Water Fluoridation and Dental Health Indicators in Rural and Urban Areas of the United States

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Executive Summary

Background: Water fluoridation is recognized as one of the most successful public health interventions ever enacted in the United States. An adequate level of fluoride in public drinking water is an effective, safe and inexpensive method to reduce dental caries, especially in children. Rural populations are more likely than urban counterparts to rely on untreated domestic wells that are unflouridated, and not all public water systems have adequate fluoridation, raising the possibility that rural populations are less likely to be protected against dental caries. This study investigated the availability of fluoridated water across urban-rural settings, and relates measures of fluoride availability to national survey measures of dental health in adults and children.

Methods: Fluoridation data were drawn from the CDC's "My Water's Fluoride" database. Dental health outcome data came from Behavioral Risk Factor Surveillance System (BRFSS) survey data for adults, and National Survey of Children's Health (NSCH) data for children. Other variables were measured from the Area Resource File. Rural-urban areas were defined at the county level using US Department of Agriculture urban influence codes; these codes were used to designate counties as metropolitan, micropolitan, or non-core.

Results: Results show that the proportion of populations with adequate public drinking water fluoridation levels were significantly higher in metropolitan areas (72.6% of the population), intermediate in micropolitan areas (67.7%), and lowest in non-core rural areas (61.2%). Greater levels of access to fluoridation were related to better dental health measures in urban areas for adults. However, in non-metropolitan or non-core areas, measures of adult or child dental health were not significantly related to fluoridation rates after controlling for other risks. Populations in rural areas, compared to urban areas, have access to fewer dentists per capita and are more likely to experience delays in receiving dental care, or to go without dental care. Children in rural areas may be at increased risk for inadequate preventive dental care compared to urban children. Adults in rural areas are at greater risk than urban adults to experience tooth loss.

Conclusions: Results suggest the need to improve access to adequately fluoridated public water for rural populations. Where rural families rely on unfluoridated well water, education programs to encourage safe levels of topical fluoride use may be valuable. Policies

to improve access to dental care in rural areas are also indicated by the results. Appropriate policy responses may include efforts to improve dental health insurance coverage, and to improve the supply of dentists practicing in rural areas. This may be accomplished through loan repayment programs or other strategies to encourage dentists to practice in rural areas, or improving reimbursement levels for dentists to treat children on public assistance programs such as Medicaid. Other policy initiatives may include programs to encourage pediatricians and family physicians at wellness visits to refer infants to a dental home at the eruption of the first tooth, expanding the Women, Infants and Children program to include a dental education component on brushing children’s teeth, and strengthening the Head Start program to allow caregivers to brush children’s teeth.

INTRODUCTION

Dental caries is the most common chronic disease among children. It is, for example, 5-8 times more common than asthma.[1] The main causes of tooth loss among adults are periodontitis and caries. Caries and tooth loss are important public health problems because of associated health care costs. In addition, caries results in pain, loss of tooth structure and function, reduced quality of life, and can lead to tooth loss and even acute systemic infection. There is also a possible connection between inflammation resulting from poor oral health and higher risk for other systemic diseases such as heart attack, stroke, diabetes, and hypertension.[2-3]

Water fluoridation is effective in preventing dental caries and promoting dental health, most clearly for children but also possibly for adults.[4-6] Water fluoridation at proper levels of 0.7 parts per million reduces the prevalence of caries significantly while not increasing levels of fluorosis.[7-8] One systematic research review found that fluoride resulted in a 29% decrease in cavity rate for children aged 4-17.[9] Public water fluoridation is highly cost effective, at an estimated cost of $0.40 per person per year in larger water systems serving 20,000 people or more, and $2.70 per person per year in small water systems serving 5,000 or fewer people.[9] For every $1 in fluoridation, an estimated $38 is saved in treatment costs.[8] The benefits of fluoridation are such that the Centers for Disease Control and Prevention identified fluoridation of drinking water as one of the greatest public health achievements of the 20th century.[6]

