JAMA Pediatrics | Original Investigation

Association Between Community Water Fluoridation and Severe Dental Caries Experience in 4-Year-Old New Zealand Children

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IMPORTANCE Robust contemporary epidemiologic evidence for the population-wide efficacy of reticulated community water fluoridation is required.

OBJECTIVE To evaluate whether community water fluoridation is associated with the national rates of severe caries among 4-year-old children in New Zealand after accounting for key sociodemographic characteristics.

DESIGN, SETTING, AND PARTICIPANTS This was a near whole population–level, natural, geospatial cross-sectional study of 4-year-old children who had a health and development assessment as part of the nationwide B4 School Check screening program conducted in New Zealand between July 1, 2010, and June 30, 2016. The extracted database included 391 677 children. However, geospatial information was missing for 18 558 children, another 32 939 children were unable to be geospatially matched, 5551 children resided in areas with changing fluoridation status, and 58 786 children had no oral health screen recorded, leaving 275 843 (70.4%) eligible children. Data were released in August 2019; statistical analysis was performed from September 2019 to December 2019.

EXPOSURES Community water fluoridation status from 2011 through 2016.

MAIN OUTCOMES AND MEASURES Severe caries experience derived from the "lift the lip" oral health screening. Analyses were adjusted for age, sex, ethnicity, area-level deprivation, and residential location differences. Multilevel mixed-effects logistic regression models were used. Sensitivity analyses based on multiple imputed data were undertaken to measure any differential influence of missing data.

RESULTS In the eligible sample of 275 843 children, the median age was 4.3 years (interquartile range, 4.1-4.6 years), 141 451 children (51.3%) were boys, and 153 670 children (55.7%) resided within fluoridated areas. Severe caries were identified for 24 226 children (15.8%) in fluoridated and 17 135 children (14.0%) in unfluoridated areas, yielding an unadjusted odds ratio of 0.93 (95% CI, 0.90-0.95). However, in the adjusted analyses, children residing in areas without fluoridation had higher odds of severe caries compared with those within fluoridated areas (odds ratio, 1.21; 95% CI, 1.17-1.24). The population attributional fraction associated with unfluoridated community water was 5.6% (95% CI, 4.7%-6.6%) in a complete case analysis.

CONCLUSIONS AND RELEVANCE This study finds that community water fluoridation continues to be associated with reduced prevalence of severe caries in the primary dentition of New Zealand's 4-year-old children.

JAMA Pediatr. doi:10.1001/jamapediatrics.2020.2201
Published online July 27, 2020.

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Oral health is integral to sustainable human development.[1] Yet oral diseases, many preventable, remain among the most prevalent of diseases affecting people globally and resulting in substantial individual and societal burdens.[2,3] These burdens are unequally shared, with children living in poverty and those from socially marginalized groups disproportionately affected.[2,4,5] However, oral health is woefully neglected, and modern dentistry is unable to combat this global challenge.[2] Radical action is needed,[6] including adopting efficacious, evidence-based upstream preventive measures.

Community water fluoridation (CWF) is regarded as one of the most effective public health interventions for equitably reducing the prevalence and severity of dental caries.[7] However, a 2015 Cochrane review challenges this stance.[8] Iheozor-Ejiofor and colleagues[8] found strong evidence for the effectiveness of CWF prior to the availability of fluoride toothpaste, but evidence in the era after fluoride toothpaste is equivocal. It has been argued that the exclusion of cross-sectional studies, defined by the Cochrane review method, may have led to these findings.[9]

The CWF debate appears to polarize and galvanize people, with opponents often arguing that it is an infringement of medical ethics and individual rights.[10] A central tenet of these anti-CWF arguments is that fluorides are unlicensed medicinal substances administered to large populations without informed consent or supervision by qualified medical practitioners. New Zealand is one of the few jurisdictions globally that has an expressed constitutional protection of the right to refuse to undergo medical treatment.[11] However, when legally challenged, the New Zealand Supreme Court ruled on June 27, 2018, that local authorities had the legal authority to fluoridate water supplies without breaching an individual's right to refuse to undergo medical treatment.[12] Others have claimed that CWF may cause serious health problems, including intellectual deficits in boys (but not girls) of mothers exposed to fluoride during pregnancy.[13] This finding has been challenged and is inconsistent with evidence syntheses reported elsewhere.[14,15] Others claim that CWF has little or no cariostatic benefits and is not sufficiently effective to justify the costs.[16] Scientific reproducibility of the CWF benefits using robust contemporary evidence, together with associated existing or newly identified risks, is vital for informing these debates.

