Investigation

Cross-sectional study of association between caries and fluoridated water among third-grade students in Pennsylvania

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ABSTRACT

Background. Caries is the most common chronic disease among children. In Pennsylvania, a comprehensive oral health Basic Screening Survey and assessment of the association between caries and community water fluoridation (CWF) among children have not been conducted.

Methods. From 2021 through 2022, the first Basic Screening Survey was conducted among third-grade students in Pennsylvania. Oral health and demographic data were collected. CWF data were provided by the Pennsylvania Department of Environmental Protection. The relative risk of developing caries in association with CWF was assessed using the GENMOD procedure in SAS, Version 9.4 (SAS Institute) in this cross-sectional study.

Results. Caries prevalence was 59.7% among 4,120 screened students. Participation in the free or reduced lunch program and CWF were each significantly associated with risk of developing caries after adjustment for age, sex, and race and ethnicity. The risk of developing caries was 33% higher among students who participated in the free or reduced lunch program than those who did not participate (relative risk, 1.33; 95% CI, 1.24 to 1.42). Students with the highest CWF coverage had a nearly 16% lower risk of developing caries than those without CWF coverage (relative risk, 0.84; 95% CI, 0.75 to 0.94).

Conclusions. CWF was significantly associated with a reduced risk of developing caries. Efforts are needed to increase CWF coverage, along with promotion of oral health education and healthy dietary habits among Pennsylvania children.

Practical Implications. Increasing CWF coverage will reduce caries burden among Pennsylvania children. Although Pennsylvania has no state laws to regulate CWF, these findings are persuasive for local municipalities to consider expanding CWF coverage.

Key Words. Caries; community water fluoridation; oral health; survey.

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Caries is the most common chronic disease among children in the United States.[1] It can cause various health issues, including pain and infections, which can lead to problems with eating, speaking, and learning. Children with caries are more likely to miss school and receive lower grades.[1] Caries occurs when foods containing sugar or other carbohydrates are consumed frequently or stay on the teeth for a prolonged period and, in combination with bacteria, acid, and saliva, form a plaque that adheres to the teeth. Over time, damage to the tooth enamel occurs and causes cavities in the teeth.[2] Nearly one-half of children aged 2 through 19 years in the United States have caries.[3] Black and Hispanic children are more likely to have caries than White children, and children from low-income households are twice as likely to have caries as children from high-income households.[4,5]

Numerous factors can affect the development of caries. Although good oral hygiene practices can prevent caries, unhealthy dietary habits, frequent snacking, and sugar-sweetened drink consumption increase the risk of developing caries.[6-8] In addition, oral health disparities according to race,

ethnicity, and socioeconomics have been observed. A higher prevalence of caries has been reported among children of racial and ethnic minority groups, such as non-Hispanic Black and Hispanic groups and among children in lower-income households.[4,9] The role of fluoride in relation to caries has been discussed widely, especially community water fluoridation (CWF) and products containing fluoride, such as toothpaste, mouthrinses, milk, and salt.[10-15] Fluoride was first added to a public water system in the United States in 1945,[16] and in 2020, nearly two-thirds of the US population received water that met fluoridation standards.[17] Several researchers have reported the beneficial effects of CWF on prevention of caries.[10,13,18,19] It is estimated that CWF can reduce caries by approximately 25%.[20]

In Pennsylvania, CWF was first adopted in Armstrong County in 1951, and many municipalities have since adopted water fluoridation to prevent caries.[21] Nearly three-fifths of the Pennsylvania population who use public water have access to fluoridated water. Although assessments of oral health and the association between caries and CWF among children have been conducted in other states and countries,[19,22-24] such an assessment has not been conducted in Pennsylvania. During the 2021-2022 school year, the first oral health Basic Screening Survey (BSS), funded by the Centers for Disease Control and Prevention and supported by the Association of State and Territorial Dental Directors (ASTDD), was conducted among a large sample of third-grade students in Pennsylvania. The objective of our study was to assess the association between the risk of developing caries and CWF among children in Pennsylvania. We hypothesized that children living in higher CWF coverage areas had a lower risk of developing caries.