Rural populations are more likely than urban populations to rely on domestic wells rather than treated water systems; 33% of people in rural counties use private wells, compared to 24% of people in urban counties.[10] Domestic wells are not treated with fluoride and usually do not contain protective levels of natural occurring fluoride. In addition, not all public water systems have adequate fluoridation, and smaller systems that are disproportionately present in rural areas may be at greater risk of not providing all indicated water treatments due to cost restrictions. These features raise the possibility that rural populations are less likely than urban populations to have adequate fluoride protection against dental caries. The current study investigates levels of population access to appropriate levels of water fluoridation in rural and urban areas of the United States, and investigates whether fluoridation rates (and other variables such as insurance status) in rural and urban areas are associated with better dental health indicators in adults and children.

Results of the study may help to inform policy decisions about improved water quality for rural populations, including the need for better access to public water that includes adequate fluoridation. The results may also suggest other important demographic or health services variables that deserve policy attention in efforts to improve dental health for rural populations.

METHODS

Hypotheses: Study hypotheses are: 1) Rural populations are more likely than urban populations to have inadequately fluoridated drinking water. 2) Inadequate fluoridation will be statistically associated with poorer dental health outcomes among both rural and urban adult and child populations.

Design and Rural-Urban Designations: A retrospective, cross-sectional design was used. Descriptive analyses were conducted to summarize study variables. Statistical comparisons were made between differences in the proportion of populations with access to fluoridated water in rural and urban settings. Then, dependent variables (e.g., adult tooth loss, caries in children) were statistically associated with adequate water fluoridation in the context of controlling for important covariates (e.g., age, race/ethnicity, dental health care, etc.)

The design includes comparative findings for rural and urban areas across several specifications of rural setting. Rural setting is defined using US Department of Agriculture urban-influence codes (UICs) to identify metropolitan (codes 1,2) and non-metropolitan (codes 3-12) areas.[11] Analyses also compared metropolitan (codes 1,2), micropolitan (codes 3,5,8) and non-core areas (codes 4,6,7, and 9-12), and summarized water fluoridation rates across all urban influence codes. Table 1 summarizes the urban influence codes used in this study.

Table 1: Urban Influence Codes

2003 Urban Influence Codes		
Code	**Description**	**Number of counties**
1	In large metro area of 1+ million residents	413
2	In small metro area of less than 1 million residents	676
3	Micropolitan area adjacent to large metro area	92
4	Noncore adjacent to large metro area	123
5	Micropolitan area adjacent to small metro area	301
6	Noncore adjacent to small metro area and contains a town of at least 2,500 residents	358
7	Noncore adjacent to small metro area and does not contain a town of at least 2,500 residents	185
8	Micropolitan area not adjacent to a metro area	282
9	Noncore adjacent to micro area and contains a town of at least 2,500 residents	201
10	Noncore adjacent to micro area and does not contain a town of at least 2,500 residents	198
11	Noncore not adjacent to metro or micro area and contains a town of at least 2,500 residents	138
12	Noncore not adjacent to metro or micro area and does not contain a town of at least 2,500 residents	174
Total U.S.		3,141

Data Sources and Independent Variables: Fluoridation data came from the Centers for Disease Control and Prevention (CDC) "My Water's Fluoride" database that includes information on the percent of the county population whose water is adequately fluoridated.[12] Adequate fluoridation is based on the CDC standard of 0.7 parts per million in drinking water. The fluoride may be naturally occurring or present as a result of supplementation by drinking water systems. The percent population covered is reported by the CDC as the number of people in the county served by water systems with adequate fluoridation divided by the total county population.

Health outcome data were drawn from the 2006 Behavioral Risk Factor Surveillance System (BRFSS) survey data for adults, and the 2007 National Survey of Children's Health (NSCH) for children. The BRFSS collects annual data from random-digit-dialing telephone surveys of the non-institutionalized U.S. civilian population aged 18 and over. Surveys are conducted in all states and the District of Columbia by state health departments in cooperation with the CDC, with a median response rate of 51%.[13] The 2006 survey was used for this study because the county of the respondent's residence was made publicly available for that year. The sample size for the BRFSS survey was 243,386.