New Zealand has a long-term national policy supporting CWF, yet only 54% of the population receives it, largely due to delegated local authority control.[17] The CWF in New Zealand involves the controlled adjustment of the fluoride concentration to between 0.7 and 1.0 mg/L.[15] Using a near whole population-level data set derived from a nationwide screening program monitoring health and development of children 4 years of age (the B4 School Check; B4SC),[18] a recent study of 318 321 children charted significant and substantial unequal ethnic and economic gradients in dental caries experiences.[5] By geospatially mapping this cohort of children, the present study aims to show the current association of CWF with severe dental caries in 4-year-old children after accounting for key confounding variables.

Key Points

Question Is community water fluoridation associated with rates of severe caries in the primary dentition of 4-year-old children in New Zealand?

Findings In this national cross-sectional study of 275 843 children, those living in areas without community water fluoridation had significantly higher odds of severe caries compared with children living in areas with water fluoridation after adjustment for age, sex, ethnicity, area-level deprivation, and residual location.

Meaning Evidence suggests that community water fluoridation continues to be an efficacious upstream population-wide intervention associated with reduced severe caries rates among preschool children.

Methods

Study Design

This was a national, natural, cross-sectional geospatial study enabled by the existence of geographically dispersed local councils that each have the legal authority to fluoridate their water supplies or to choose not to exercise this authority. New Zealand's Health and Disability Ethics Committee defined this study as minimal-risk observational research not needing formal ethics committee review or further participant consent. Use of the B4SC data was approved by the Ministry of Health (MoH). No one received compensation or was offered any incentive for participating in this study.

Participants

The participants included New Zealand children aged 4 years who had their B4SC assessment between fiscal years (from July 1 to June 30) 2010 to 2011 through 2015 to 2016, inclusive. Children who were unable to be assigned to a CWF group, children who resided in areas having a CWF status change between 2011 and 2016, or children who had no oral health screening recorded were excluded.

Primary Measures

The B4SC captures various demographic and health measures, including a "lift the lip" oral health screen.[18,19] Conducted by trained registered nurses or nurse practitioners who were equipped with photographic reference examples, children's teeth are classified as (1) no visible caries; (2) chalky patches (enamel demineralization) and possible initial enamel breakdown on anterior teeth; (3) obvious caries between anterior teeth or along the gum line; (4) partial coronal breakdown of anterior teeth (as in teeth collapsing due to caries); (5) carious retained roots, with whole crowns of anterior teeth gone; or (6) severe caries including posterior teeth.[18] We used a classification similar to that previously described[5] and consistent with the American Academy of Pediatric Dentistry definition[20] to indicate severe caries experience for children classified with "lift the lip" categories 2 to 6.

Water fluoridation data for 2011 and 2016 were extracted by the Institute of Environmental Science and Research (ESR) from a drinking water database maintained on behalf of the MoH. This database captures public reticulated supplies; few (if any) private reticulated supplies are fluoridated. Geospatial data were not included in the database holdings. Fluoridated water supplies were mapped spatially and joined to city and locality shapefiles at the meshblock level. A meshblock is the smallest geographic unit for which statistical data are collected and processed by Statistics New Zealand; in 2013, New Zealand was partitioned into 46 637 such units (typically populated by 60-110 people).[21] This mapping provided a geographical boundary area that was fluoridated or not for New Zealand in 2011 and 2016. Meshblocks were identified in the ArcGIS geographic information system software (Environmental Systems Research Institute) if they intersected with the localities that were listed as fluoridated. Population-weighted centroids for meshblocks were identified within the fluoridated areas using ArcGIS if the meshblock centroid was completely within the area defined as fluoridated.