METHODS

During the 2021-2022 school year, the Pennsylvania Department of Health (DOH), in collaboration with the Pennsylvania Coalition for Oral Health and the Pennsylvania Department of Education (PDE), conducted the first oral health BSS among third-grade students in Pennsylvania. Public schools, including charter schools, were selected to participate. With technical support from ASTDD, a statewide sample was drawn randomly, proportional to the school district size and stratified according to the geographic region, and weights were calculated on the basis of the number of students enrolled and the number of third-grade students screened in each school.[25] Similar to other states, this BSS included third-grade students only. The institutional review board at the Pennsylvania DOH approved the BSS.

Screening information was shared with school administrators and consent forms were distributed to parents. Parents could agree or decline to have their children participate. The BSS invitation was initially sent to 80 schools and 74 chose to participate, yielding a participation rate of 92.5%. For each school that participated, all third-grade students were screened, except those who were absent on the screening day or whose parents declined to let them participate. Ten public health dental hygiene practitioners and 2 certified school dental hygienists approved by the Pennsylvania DOH and the PDE conducted the oral health screenings. All screeners received 2 online training sessions from ASTDD. The curriculum was developed by ASTDD and Centers for Disease Control and Prevention. After the training, ASTDD conducted an evaluation for calibration to minimize inconsistencies among the screeners.

Four oral health indicators were assessed for each student by means of visual examination. These indicators were untreated caries, treated caries, dental sealant application on permanent molars, and dental treatment urgency. Untreated caries was defined as the observation of breakdown of the enamel surface, including pits, fissures, and smooth tooth surfaces. Treated caries was defined as the presence of any type of restoration, including a temporary restoration, or a tooth that was missing because it had been extracted as a result of caries. Dental sealant application was defined as the presence of at least 1 sealant on a permanent molar. Dental treatment urgency was the determination of how soon a treatment was needed.[26] As in previous studies,[10,19] the primary outcome variable was caries, defined as either untreated or treated caries. A survey form was designed to collect these 4 indicators and students' basic information, including school name and student identification number. PDE provided information on students' sex, date of birth, race and ethnicity, rural or urban location, and free or reduced lunch program status through matching the student identification number in the PDE database. In Pennsylvania, a county is rural if the number of people is fewer than 291 per square mile and a county is urban if the number of people is 291 or more per square mile.[27]

ABBREVIATION KEY

ASTDD: The Association of State and Territorial Dental Directors.
BSS: Basic Screening Survey.
CWF: Community water fluoridation.
NA: Not applicable.

The Pennsylvania Department of Environmental Protection provided the CWF data. For confidentiality, school locations rather than students' home locations were used to evaluate CWF. School addresses were geocoded and matched with the CWF coverage area by the water treatment facility. Because most students lived within a reasonable distance from the attending schools, a 5-mile radius from each school was used to evaluate the coverage area of CWF. ArcGIS software (ESRI) was used to calculate the coverage area for fluoridated and nonfluoridated water on the basis of the supply area of water facilities within the 5 miles. A CWF coverage percentage was calculated with the fluoridated water areas divided by the fluoridated and nonfluoridated water areas. The percentage ranged from 0% (fluoridated water was unavailable) through 100% (all community water was fluoridated).

In this cross-sectional study, areas without CWF were used as the reference group. In areas with CWF, the percentage of CWF coverage was categorized into tertiles to assess the association between CWF coverage and risk of developing caries. Relative risk (RR) was used to estimate the likelihood of caries. The GENMOD procedure in SAS, Version 9.4 (SAS Institute) was used to calculate the RR and the 95% CI as well as to test the trend of dose effect and interactions.[28,29] Age was calculated on the basis of date of birth and September 1, 2021. Age was grouped as 7 through 8 years and 9 through 11 years for data analysis. Age, sex, race and ethnicity, urban and rural location, and free or reduced lunch program status (as a surrogate for poverty) were treated as confounding factors. Race and ethnicity included non-Hispanic White, non-Hispanic Asian, non-Hispanic Black, Hispanic, and other, as defined in the PDE database. Interactions between CWF coverage and each of the confounding variables were tested using the GENMOD procedure in SAS, Version 9.4. Missing values for the following analytic variables were excluded from the analysis: age, sex, race and ethnicity, free or reduced lunch status, urban or rural location, CWF, or caries. SAS, Version 9.4 was used for all data analyses and ArcGIS software was used to calculate the CWF coverage area of each water facility. All analyses were weighted and significance was determined at P values less than .05. All percentages reported in the article were based on the weighted analyses. With weighted analyses, the survey sample was representative of all third-grade students in public schools, including charter schools, in Pennsylvania during the 2021 through 2022 school year.