The NSCH is sponsored by the Maternal and Child Health Bureau of the Health Resources and Services Administration.[14] The 2007 survey is the most recently available and included 86,544 completed telephone surveys regarding the health and well-being of children aged 0-17. The publicly available NSCH data do not identify the geographic location (i.e., the county) where the survey respondent lived. To access this variable, study investigators (Hendryx and Gurka) completed a data confidentiality training and traveled to the National Center for Health Statistics offices in Hyattsville, MD to access and analyze the data on-site.

Dependent Variables: From the NSCH, dental health problems for children were the outcomes of interest, and in particular the presence of caries. Presence of caries was measured by a "Yes" response to the question, "To the best of your knowledge, did [the selected child] have decayed teeth or cavities within the past 6 months?" Also used as a dependent variable was an item measuring the overall condition of the child's teeth, response options including "excellent", "very good", "good", "fair", or "poor"; for logistic regression analysis this item was dichotomized into "excellent" or "very good" versus "good", "fair", or "poor".

From the BRFSS, dental health problems for adults were the outcomes of interest. This was measured by an item that assessed tooth loss. Tooth loss was measured as the number of permanent teeth that have been removed over the lifetime as a result of tooth decay or gum disease (respondents were instructed not to include teeth lost to injury or orthodontics). This item was scored on the original BRFSS survey on a 4-point scale as follows: 4= all teeth lost; 3=more than 5 teeth but less than all; 2=1 to 5 teeth lost; 1=no teeth lost; for logistic analysis this time was dichotomized as any tooth loss (a score of 1 vs. 2, 3 or 4.)

Analysis: Data analyses included calculation of descriptive and inferential statistics. Rural-urban differences were calculated for dental health measures, water fluoridation differences, and differences in dental care measures. For analysis of Hypothesis 1, differences in rural-urban adequacy of fluoridation were tested using chi-square analyses, which include separate analyses for three definitions of rural setting as defined by urban influence codes: 1) metropolitan vs. non-metropolitan; 2) metropolitan vs. micropolitan vs. non-core; and 3) differences along all 12 categories of the urban influence codes.

For analysis of Hypothesis 2, separate analyses were conducted for adult and child specifications of dental health. The key independent variable was percent of the population with adequate water fluoridation. Key covariates include age of survey respondent (BRFSS) or age of child (NSCH), measures of dental health use, race/ethnicity, sex, education, income, adult smoking, Body Mass Index (BMI), alcohol consumption, diabetes co-morbidity, and rural-urban setting. These covariates were selected based on previous research that they are dental health risk factors. Smoking[15] and alcohol consumption[16] have been linked to poorer dental health, as has diabetes,[17] and obesity reflective of poorer nutritional habits such as foods with high sugar content.[18-19] Low education, low income, and racial minority status are linked to poorer dental health through socioeconomic differences in diet, access to dental care, and use of fluoride toothpaste.[20-21] Males relative to females are less likely to receive preventive dental care.[22] Exact covariates were not identical between the BRFSS and NSCH due to differences in specific items available from each survey.

Survey data were analyzed using SAS Proc Surveyfreq, Surveymean, or Surveylogistic to account for the population weights employed in the BRFSS and NSCH designs and for the complex survey designs. For children, the logistic regression analysis modeled the two dependent variables described above, first the odds of caries, and then the odds of "less than very good" condition of the teeth. The independent variables were fluoridation and covariates. These models included variables at the level of the child and family/household as well as variables on the county-level. NCHS covariates included information on the child's age and sex, race/ethnicity, health insurance (rated by the parent as absent, present but inadequate, or adequate), parent education (less than high school high school or more than high school), household income above or below poverty, a rating of whether necessary dental care had been delayed or not received, whether or not the household was non-English speaking, family structure (parents married versus any other structure), presence of adult smoking in the household, and number of dental visits in the last year. Measured at the county level were two additional covariates, percent population below poverty, and dentists per 1,000 population.

For adults, the analysis modeled the odds of the dependent variable of any tooth loss. The model included factors at the level of the adult as well as variables at the county-level.

