426	49.7 (43.1-56.3)	0.43
		Mean (95%CI)		**Mean (95%CI)**	
Number of decayed teeth		2.13 (1.69-2.56)		2.07 (1.60-2.54)	0.36

TABLE A2.2. Comparison of initial samples and final analysis samples with complete cases (12-y-olds and 15- to 19-y-olds)

	Initial sample (n = 12 773)		Complete Cases (n = 11 585)		
	n	% (95%CI)	n	% (95%CI)	*P*-value
Ethnic group					
Whites	5100	47.1 (38.0-56.3)	4780	46.8 (35.9-55.9)	0.35
Pardos	6004	40.5 (34.2-47.2)	5576	41.9 (34.1-50.1)	
Blacks	1310	11.2 (8.7-14.4)	1229	11.3 (8.6-14.6)	
Sex					
Female	6637	51.2 (44.9-52.9)	5578	51.5 (50.2-52.7)	0.06
Male	6136	48.8 (47.6-50.1)	6007	48.5 (47.3-49.8)	
Per capita income					
Below minimum wage	7264	55.9 (51.2-60.6)	6967	56.2 (51.7-60.6)	0.29
At or above minimum wage	4788	44.1 (39.4-48.8)	4618	43.8 (39.4-48.3)	
Untreated dental caries (D ≥ 1)	6073	47.0 (39.0-55.2)	5594	46.6 (38.7-54.7)	0.28
		Mean (95%CI)		**Mean (95%CI)**	
Number of decayed teeth		1.63 (1.06-2.22)		1.61 (1.05-2.17)	0.60

APPENDIX 3

SENSITIVITY ANALYSES

Two sensitivity analyses were performed

In the main analyses, the majority of nonfluoridated cities had low HDI levels, therefore this group was not further divided into low and high HDI cities. In the first sensitivity analysis, participants from the 10 nonfluoridated cities with high HDI (>0.73) were excluded. Comparing only low HDI/nonfluoridated cities with low HDI/fluoridated cities yielded similar results (Tables A3.1 and A3.2).

A second sensitivity analysis was performed with caries experience measured via the dmft/DMFT index (count variable, Tables A3.3) and the percentage of individuals with dmft/DMFT ≥1 (binary variable, Tables A3.4) in the three investigated contexts.

TABLE A3.1. Sensitivity analysis of ethnic inequalities in the prevalence of untreated caries (nonfluoridated cities with high HDI excluded). SB Brazil 2010

	Nonfluoridated cities with low HDI[a]		Fluoridated cities with low-HDI	
	OR (95% CI)		OR (95% CI)	
	Unadjusted	Adjusted*	Unadjusted	Adjusted*
5-y-olds				
Ethnic group				
Whites	1	1	1	1
Pardos	1.21 (0.95-1.53)	1.09 (0.85-1.39)	0.94 (0.63-1.41)	0.85 (0.56-1.29)
Blacks	1.06 (0.68-1.67)	0.95 (0.60-1.50)	1.21 (0.65-2.27)	1.08 (0.57-2.05)
Per capita income				
<1 MW	1	1	1	1
≥1 MW	0.42 (0.35-0.50)	0.42 (0.32-0.53)	0.57 (0.38-0.83)	0.54 (0.36-0.81)
12- and 15- to 19-y-olds				
Ethnic group				
Whites	1	1	1	1
Pardos	1.50 (1.24-1.82)	1.30 (1.06-1.59)	1.20 (0.88-1.64)	1.15 (0.84-1.59)
Blacks	1.72 (1.21-2.42)	**1.47 (1.03-2.11)**	1.61 (1.03-2.52)	1.37 (0.87-2.16)
Per capita income				
<1 MW	1	1	1	1
≥1 MW	0.50 (0.44-0.57)	0.46 (0.38-0.55)	0.57 (0.43-0.76)	0.54 (0.40-0.73)

[a] Excluding cities with high-HDI (>0.73); MW, minimum wage (R$510 year 2010).* Adjusted for age (only permanent dentition), sex and income.Bold values are statistical significant values.