Sociodemographic Variables

All sociodemographic variables were derived from the B4SC data set. Sex was categorized as girls and boys. Age (in months) was calculated from B4SC assessment and birth dates. Ethnicity was based on parental or caregiver report, which allows for multiple identifications. Using the ethnicity protocols of the MoH, children with multiple identifications were assigned a single ethnicity via the prioritization hierarchy: (1) Māori; (2) Pasifika; (3) Asian; (4) Middle Eastern, Latin American, and African; and (5) European/other.[22] A meshblock-defined level of deprivation was measured using the New Zealand Deprivation Index 2013 (NZDep2013)[23] and based on the child's recorded residential address at their B4SC assessment. The NZDep2013 combines 2013 census data relating to income, home ownership, employment, qualifications, family structure, housing, access to transport, and communications into a single measure. Each meshblock is assigned a score from 1 (least deprived) to 10 (most deprived) based on decile splits. Quintiles were used here, as is commonly used.[24] Residential location was derived from the New Zealand standard classification: (1) main urban (≥30 000 people); (2) secondary urban (10 000-29 999 people); (3) minor urban (1000-9999 people); (4) rural center (300-999 people); and (5) other rural.[25]

Procedure

A detailed description of B4SC procedures appears elsewhere.[18] In brief, after receiving informed written consent, B4SC assessments are conducted in various locations—depending on community needs—and normally takes 45 to 60 minutes to complete. If concerns are identified, the child and their parents or caregivers are offered information and support, which include clinical pathways and referral processes. Held by the MoH, the B4SC National Information System stores data relating to the child, permission, assessments and checks, and any issues identified and referrals made. This system is designed to provide nonidentifiable information for monitoring the performance of the B4SC program, for tracking the population health status of 4-year-old children, and for approved research studies.[18] After application and approval, anonymous unit record data were released for the variables above, together with the meshblock corresponding to each child's recorded residential address at their B4SC assessment. These data were deterministically matched by meshblock to the ESR-sourced CWF status file for 2011 and 2016.

Statistical Analysis

Reporting of analyses followed the Reporting of Studies Conducted Using Observational Routinely-Collected Health Data (RECORD) guideline.[26] Fluoridation status at children's primary residential addresses in years 2011 and 2016 was described and concordance and agreement assessed using the Cohen κ statistic. Because children were nested in meshblocks, multilevel mixed-effects logistic regression models with robust Huber-White sandwich variance estimators were used with meshblock-level random intercepts. A main effects model was derived using a forward selection procedure that sequentially selected variables that minimized the Bayesian Information Criterion (BIC) and had a significant Ward Type III χ^2 statistic.[27] All 2-factor interaction combinations, including those with CWF status, were then sequentially added to this main effects model using the same selection criteria to derive the final model. Sensitivity analyses were conducted using chained equations multiple imputation (M = 50) methods for all variables in the adjusted model. Two scenarios were considered: (1) using participants in the B4SC data set who had a valid meshblock but who had been excluded due to residing in an area with changed CWF status or not having a "lift the lip" test recorded; and (2) using the full B4SC data set by assigning those with a missing or unmatched meshblock to a new miscellaneous category. Population attributional fractions were then ascertained for complete case and imputed results using the method introduced by Greenland and Drescher.[28] All analyses were performed using Stata SE, version 16.0 (StataCorp LLC), and a 2-tailed α = .05 defined statistical significance. Data were released in August 2019; statistical analysis was performed from September 2019 to December 2019.

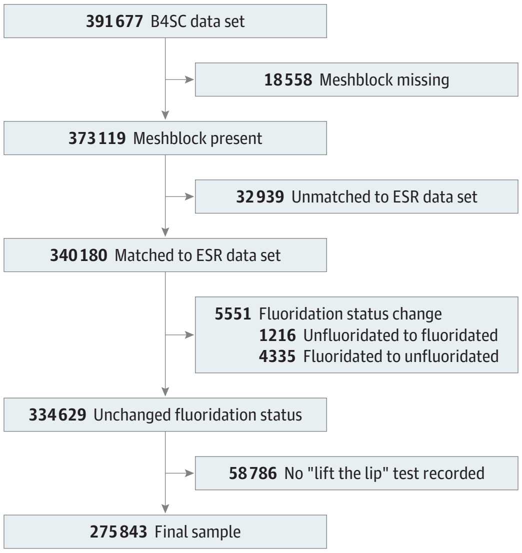
Results

Participants

The full B4SC data set contained information on 391 677 children, of whom 275 843 (70.4%) were matched to the ESR data set, resided in unchanged CWF areas, and had a "lift the lip" test undertaken and recorded (**Figure**). These 275 843 children defined the eligible sample.