BRFSS covariates included information on the respondent's age and sex, race/ethnicity, smoking status (current smoker yes or no), drinking status (none, moderate or heavy alcohol consumption [heavy is defined as more than 2 drinks per day for males and more than 1 drink per day for females per BRFSS guidelines]), married (yes or no), education (high school or less versus more than high school), household income less than $25,000 (yes or no), underweight, overweight or obese based on BMI, co-morbid diabetes (yes or no), presence or absence of health insurance, and receipt of a dental care visit within the last two years (yes or no). County level covariates included percent population below poverty, and dentists per 1,000 population.

In order to obtain parsimonious models, a backwards selection process was utilized, in which a full model is first fit, and then individual variables were removed in a stepwise fashion based on lack of significance. The final models only include variables whose p-values are less than 0.15. A p value of .15 is commonly employed for backward selection models as opposed to p values of .05 or .10 to identify the best subset of independent variables to retain in a model. Covariates significant at p<.15 can influence the significance of the primary test of interest (i.e., the p value for fluoridation and dental health) and so should be retained in final models even though the covariates themselves are not significant.[23] Two variables were deleted from the final models based on backward selection: underweight as measured by BMI on both the BRFSS and NSCH models, and marital status from the BRFSS model.

RESULTS

Hypothesis 1: Rural populations were significantly more likely than urban populations to have inadequately fluoridated drinking water. Hypothesis 1 was thus supported. The percent of the population with fluoridated public drinking water was 72.6% in metropolitan areas, and 63.3% in non-metropolitan areas (F=45.93, df=1, 3045, p<.0001).

Differences between metropolitan, micropolitan, and non-core areas were also significant (F=30.41, df=2, 3044, p<.0001) and post-hoc means tests to correct for Type I error showed that all three groups were significantly different from each other. These results are summarized in Table 2.

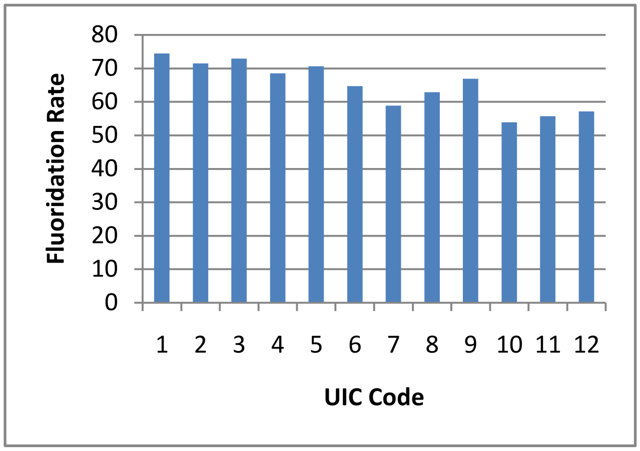
Table 2: The percent of the population with adequate fluoridation levels in metropolitan, micropolitan, and non-core counties.

	Metropolitan	Micropolitan	Non-Core
Number of counties	1035	655	1357
Percent of population with fluoridated water*	72.6	67.7	61.2

*F test comparing group means = 30.41; df=2, 3044; p<.0001.

Differences between fluoridation rates across all 12 urban-influence codes were also significant (F=9.06, df=11, 3035, p<.0001). Figure 1 summarizes these differences. There was a trend for declining fluoridation rates along the UIC continuum from most urban to most rural, although the effect is not monotonic. The lowest rates were found for UIC codes 10-12 which represent the most rural areas; for each of these codes, less than 60% of the population had access to adequately fluoridated water.

Figure 1: Fluoridation Rates across UICs



Hypothesis 2: Hypothesis 2 stated that lower fluoridation levels would be statistically associated with poorer dental health outcomes among both rural and urban populations for both adults and children. This hypothesis was supported for metropolitan counties but not for non-metropolitan, and then only for results for adults. Controlling for covariates, a greater degree of water fluoridation was related to lower risk of adult tooth loss in metropolitan counties (p<.003). However, when the model was run for non-metropolitan counties greater fluoridation was not statistically associated with dental health scores. The BRFSS model results for metropolitan and non-metropolitan counties are summarized in Table 3.