TABLE A3.2. Sensitivity analysis of ethnic inequalities in the mean number of decayed teeth (nonfluoridated cities with high HDI excluded). SB Brazil 2010

	Nonfluoridated cities with low HDI[a]		Fluoridated cities with low-HDI	
	RR (95% CI)		RR (95% CI)	
	Unadjusted	Adjusted*	Unadjusted	Adjusted*
5-y-olds				
Ethnic group				
Whites	1	1	1	1
Pardos	1.31 (1.12-1.48)	**1.19 (1.05-1.39)**	0.99 (0.75-1.30)	0.95 (0.72-1.25)
Blacks	1.38 (1.03-1.80)	**1.30 (1.01-1.72)**	1.01 (0.66-1.54)	1.01 (0.65-1.51)
Per capita income				
<1 MW	1	1	1	1
≥1MW	0.48 (0.42-0.55)	0.50 (0.42-0.59)	0.50 (0.44-0.57)	0.67 (0.51-0.89)
12- and 15- to 19-y-olds				
Ethnic group				
Whites	1	1	1	1
Pardos	1.21 (1.08-1.36)	1.09 (0.97-1.23)	1.13 (0.92-1.38)	1.12 (0.92-1.36)
Blacks	1.31 (1.08-1.60)	**1.22 (1.01-1.49)**	1.36 (1.04-1.76)	1.20 (0.93-1.56)
Per capita income				
<1 MW	1	1	1	1
≥1 MW	0.67 (0.62-0.74)	0.61 (0.55-0.69)	0.62 (0.56-0.67)	0.60 (0.50-0.73)

[a] Excluding cities with high-HDI (>0.73); MW, minimum wage (R$510 year 2010); RR, rate ratio.* Adjusted for age (only permanent dentition), sex and income.Bold values are statistical significant values.

TABLE A3.3. Sensitivity analysis: Results of multilevel logistic regression models predicting odds of having any caries experience (dmft/DMFT ≥1) in the three investigated contexts. SB Brazil 2010

	No Fluoridation		WF and low-HDI		WF and high-HDI	
	OR (95%CI)		OR (95%CI)		OR (95%CI)	
	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]
5-y-olds						
Ethnic group						
White	1	1	1	1	1	1
Pardos	1.45 (1.21-1.72)	**1.31 (1.10-1.56)**	0.81 (0.54-1.20)	0.76 (0.50-1.14)	1.30 (1.11-1.51)	**1.18 (1.01-1.38)**
Blacks	1.14 (0.81-1.60)	1.03 (0.72-1.44)	0.79 (0.43-1.43)	0.74 (0.40-1.35)	1.42 (1.10-1.83)	1.26 (0.98-1.64)
Per capita income						
<1 MW	1	1	1	1	1	1
≥1 MW	0.45 (0.38-0.54)	0.47 (0.39-0.56)	0.75 (0.51-1.12)	0.71 (0.41-1.06)	0.51 (0.44-0.59)	0.52 (0.45-0.60)
12- and 15- to 19-y-olds						
Ethnic group						
White	1	1	1	1	1	1
Pardos	1.31 (1.12-1.54)	**1.24 (1.06-1.46)**	1.13 (0.79-1.60)	1.18 (0.82-1.71)	1.30 (1.15-1.46)	**1.28 (1.13-1.45)**
Blacks	1.39 (1.04-1.83)	**1.31 (1.00-1.74)**	1.34 (0.80-2.23)	1.11 (0.65-1.82)	1.54 (1.31-1.86)	**1.45 (1.21-1.74)**
Per capita income						
<1 MW	1	1	1	1	1	1
≥1 MW	0.67 (0.58-0.78)	0.63 (0.54-0.73)	0.81 (0.58-1.13)	0.72 (0.51-1.03)	0.72 (0.64-0.80)	0.67 (0.60-0.75)

[a] Adjusted for age (only permanent dentition), sex, income.Bold values are statistical significant values.