The sociodemographic characteristics of children included in the eligible sample and excluded children are presented in **Table 1**. The eligible sample had a median age of 4.3 years (interquartile range, 4.1-4.6 years), and boys comprised 51.3%. European/other was the primary racial/ethnic identification for 54.3% of the sample, 24.9% of the sample lived in the most deprived quintile, and 73.5% of the sample were domiciled in main urban areas. For 149 233 children defined as European/other, only 2587 (1.7%) were originally identified as "other."

Figure. Participant Flowchart



B4SC represents B4 School Check; ESR, Environmental Science and Research.

Comparing children in the eligible sample to those excluded, there was no difference in sex (P = .37), but significant differences emerged in age, ethnic identification, NZDep2013, and residential location (all P < .001). For children excluded, their median age was 4.3 years (interquartile range, 4.1-4.6 years); 24.7% and 12.4% were Māori and Pasifika, respectively, compared with 23.2% and 10.5% of those included; 25.2% were in the most deprived quintile compared with 24.9% of those included; and 74.5% resided in a main urban area compared with 73.5% of those included.

CWF Status

The primary residential location meshblocks of 340 180 children in the B4SC data set that could be matched to the ESR file (Figure) were in CWF areas for 192 187 participants (56.5%) in 2011 and 189 068 participants (55.6%) in 2016. Concordance was high between years (κ = 0.97), with 187 852 addresses (55.2%) of the children within CWF areas in both years, 146 777 addresses (43.1%) within unfluoridated areas in both years, and the remaining 5551 addresses (1.6%) having a change in status. Specifically, 1216 children (0.4%) resided in areas that were unfluoridated in 2011 and fluoridated in 2016, whereas 4335 addresses of children (1.3%) were fluoridated in 2011 and unfluoridated in 2016. Given the negligible discordance in CWF status over time, only children with addresses in which CWF status was concordant between 2011 and 2016 were investigated. **Table 2** gives the sociodemographic distributions of the eligible sample, partitioned by CWF status. Clear differences emerged, with children living in fluoridated areas less likely to be European/other (69 308 [45.2%] vs 79 925 [65.7%]) and more likely to reside in the most deprived (44 036 [28.7%] vs 24 668 [20.2%]) and main urban areas (143 330 [93.3%] vs 59 294 [48.5%]) compared with their counterparts domiciled in unfluoridated areas.

Table 1. Sociodemographic Characteristics of 275 843 Children Included in the Eligible Sample and of 115 834 Excluded Children

	No. (%) of children	
Characteristic	Eligible children	Excluded children
Sex[a]		
Female	134 309 (48.7)	56 172 (48.5)
Male	141 451 (51.3)	59 535 (51.5)
Ethnicity[b]		
European or other	149 233 (54.3)	58 073 (50.5)
Māori	63 842 (23.2)	28 377 (24.7)
Pasifika	28 928 (10.5)	14 238 (12.4)
Asian	28 996 (10.5)	12 272 (10.7)
MELAA	3996 (1.5)	2115 (1.8)
NZDep2013[c]		
1 (Least deprived)	51 708 (18.8)	19 046 (19.6)
2	50 718 (18.4)	17 316 (17.8)
3	50 528 (18.3)	17 565 (18.1)
4	54 117 (19.6)	18 842 (19.4)
5 (Most deprived)	68 704 (24.9)	24 472 (25.2)
Residential location[d]		
Urban		
Main	202 624 (73.5)	47 910 (74.5)
Secondary	15 818 (5.7)	3266 (5.1)
Minor	22 006 (8.0)	5677 (8.8)
Rural center	4440 (1.6)	1131 (1.8)
Rural or remote	30 955 (11.2)	6353 (9.9)

Abbreviations: MELAA, Middle Eastern, Latin American, and African; NZDep2013, New Zealand Deprivation Index 2013.

[a] Values missing for 83 children (0.03%) in the eligible sample and 127 excluded children (0.1%).

[b] Values missing for 848 children (0.3%) in the eligible sample and 764 excluded children (0.7%).

[c] Values missing for 68 children (0.02%) in the eligible sample and 18 593 excluded children (16.1%).

[d] Values missing for 51 497 excluded children (44.5%).