Table 3: Final BRFSS model results for effects of percent of population with fluoridated water on odds of adult tooth loss (yes/no) for metropolitan and non-metropolitan counties. Model values are odds ratios (OR) with 95% confidence intervals (95% CI).

	Metropolitan (N=161,494)		Non-metropolitan (N=39,423)	
	OR (95% CI)	P value	OR (95% CI)	P value
Percent with fluoridated water	0.999 (0.998, 0.999)	.016	1.001 (0.999, 1.002)	.08
Female	1.07 (1.02, 1.12)	.005	1.04 (0.97, 1.12)	.27
Non-smoker	0.49 (0.47, 0.51)	<.0001	0.48 (0.45, 0.52)	<.0001
Non-drinker	1.28 (1.21, 1.34)	<.0001	1.38 (1.26, 1.51)	<.0001
Heavy drinker	0.89 (0.81, 0.98)	.02	0.84 (0.72, 0.98)	.03
High school education or less	1.91 (1.81, 2.01)	<.0001	1.96 (1.76, 2.19)	<.0001
Household income <$25,000	1.54 (1.44, 1.65)	<.0001	1.60 (1.47, 1.74)	<.0001
African American	2.60 (2.42, 2.80)	<.0001	2.27 (1.98, 2.60)	<.0001
Asian American	1.84 (1.60, 2.12)	<.0001	1.10 (0.80, 1.51)	.57
Native American	1.76 (1.47, 2.10)	<.0001	1.62 (1.22, 2.14)	.0008
Hispanic	0.84 (0.67, 1.04)	.11	0.73 (0.53, 0.98)	.04
Health insurance	1.24 (1.15, 1.32)	<.0001	1.13 (0.98, 1.29)	.09
Age in years	1.061 (1.059, 1.062)	<.0001	1.062 (1.059, 1.064)	<.0001
Overweight or obese	1.26 (1.20, 1.32)	<.0001	1.15 (1.06, 1.25)	.001
County supply of dentists less than national median	1.12 (1.05, 1.19)	.001	1.26 (1.15, 1.39)	<.0001
Recent visit to a dentist	0.90 (0.85, 0.96)	.0004	0.78 (0.71, 0.85)	<.0001
Co-morbid diabetes	1.42 (1.30, 1.54)	<.0001	1.37 (1.21, 1.55)	<.0001

For children's dental health measures, it was found that fluoridation rates were not significantly related to the measures of either caries or overall condition of the teeth for urban or rural areas. The overall models for the two measures of children's dental health are summarized in Table 4 and 5.

Table 4 shows an interesting interaction between rural-urban status and number of dental visits. The table shows that for children in urban areas, having two or more visits to a dentist lowers the risk of dental caries. In other words, rural children with two or more dental visits have a higher risk of caries. Another way to phrase this is that the acuity level of children receiving care in rural areas is higher. (In contrast, this interaction was not significant for the measure of overall condition of the teeth and so was not included in the final Table 5 model.) A possible interpretation of these findings is that children in urban areas have better access to *preventive* dental care that reduces caries risk, whereas access to preventive care is worse in rural areas, leading to more dental visits for children after development of caries. Preventive care and education received at the dental office – e.g., education and instruction on the importance of brushing and flossing – affects the preventive behaviors that children and parents engage in at home, so that less preventive care at home may translate eventually into caries development and the need for dental visits for treatment rather than prevention.