RESULTS

Among 6,058 third-grade students in the 74 schools, 4,234 (69.9%) participated in the BSS. Of the 1,824 students (30.1%) who did not participate, 1,364 had parents who declined to let them participate and 460 were absent on the screening day. Through matching of the student identification number, PDE provided information on sex, date of birth, race and ethnicity, rural or urban location, and free or reduced lunch program status for all 4,234 students. Among these 4,234 students, 114 (2.7%) were excluded from this study because of missing values. The remaining 4,120 students represented 30 of the 67 counties in Pennsylvania, including 15 urban counties and 15 rural counties. In the weighted analyses, the mean age of the screened students was 8.6 years, ranging from 7.4 through 10.7 years; 50.4% were boys, 49.6% were girls, 63.3% were non-Hispanic White, 15.5% were Hispanic, 9.2% were non-Hispanic Black, 8.7% were multiracial or other, and 3.2% were non-Hispanic Asian. Among the participating students, 49.8% were enrolled in free or reduced lunch programs and 69.8% lived in urban counties.

Prevalence of caries was 59.7% (95% CI, 56.6% to 62.8%) among third-grade students in Pennsylvania. Table 1 presents the prevalence of caries according to each of the characteristics of students. Older students had a slightly higher prevalence of caries than younger students (60.8% vs 58.6%; $P = .27$). Prevalence was close between male and female students (59.3% vs 60.2%; $P = .61$), and prevalence was lower among non-Hispanic White students (57.0%) than racial and ethnic minority students (66.2% for non-Hispanic Asian students, 65.1% for non-Hispanic Black students, 64.8% for Hispanic students, and 62.5% for other racial and ethnic minority students). Prevalence was significantly higher among students who participated in the free or reduced lunch program than among students who did not participate (68.3% vs 51.3%; $P < .0001$). Prevalence was equivalent between students living in rural and urban areas (60.3% vs 59.5%; $P = .81$). Prevalence was higher among students who lived in areas without CWF (63.2%) than among students who lived in areas with CWF, although the difference was not statistically significant ($P = .26$, unadjusted analysis).

Table 2 presents the CWF coverage according to each of the characteristics of students separately. The coverage did not differ among students classified according to age and sex. The coverage

Table 1. Student characteristics according to presence of caries in Pennsylvania, 2021-2022.

CHARACTERISTIC*	CARIES	NO CARIES	WEIGHTED *P* VALUE
Age, Y			
7-8, unweighted no. (weighted %)	1,127 (58.6)	790 (41.4)	.27
9-11, unweighted no. (weighted %)	1,378 (60.8)	850 (39.2)	
Total no.	2,505	1,640	
Sex			
Male, unweighted no. (weighted %)	1,245 (59.3)	846 (40.7)	.61
Female, unweighted no. (weighted %)	1,260 (60.2)	794 (39.8)	
Total no.	2,505	1,640	
Race and Ethnicity			
Non-Hispanic White, unweighted no. (weighted %)	1,458 (57.0)	1,101 (43.0)	.01
Non-Hispanic Asian, unweighted no. (weighted %)	96 (66.2)	50 (33.8)	
Non-Hispanic Black, unweighted no. (weighted %)	271 (65.1)	142 (34.9)	
Hispanic, unweighted no. (weighted %)	522 (64.8)	263 (35.2)	
Other, unweighted no. (weighted %)	188 (62.5)	105 (37.5)	
Total no.	2,535	1,661	
Free or Reduced Lunch			
No, unweighted no. (weighted %)	1,055 (51.3)	976 (48.7)	< .0001
Yes, unweighted no. (weighted %)	1,450 (68.3)	664 (31.7)	
Total no.	2,505	1,640	
Location			
Rural, unweighted no. (weighted %)	683 (60.3)	463 (39.7)	.81
Urban, unweighted no. (weighted %)	1,852 (59.5)	1,198 (40.5)	
Total no.	2,535	1,661	
Community Water Fluoridation Coverage			
No, unweighted no. (weighted %)	1,035 (63.2)	629 (36.8)	.26
< 33%, unweighted no. (weighted %)	487 (59.9)	336 (40.1)	
33%-66%, unweighted no. (weighted %)	544 (55.7)	358 (44.3)	
> 66%, unweighted no. (weighted %)	469 (56.8)	338 (43.2)	
Total no.	2,535	1,661	