Severe Dental Caries Experience

Overall, 41 360 four-year-old children (15.0%) in the eligible sample had evidence for severe dental caries experience. On a crude level and ignoring the different child profiles, 24 226 children (15.8%) in fluoridated areas had evidence for severe caries experience compared with 17 135 children (14.0%) in unfluoridated areas, suggesting that children residing in areas without fluoridation had odds of severe caries 0.93 times (95% CI, 0.90-0.95) that of those within fluoridated areas. However, in addition to differing CWF exposure patterns among children, differences emerged in severe caries experience rates in ethnic groupings, NZDep2013 levels, and residential locations (**Table 3**).

Adjusted Analyses

In developing the complete case (n = 274 604) main effects model, at step 1, ethnicity was added (BIC = 213 095.9) followed by NZDep2013 (BIC = 210 758.9), age (BIC = 209 864.5), sex (BIC = 209 826.5), and, at step 5, residential location (BIC = 209 813.8). All included variables were significantly associated with severe caries experience in this main-effects

Table 2. Sociodemographic Characteristics of the Eligible Children by Fluoridated (153 670 [55.7%]) and Unfluoridated (122 173 [44.3%]) Community Water Fluoridation Status Groupings

Characteristic	No. (%) of children	
	Fluoridated	Unfluoridated
Sex[a]		
Female	74 713 (48.6)	59 596 (48.8)
Male	78 908 (51.4)	62 543 (51.2)
Ethnicity[b]		
European or other	69 308 (45.2)	79 925 (65.7)
Māori	32 214 (21.0)	31 628 (26.0)
Pasifika	25 216 (16.5)	3712 (3.0)
Asian	23 427 (15.3)	5569 (4.6)
MELAA	3114 (2.0)	882 (0.7)
NZDep2013[c]		
1 (Least deprived)	28 345 (18.4)	23 363 (19.1)
2	25 488 (16.6)	25 230 (20.7)
3	26 034 (16.9)	24 494 (20.1)
4	29 739 (19.4)	24 378 (20.0)
5 (Most deprived)	44 036 (28.7)	24 668 (20.2)
Residential location		
Urban		
Main	143 330 (93.3)	59 294 (48.5)
Secondary	7286 (4.7)	8532 (7.0)
Minor	2198 (1.4)	19 808 (16.2)
Rural center	129 (0.1)	4311 (3.5)
Rural or remote	727 (0.5)	30 228 (24.7)

Abbreviations: MELAA, Middle Eastern, Latin American, and African; NZDep2013, New Zealand Deprivation Index 2013.

[a] Values missing for 49 children (0.03%) in the fluoridated group and 34 children (0.03%) in the unfluoridated group.

[b] Values missing for 391 children (0.3%) in the fluoridated group and 457 children (0.4%) in the unfluoridated group.

[c] Values missing for 28 children (0.02%) in the fluoridated group and 40 children (0.03%) in the unfluoridated group.

model (all $P < .001$). Next, all 2-factor interactions were considered. At step 1, the ethnicity × NZDep2013 interaction was added (BIC = 209 807.3); however, at step 2, no other 2-factor interaction resulted in a lower BIC, and model building terminated. This ethnicity × NZDep2013 interaction was significant ($P < .001$) and was thus included in the final model. **Table 4** presents the results from this final model and reveals that the adjusted odds of severe caries was 1.21 (95% CI, 1.17-1.24) for children in unfluoridated areas compared with those in fluoridated areas. The population attributional fraction of severe caries experience associated with unfluoridated community water was estimated as 5.6% (95% CI, 4.7%-6.6%).

Sensitivity Analyses

Chained equations multiple imputations were undertaken for missing data using the following: multinomial logistic regression for ethnic identification and residential location; ordered logistic regression for caries and NZDep2013; binary logistic regression for sex, CWF status in 2011, and CWF status in 2016; and linear regression for age. For the model in which participants had a valid meshblock (scenario 1, n = 340 180),

Table 3. Distribution of Severe Caries Status Across Sociodemographic Characteristics Among 275 843 Eligible Children