TABLE A3.4. Sensitivity analysis: Results of negative binomial regression models estimating rate ratios for dmft/DMFT in the three investigated contexts. SB Brazil 2010

	No Fluoridation		WF and low-HDI		WF and high-HDI	
	RR (95%CI)		RR (95%CI)		RR (95%CI)	
	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]
5-y-olds (dmft)						
Ethnic group						
White	1	1	1	1	1	1
Pardos	1.30 (1.15-1.46)	**1.19 (1.06-1.35)**	0.96 (0.75-1.24)	0.94 (0.73-1.20)	1.20 (1.05-1.37)	1.12 (0.98-1.27)
Blacks	1.29 (1.03-1.63)	**1.20 (0.96-1.50)**	1.02 (0.70-1.47)	0.99 (0.69-1.43)	1.44 (1.15-1.79)	**1.36 (1.09-1.69)**
Per capita income						
<1 MW	1	1	1	1	1	1
≥1 MW	0.53 (0.46-0.60)	0.54 (0.48-0.62)	0.77 (0.60-1.00)	0.77 (0.59-0.98)	0.58 (0.52-0.66)	0.60 (0.52-0.67)
12- and 15- to 19-y-olds (DMFT)						
Ethnic group						
White	1	1	1	1	1	1
Pardos	1.01 (0.93-1.09)	0.99 (0.92-1.07)	0.95 (0.81-1.11)	0.99 (0.85-1.14)	1.19 (1.10-1.29)	**1.17 (1.09-1.22)**
Blacks	1.09 (0.95-1.24)	**1.09 (0.97-1.23)**	1.06 (0.85-1.31)	1.01 (0.82-1.23)	1.28 (1.14-1.45)	**1.22 (1.10-1.37)**
Per capita income						
<1 MW	1	1	1	1	1	1
≥1 MW	0.92 (0.85-0.99)	0.85 (0.79-0.91)	0.96 (0.83-1.12)	0.85 (0.73-1.98)	0.83 (0.77-0.89)	0.76 (0.71-0.82)

[a] Adjusted for age (only permanent dentition), sex, income.Bold values are statistical significant values.

APPENDIX 4

Table A4.1.Results of multilevel negative binomial regression models estimating rate ratio for the mean number of untreated decayed teeth in the three contexts. SB Brazil 2010

	No Fluoridation		WF and low-HDI		WF and high-HDI	
	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]
	RR (95%CI)	RR (95%CI)	RR (95%CI)	RR (95%CI)	RR (95%CI)	RR (95%CI)
Children						
Ethnic group						
White	1	1	1	1	1	1
Pardos	1.29 (1.14-1.47)	1.18 (1.04-1.34)	0.99 (0.75-1.30)	0.95 (0.72-1.25)	1.25 (1.09-1.44)	1.13 (0.99-1.31)
Blacks	1.38 (1.09-1.76)	1.27 (1.01-1.61)	1.01 (0.66-1.54)	1.01 (0.65-1.51)	1.66 (1.31-2.08)	1.59 (1.27-1.99)
Per capita Income						
<1 MW	1	1	1	1	1	1
≥1 MW	0.48 (0.42-0.55)	0.50 (0.44-0.57)	0.50(0.44-0.57)	0.67 (0.51-0.89)	0.50 (0.44-0.57)	0.50 (0.44-0.57)
Adolescents						
Ethnic group						
White	1	1	1	1	1	1
Pardos	1.25 (1.14-1.38)	1.18 (1.08-1.30)	1.13 (0.92-1.38)	1.12 (0.92-1.36)	1.38 (1.25-1.53)	1.34 (1.21-1.48)
Blacks	1.32 (1.13-1.57)	1.25 (1.07-1.46)	1.36 (1.04-1.76)	1.20 (0.93-1.56)	1.61 (1.39-1.88)	1.47 (1.26-1.70)
Per capita income						
<1 MW	1	1	1	1	1	1
≥1 MW	0.67 (0.62-0.74)	0.66 (0.60-0.72)	0.62 (0.56-0.67)	0.60 (0.50-0.73)	0.62 (0.56-0.67)	0.61 (0.56-0.67)

Abbreviations: MW, minimum wage; RR, rate ratios.[a] Adjusted for gender, income, age (only permanent dentition).