* Each of the characteristics and fluoridated water coverage were assessed separately.

differed significantly among students according to race and ethnicity. The percentages of students living in an area without CWF were as follows: 65.8% among other racial and ethnic minority students, 42.7% among non-Hispanic White students, 33.1% among non-Hispanic Black students, 28.9% among Hispanic students, and 14.1% among non-Hispanic Asian students. Although the proportion of students living in an area without CWF was equivalent among students participating or not participating in the free or reduced lunch program, the proportion differed in areas classified according to the CWF tertiles ($P = .03$). According to urban or rural location, 56.5% of students in rural areas had no CWF compared with 33.9% of students in urban areas ($P = .06$).

In Pennsylvania, 3,501 public water facilities submitted data to the Pennsylvania Department of Environmental Protection. These facilities provide water to approximately 79% of the Pennsylvania population. The remaining 21% of the population may use private water sources. The 3,501 water facilities included 1,046 that fluoridated water and 2,455 that did not fluoridate water. Among the population served by public water, approximately 60% use fluoridated water. For the areas where the 74 schools were located, 350 facilities provided water, which included 117 facilities with fluoride treatment and 233 facilities without fluoride treatment. Of the 74 schools, 45 had fluoridated water within 5 miles and 29 had no fluoridated water within the 5-mile area. Among the 45 schools with fluoridated water, the mean percentage of fluoridated water area within 5 miles was 87.4%, ranging from 5.0% through 100.0%.

Table 2. Student characteristics according to fluoridated water coverage in Pennsylvania, 2021-2022.

CHARACTERISTIC*	FLUORIDATED WATER COVERAGE				WEIGHTED *P* VALUE
	No	<33%	33%-66%	>66%	
Age, Y					
7-8, unweighted no. (weighted %)	749 (39.9)	369 (16.9)	432 (21.4)	367 (21.9)	.24
9-11, unweighted no. (weighted %)	864 (37.9)	454 (18.3)	470 (19.9)	440 (24.0)	
Total no.	1,613	823	902	807	
Sex					
Male, unweighted no. (weighted %)	833 (39.4)	412 (17.0)	432 (20.2)	414 (23.3)	.68
Female, unweighted no. (weighted %)	780 (38.2)	411 (18.2)	470 (20.9)	393 (22.7)	
Total no.	1,613	823	902	807	
Race and Ethnicity					
Non-Hispanic White, unweighted no. (weighted %)	1,150 (42.7)	603 (19.96)	414 (19.3)	392 (18.2)	<.0001
Non-Hispanic Asian, unweighted no. (weighted %)	23 (14.1)	68 (38.7)	6 (3.8)	49 (43.4)	
Non-Hispanic Black, unweighted no. (weighted %)	130 (33.1)	75 (18.7)	85 (16.6)	123 (31.6)	
Hispanic, unweighted no. (weighted %)	197 (28.9)	35 (4.2)	373 (35.8)	180 (31.1)	
Other, unweighted no. (weighted %)	164 (65.8)	42 (9.5)	24 (5.7)	63 (18.9)	
Total no.	1,664	823	902	807	
Free/Reduced Lunch					
No, unweighted no. (weighted %)	775 (38.1)	576 (23.4)	374 (19.6)	306 (19.0)	.03
Yes, unweighted no. (weighted %)	838 (39.6)	247 (11.8)	528 (21.5)	501 (27.1)	
Total no.	1,613	823	902	807	
Location					
Rural, unweighted no. (weighted %)	747 (56.5)	55 (4.3)	199 (21.7)	145 (17.4)	.06
Urban, unweighted no. (weighted %)	917 (33.9)	768 (22.5)	703 (19.1)	662 (24.4)	
Total no.	1,664	823	902	807	

* Each of the characteristics and fluoridated water coverage were assessed separately.