Characteristic	Severe caries indicated, No. (%)	
	Yes	No
Sex[a]		
Female	19 439 (14.5)	114 870 (85.5)
Male	21 900 (15.5)	119 551 (84.5)
Ethnicity[b]		
European or other	10 790 (7.2)	138 443 (92.8)
Māori	15 506 (24.3)	48 336 (75.7)
Pasifika	9112 (31.5)	19 816 (68.5)
Asian	5179 (17.9)	23 817 (82.1)
MELAA	663 (16.6)	3333 (83.4)
NZDep2013[c]		
1 (Least deprived)	3680 (7.1)	48 028 (92.9)
2	4584 (9.0)	46 134 (91.0)
3	5876 (11.6)	44 652 (88.4)
4	8660 (16.0)	45 457 (84.0)
5 (Most deprived)	18 555 (27.0)	50 149 (73.0)
Residential location		
Urban		
Main	31 082 (15.3)	171 542 (84.7)
Secondary	1961 (12.4)	13 857 (87.6)
Minor	4042 (18.4)	17 964 (81.6)
Rural center	781 (17.6)	3659 (82.4)
Rural or remote	3494 (11.3)	27 461 (88.7)

Abbreviations: MELAA, Middle Eastern, Latin American, and African; NZDep2013, New Zealand Deprivation Index 2013.

[a] Values missing for 83 children (0.03%).

[b] Values missing for 848 children (0.3%).

[c] Values missing for 68 children (0.02%).

the adjusted odds of severe caries was 1.19 (95% CI, 1.15-1.22) for those in unfluoridated areas compared with children in fluoridated areas, which results in an estimated population attributional fraction of 5.1% (95% CI, 4.3%-6.2%). By assigning participants with a missing meshblock to a new common miscellaneous category (scenario 2, n = 391 677), the model yielded an adjusted odds ratio of 1.15 (95% CI, 1.08-1.23) and associated population attributional fraction of 4.1% (95% CI, 2.2%-6.2%).

Discussion

In this national, contemporary, natural cross-sectional study, from crude analyses it appeared that caries rates were higher in CWF areas. However, when children's age, sex, ethnicity, area-level deprivation, and residential location were accounted for, significantly lower rates of caries were found among children living in CWF areas in both complete case and imputed analyses. This finding strongly underlines the necessity of applying apposite statistical methods, accounting for importantly differing factors. The population attributional fraction of severe caries experience associated with unfluoridated community water in complete case (and imputed) analy-

Table 4. Adjusted Odds Ratios and Associated 95% CIs From the Final Multivariable Model of Severe Caries Experience (n = 274 604)

Variable	AOR (95% CI)
Age, mo	1.051 (1.047-1.054)
Water fluoridation	
Yes	1 [Reference]
No	1.21 (1.17-1.24)
Sex	
Female	1 [Reference]
Male	1.09 (1.06-1.11)
Residential location	
Urban	
Main	1 [Reference]
Secondary	0.85 (0.80-0.91)
Minor	1.08 (1.03-1.14)
Rural center	1.05 (0.94-1.16)
Rural or remote	1.12 (1.06-1.17)
Ethnicity by NZDep2013	
European or other	
1 (Least deprived)	1 [Reference]
2	1.16 (1.08-1.24)
3	1.43 (1.33-1.52)
4	1.76 (1.65-1.89)
5 (Most deprived)	2.66 (2.48-2.86)
Māori	
1 (Least deprived)	2.43 (2.19-2.69)
2	3.08 (2.82-3.36)
3	4.04 (3.75-4.35)
4	5.37 (5.03-5.73)
5 (Most deprived)	8.32 (7.86-8.81)
Pasifika	
1 (Least deprived)	3.50 (2.91-4.20)
2	5.10 (4.47-5.80)
3	5.94 (5.33-6.62)
4	7.58 (6.99-8.22)
5 (Most deprived)	11.69 (10.99-12.43)
Asian	
1 (Least deprived)	3.59 (3.27-3.94)
2	4.19 (3.82-4.59)
3	4.21 (3.86-4.60)
4	4.63 (4.26-5.03)
5 (Most deprived)	5.60 (5.13-6.12)
MELAA	
1 (Least deprived)	2.29 (1.75-3.00)
2	2.60 (1.99-3.40)
3	2.89 (2.32-3.62)
4	4.63 (3.85-5.57)
5 (Most deprived)	6.45 (5.49-7.59)

Abbreviations: AOR, adjusted odds ratio; MELAA, Middle Eastern, Latin American, and African; NZDep2013, New Zealand Deprivation Index 2013.

ses were 5.6% (5.1% and 4.1%), indicating that approximately 1 in every 18 (20 and 24) children's caries experience could be attributed to a lack of CWF.