Table 3 presents the results of the unadjusted analysis and multivariable analysis, which included age, sex, race and ethnicity, free or reduced lunch program, urban or rural location, and CWF coverage. In the multivariable analysis, age, sex, and urban or rural location were not significantly associated with the risk of developing caries. According to race and ethnicity, the risk was significantly higher among non-Hispanic Asian students than non-Hispanic White students (RR, 1.16; 95% CI, 1.02 to 1.31; $P = .02$), but the risk was not significantly higher for the other racial and ethnic minority groups. Students who participated in the free or reduced lunch program had a significantly higher risk than students who did not participate (RR, 1.33; 95% CI, 1.24 to 1.42; $P < .0001$). After confounding variable adjustment, higher CWF coverages were significantly associated with a lower risk of developing caries (RR, 0.86; 95% CI, 0.74 to 0.99 for 33% through 66% CWF coverage; $P = .03$; RR, 0.84; 95% CI, 0.75 to 0.94 for >66% CWF coverage; $P = .002$). Trend test indicated that there was a significant dose effect for the tertiles of CWF coverage in association with the risk of developing caries (P value for trend $< .0001$). Interaction tests did not identify significant interactions between CWF coverage and covariates on the risk of developing caries.

DISCUSSION

We found that higher levels of CWF were associated with reduced prevalence of caries, consistent with findings from previous studies.[11,18,19,30] In the United States, fluoride was first introduced to public water systems in 1945[16]; ever since, the association between CWF and lower prevalence of caries has been observed in the United States and other countries.[10,13,19] These findings led to the expansion of fluoridation programs in many countries as well as fluoridated products, such as toothpaste, mouthrinses, milk, and salt.[10-15] Data continue to support the role of CWF in the prevention of caries. In a large cross-sectional study published in 2018, Slade and colleagues[19] reported that the

Table 3. Weighted crude and adjusted risk of caries among third-grade students in Pennsylvania, 2021-2022.

VARIABLE	CARIES, UNWEIGHTED NO. (WEIGHTED %)		CRUDE RELATIVE RISK (95% CI)	ADJUSTED RELATIVE RISK (95% CI)
	Yes	No		
Age, Y				
7-8	1,127 (58.6)	790 (41.4)	1.00	1.00
9-11	1,378 (60.8)	850 (39.2)	1.04 (0.97 to 1.11)	1.04 (0.98 to 1.10)
Sex				
Male	1,245 (59.3)	846 (40.7)	1.00	1.00
Female	1,260 (60.2)	794 (39.8)	1.02 (0.96 to 1.07)	1.01 (0.96 to 1.06)
Race and Ethnicity				
Non-Hispanic White	1,458 (57.0)	1,101 (43.0)	1.00	1.00
Non-Hispanic Asian	96 (66.2)	50 (33.8)	1.16 (1.01 to 1.34)	1.16 (1.02 to 1.31)
Non-Hispanic Black	271 (65.1)	142 (34.9)	1.14 (1.02 to 1.27)	1.04 (0.93 to 1.15)
Hispanic	522 (64.8)	263 (35.2)	1.14 (1.03 to 1.26)	1.06 (0.97 to 1.17)
Other	188 (62.5)	105 (37.5)	1.10 (1.00 to 1.21)	1.08 (0.98 to 1.19)
Free or Reduced Lunch				
No	1,055 (51.3)	976 (48.7)	1.00	1.00
Yes	1,450 (68.3)	664 (31.7)	1.33 (1.23 to 1.44)	1.33 (1.24 to 1.42)
Location				
Rural	683 (60.3)	463 (39.7)	1.00	1.00
Urban	1,852 (59.5)	1,198 (40.5)	0.99 (0.89 to 1.10)	1.01 (0.91 to 1.12)
Community Water Fluoridation Coverage				
No	1,035 (63.2)	629 (36.8)	1.00	1.00
<33%	487 (59.9)	336 (40.1)	0.95 (0.81 to 1.11)	0.96 (0.84 to 1.11)
33%-66%	544 (55.7)	358 (44.3)	0.88 (0.74 to 1.04)	0.86 (0.74 to 0.99)
>66%	469 (56.8)	338 (43.2)	0.89 (0.80 to 1.01)	0.84 (0.75 to 0.94)
***P* Value for Trend**	NA*	NA	NA	<.0001

* NA: Not applicable.

prevalence of caries among children was inversely related to the percentage of the population with CWF. A 2022 British report[18] found that CWF was inversely associated with caries and related hospitalizations. Findings from our study showed that students living in CWF areas had a lower risk of developing caries and CWF coverage had a dose effect in the protection against caries.

Pennsylvania is the fifth largest US state in population; most of the population lives in urban areas, where the dentist workforce is larger than in rural areas.[31] Slightly more than three-quarters of the Pennsylvania population use community water and fewer than two-thirds of this population have access to CWF. This means only one-half of the Pennsylvania population receives fluoridated water. The naturally occurring fluoride levels in the groundwater supplies in Pennsylvania range from nondetectable to approximately 0.2 mg/L, lower than the recommended 0.7 mg/L in CWF. The occurrence of fluoride in surface water is likely nondetectable, but trace levels can exist.[32] Thus, residents who consume private water are not likely to benefit from fluoride. Pennsylvania ranks 37th in the country in providing CWF to its residents,[33] and the coverage is lower than the 77.1% Healthy People 2030 objective.[34] Given an estimated 25% reduction in caries with CWF,[33] if Pennsylvania achieves the Healthy People 2030 objective, caries may be prevented among one-quarter million school-aged children in Pennsylvania. The prevalence of caries in Pennsylvania was approximately 10% higher than the national level among children of similar ages.[3] The higher prevalence indicates that there are gaps in Pennsylvania in caries prevention. In addition to the expansion of oral health education and preventive oral health care services, increasing CWF would be an effective strategy in ultimately reducing the burden of caries.

Seventeen states have laws intended to provide CWF to prevent caries,[35] but Pennsylvania is among those states without such laws. In Pennsylvania, each municipality determines whether the local community water should be fluoridated. Numerous cities and communities have enacted policies to ensure that the community water is fluoridated to the optimal level.[36] However, CWF coverage is still low in Pennsylvania. The lack of state laws and concerns about the potential toxicity of fluoride might be among the reasons why CWF coverage is low in Pennsylvania.[37-40]

There are several limitations in our study. First, student addresses were unavailable for the CWF assessment. Because school addresses were used, all students attending the same school were assigned the same CWF exposure. Misclassifications might occur if some students did not have access to CWF at their home addresses. Second, CWF was assessed as a percentage of CWF areas over the total areas with and without CWF. A better CWF measurement was the percentage of population or households with CWF, but such data were not available in this study. Third, the assumption that most students living within 5 miles of the school might miss some CWF areas because it is likely that some students might live outside the 5 mile area. However, because the percentage of CWF coverage was calculated on the basis of CWF coverage and non-CWF coverage, missing some water facilities should have little impact on the results. In addition, because students were not interviewed for their oral health practices, food, and dietary habits, or use of preventive oral health care services, these factors could not be evaluated. Moreover, information on student oral health care insurance was not available. The availability of this information would allow for the adjustment of the potential use of preventive oral health care in the data analysis. Furthermore, the actual CWF exposure for each student was not available, therefore, the risk assessment was based on the assumption that a student living in a higher CWF coverage area also had higher CWF exposure. As a result, the risk assessment of caries was of an ecological nature.

CONCLUSIONS

The prevalence of caries was high among Pennsylvanian children. CWF had a protective effect as well as a dose effect against caries, which adds to the existing evidence to support the expansion of CWF coverage in Pennsylvania. In addition, oral health education is needed for children and their families at schools and pediatric and dental clinics to improve personal oral hygiene practices and promote healthy dietary habits among children. ■

DISCLOSURE

None of the authors reported any disclosures.