These findings inculcate those previously described. The latest New Zealand Oral Health Survey of 1431 children aged 2 to 17 years (987 of whom had dental examinations) conducted in 2009 revealed a reduction in dental decay of 40% attributed to CWF.[29] A representative Australian study of 10 599 children aged 5 to 8 years conducted in 2012 to 2014 found the adjusted, weighted primary dentition caries prevalence was 32.0% for those with full lifetime CWF exposure compared with 45.2% for those without any exposure.[30] Thus, even in this post-fluoride toothpaste availability era, the present near whole population-wide study and other studies provide evidence that CWF continues to be effective in reducing children's tooth decay.[14,15]

Despite the weight of this evidence, the polarized CWF debate continues, and often a vociferous minority have a disproportionate influence, using misinformation and rhetoric to induce doubts in the minds of the public and government officials.[31,32] A recent example occurred in Hamilton,[33] New Zealand's fourth most-populous city. Although New Zealand has a long-term national policy supporting CWF, there is no legislative requirement, and local authorities typically decide.[17] Thus, CWF implementation or continuance can be disrupted by a relatively small group of local constituents. Lobbied by antifluoridationists, in June 2013, Hamilton's City Councilors voted 7 to 1 in favor of halting CWF in their region. Widespread public debate ensued, culminating in a petition calling for a CWF referendum. A nonbinding referendum was held during the October 2013 local government elections, with 70% favoring CWF resumption. In March 2014, the council voted 9 to 1 in favor of recommencing fluoridation, which was duly enacted. This poses an important public policy consideration—should these critical decisions around oral health be subject to such ongoing public whims and political vagaries?

It must be acknowledged that there are practical limitations to CWF, with cost being one. While the cost of accurate continuous control is considerable, a benefit-cost analysis of CWF concluded that adding fluoride to New Zealand's water treatment plants supplying populations of more than 5000 people represents a cost savings and for those supplying more than 500 people it is likely to represent a cost savings, but for those plants supplying fewer than 500 people, it is harder to justify CWF on economic grounds.[34] However, in reducing inequity, decision makers might look beyond purely economic arguments.

Strengths and Limitations

This study has strengths and weaknesses. The near whole population–level contemporary study—with CWF exposure approximately equally split, availability of important confounding variables, and statistical treatment of the data, including the use of sensitivity analyses and adoption of the RECORD guideline—significantly strengthens the study's findings. Availability of unit-record data also mitigates possible ecological fallacy bias, a potential limitation noted in previous New Zealand research.[4] Primary weaknesses include both exposure and outcome measures and their temporal association. The CWF exposure was based on children's address at their B4SC assessment. A recent New Zealand birth cohort study reveals that, between birth and 2 years of age, 45% of children had moved at least once.[35] However, more than half moved fewer than 5 km from their previous home. Thus, most residentially mobile children are likely to maintain a constant CWF exposure status. Nonetheless, exposure misclassification will exist, serving to dampen the reported effect sizes. Severe caries experience was based on the "lift the lip" screenings. Although used before in research,[5] this screen has yet to be clinically validated. Owing to the study's cross-sectional design, children's prior fluoride exposure cannot be causally linked to their subsequent caries risk. Finally, oral health behaviors and other germane factors (such as diet) were unavailable, and these behaviors and factors may further affect the reported adjusted estimates.

Conclusions

The severe caries rates and levels of inequity observed here underscore modern dentistry's inability to combat New Zealand children's oral health needs,[6] particularly in the current neoliberal climate. Increasing proven upstream population-wide prevention initiatives and squarely tackling social and commercial determinants through evidence-based regulation and legislative changes have been advocated.[6] Although no panacea, accumulating evidence from the present study and elsewhere suggests that CWF should continue to form an integral part of any such strategy.

ARTICLE INFORMATION

Accepted for Publication: April 25, 2020.

Published Online: July 27, 2020. doi:10.1001/jamapediatrics.2020.2201

Author Contributions: Drs Schluter and Hobbs had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
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Administrative, technical, or material support: Schluter, Atkins, Mattingley, Lee.

Conflict of Interest Disclosures: None reported.

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