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1. Oral health tips for children. Centers for Disease Control and Prevention. May 15, 2024. Accessed May 29, 2024. https://www.cdc.gov/oral-health/prevention/oral-health-tips-for-children.html?CDC_AAref_Val=https://www.cdc.gov/oralhealth/basics/childrens-oral-health/index.html

2. Tooth decay (caries or cavities) in children. Children's Hospital of Philadelphia. Accessed January 26, 2024. https://www.chop.edu/conditions-diseases/tooth-decay-caries-or-cavities-children

3. Fleming E, Afful J. Prevalence of total and untreated dental caries among youth: United States, 2015-2016. *NCHS Data Brief*. 2018;(307):1-8.

4. Choi SE, White J, Mertz E, Normand SL. Analysis of race and ethnicity, socioeconomic factors, and tooth decay among US children. *JAMA Netw Open*. 2023;6(6):e2318425. doi:10.1001/jamanetworkopen.2023.18425

5. Vasireddy D, Sathiyakumar T, Mondal S, Sur S. Socioeconomic factors associated with the risk and prevalence of dental caries and dental treatment trends in children: a cross-sectional analysis of National Survey of Children's Health (NSCH) Data, 2016-2019. *Cureus*. 2021;13(11):e19184. doi:10.7759/cureus.19184

6. Chi DL, Scott JM. Added sugar and dental caries in children: a scientific update and future steps. *Dent Clin North Am*. 2019;63(1):17-33.

7. Hong J, Whelton H, Douglas G, Kang J. Consumption frequency of added sugars and UK children's dental caries. *Community Dent Oral Epidemiol*. 2018;46(5):457-464.

8. Shetty A. Significance of sugar intake in young adults: a review. *Int J Adolesc Med Health*. 2021;33(6):375-378.

9. Oral health surveillance report: trends in dental caries and sealants, tooth retention, and edentulism, United States, 1999–2004 to 2011–2016. Centers for Disease Control and Prevention, US Dept of Health and Human Services. 2019. Accessed January 26, 2024. https://www.cdc.gov/oral-health/media/pdfs/Oral-Health-Surveillance-Report-2019-h.pdf

10. Pollick H. The role of fluoride in the prevention of tooth decay. *Pediatr Clin North Am*. 2018;65(5):923-940.

11. ten Cate JM. Contemporary perspective on the use of fluoride products in caries prevention. *Br Dent J*. 2013;214(4):161-167.

12. Griffin SO, Regnier E, Griffin PM, Huntley V. Effectiveness of fluoride in preventing caries in adults. *J Dent Res*. 2007;86(5):410-415.

13. O'Mullane DM, Baez RJ, Jones S, et al. Fluoride and oral health. *Community Dent Health*. 2016;33(2):69-99.

14. Whelton HP, Spencer AJ, Do LG, Rugg-Gunn AJ. Fluoride revolution and dental caries: evolution of policies for global use. *J Dent Res*. 2019;98(8):837-846.

15. Rugg-Gunn A, Banoczy J. Fluoride toothpastes and fluoride mouthrinses for home use. *Acta Med Acad*. 2013;42(2):168-178.

16. The story of fluoridation. National Institute of Dental and Craniofacial Research, National Institutes of Health. Accessed January 26, 2024. https://www.nidcr.nih.gov/health-info/fluoride/the-story-of-fluoridation

17. Hung M, Mohajeri A, Chiang J, et al. Community water fluoridation in focus: a comprehensive look at fluoridation levels across America. *Int J Environ Res Public Health*. 2023;20(23):7100.

18. Water Fluoridation: Health Monitoring Report for England 2022. Office for Health Improvement and Disparities. 2022. Accessed May 30, 2024. https://assets.publishing.service.gov.uk/media/622ee4518fa8f56c1d3113dd/water-fluoridation-health-monitoring-report-2022.pdf

19. Slade GD, Grider WB, Maas WR, Sanders AE. Water fluoridation and dental caries in U.S. children and adolescents. *J Dent Res*. 2018;97(10):1122-1128.

20. Community water fluoridation. Centers for Disease Control and Prevention. Accessed January 27, 2024. https://www.cdc.gov/fluoridation/index.html

21. Fluoridation moves in state. ActionPA.org. Accessed February 15, 2024. https://www.actionpa.org/fluoride/pa1956.html

22. Meyer J, Margaritis V, Jacob M. The impact of water fluoridation on Medicaid-eligible children and adolescents in Alaska. *J Prev*. 2022;43(1):111-123.

23. Bomfim RA, Watt RG, Tsakos G, Heilmann A, Frazao P. Does water fluoridation influence ethnic inequalities in caries in Brazilian children and adolescents? *Community Dent Oral Epidemiol*. 2022;50(4):321-332.

24. Schluter PJ, Hobbs M, Atkins H, Mattingley B, Lee M. Association between community water fluoridation and severe dental caries experience in 4-year-old New Zealand children. *JAMA Pediatr*. 2020;174(10):969-976.

25. ASTDD Basic Screening Surveys. The Association of State and Territorial Dental Directors. Accessed March 16, 2024. https://www.astdd.org/basic-screening-survey-tool/

26. Basic Screening Surveys: an approach to monitoring community oral health—preschool & school children. Association of State and Territorial Dental Directors. Accessed April 19, 2024. https://www.azdhs.gov/documents/prevention/womens-childrens-health/oral-health/infant-youth/ASTDD-BSS-manual.pdf

27. Rural-urban maps. Center for Rural Pennsylvania. Accessed March 18, 2024. https://www.rural.palegislature.us/demographics_rural_urban.html

28. McClintock S, Ma ZQ, Rieger RH. Incorrect inference in prevalence trend analysis due to misuse of the odds ratio. *Ann Epidemiol*. 2016;26(2):136-140.

29. Usage note 23003: estimating a relative risk (also called risk ratio, prevalence ratio). SAS Institute. Accessed April 10, 2024. https://support.sas.com/kb/23/003.html

30. Sanders AE, Grider WB, Maas WR, Curiel JA, Slade GD. Association between water fluoridation and income-related dental caries of US children and adolescents. *JAMA Pediatr*. 2019;173(3):288-290.

31. Pennsylvania Department of Health. *2021 Pennsylvania's Dentist and Dental Hygienist Workforce Survey Report*. Pennsylvania Department of Health; 2023.

32. Water quality FAQs. Pennsylvania American Water. Accessed May 16, 2024. https://amwater.com/paaw/water-quality/water-quality-faqs

33. Centers for Disease Control and Prevention. Community water fluoridation: 2020 water fluoridation statistics. Accessed May 29, 2024. https://www.cdc.gov/fluoridation/php/statistics/2020-water-fluoridation-statistics.html?CDC_AAref_Val=https://www.cdc.gov/fluoridation/statistics/2020stats.htm

34. Healthy People 2030. US Department of Health and Human Services. Accessed January 31, 2024. https://health.gov/healthypeople

35. Mandatory fluoridation in the U.S. Fluoride Action Network. December 13, 2019. Accessed January 31, 2024. https://fluoridealert.org/content/mandatory-fluoridation-in-the-u-s

36. Pennsylvania Department of Environmental Protection. *Community Water Fluoridation: A Plan for Pennsylvania*. Pennsylvania Department of Environmental Protection; 2020.

37. Water fluoridation in Pennsylvania. ActionPA.org. Accessed January 31, 2024. https://www.actionpa.org/fluoride

38. Guth S, Huser S, Roth A, et al. Toxicity of fluoride: critical evaluation of evidence for human developmental neurotoxicity in epidemiological studies, animal experiments and in vitro analyses. *Arch Toxicol*. 2020;94(5):1375-1415.

39. Vieira AR. Fluoride toxicity. *Monogr Oral Sci*. 2021;30:140-148.

40. Aoun A, Darwiche F, Al Hayek S, Doumit J. The fluoride debate: the pros and cons of fluoridation. *Prev Nutr Food Sci*. 2018;23(3):171-180.