Table 4: Final NSCH Logistic Model of Odds of Dental Caries among Children

Variables	Odds Ratio	95% CI	p-value[†]
Female	1.01	(0.93, 1.10)	0.7805
Age Category (vs. 1-5 years)			
6-11 years	1.83	(1.57, 2.13)	< 0.0001
12-17 years	1.30	(1.11, 1.51)	0.0009
Ethnicity (vs. Non-Hispanic White)			
Non-Hispanic Black	1.18	(1.03, 1.36)	0.0163
Hispanic	1.26	(1.07, 1.49)	0.0053
Other	1.28	(1.07, 1.52)	0.0058
Household Education (vs. More than HS)			
HS Degree	1.33	(1.19, 1.48)	< 0.0001
Less than HS	1.54	(1.30, 1.83)	< 0.0001
Insurance Status (vs. Adequate Insurance)			
Inadequate	1.14	(1.01, 1.29)	0.0296
Uninsured	1.35	(1.17, 1.55)	< 0.0001
Under the Federal Poverty Line	1.37	(1.21, 1.54)	< 0.0001
Non-English Speaking	1.57	(1.24, 1.99)	0.0002
"Other" Family Structure	1.08	(0.98, 1.20)	0.1212
Smoker in the Home	1.41	(1.23, 1.61)	< 0.0001
Dental care delayed or not received	4.98	(3.92, 6.34)	< 0.0001
Metro County*			
0 dental visits	1.24	(0.95, 1.62)	0.1140
1 dental visits	1.10	(0.92, 1.32)	0.2875
2 dental visits	0.82	(0.72, 0.94)	0.0029
Dentists Per 1000 Population in County	0.94	(0.82, 1.07)	0.3309
Percent in Poverty in County	0.99	(0.99, 1.01)	0.3477
Percent Fluoridated Water in County	0.99	(0.99, 1.00)	0.4277

*Significant interaction between number of dental visits and metro status (p = 0.0009)

Additional rural findings: Although not specific to a study hypothesis, Table 3 shows additional variables that were related to lower risk of adult tooth loss in rural areas. Important among these are two health services measures, including receipt of more recent dental care, and a greater per capita supply of dentists; both of these variables are associated with lower odds of tooth loss in rural areas. In urban areas, the dentist supply variable was not associated with lower odds of tooth loss.

Similarly for children, dental care that was delayed or not received was associated with greater odds of caries, and greater odds of poorer teeth condition. There was a significant interaction between rural-urban setting and number of dental visits: an increasing number of dental visits was more strongly related to dental caries in rural areas than in urban areas.

Table 5: Final NSCH Logistic Model of Odds for Children with Less than Very Good Teeth Condition

Variables	Odds Ratio	95% CI	p-value†
Female	1.19	(1.10, 1.29)	< 0.0001
Age Category (vs. 1-5 years)			
6-11 years	2.49	(2.19, 2.83)	< 0.0001
12-17 years	1.94	(1.71, 2.20)	< 0.0001
Ethnicity (vs. Non-Hispanic White)			
Non-Hispanic Black	1.84	(1.64, 2.08)	< 0.0001
Hispanic	1.90	(1.60, 2.24)	< 0.0001
Other	1.44	(1.26, 1.65)	< 0.0001
Household Education (vs. More than HS)			
HS Degree	1.59	(1.45, 1.74)	< 0.0001
Less than HS	1.75	(1.52, 2.01)	< 0.0001
Insurance Status (vs. Adequate Insurance)			
Inadequate	1.43	(1.31, 1.57)	< 0.0001
Uninsured	1.49	(1.33, 1.68)	< 0.0001
Under the Federal Poverty Line	1.63	(1.44, 1.84)	< 0.0001
Non-English Speaking	2.39	(2.00, 2.86)	< 0.0001
"Other" Family Structure	1.28	(1.16, 1.40)	< 0.0001
Smoker in the Home	1.55	(1.37, 1.74)	< 0.0001
Dental care delayed or not received	2.84	(2.33, 3.46)	< 0.0001
Metro County	0.95	(0.87, 1.04)	0.2777
Number of Dental Visits (vs. 0)			
1	0.92	(0.81, 1.05)	0.2073
2 or More	0.84	(0.74, 0.95)	0.0068
Dentists per 1,000 Population in County	0.88	(0.78, 1.00)	0.0510
Percent in Poverty in County	1.00	(0.99, 1.01)	0.7663
Percent Fluoridated Water in County	1.00	(0.99, 1.00)	0.4959

Tables 6 and 7 show rural-urban differences in tooth loss for adults, caries and teeth condition for children, and dental care use and supply variables. In addition to lower fluoridation population coverage, rural areas, compared to urban areas, had a lower supply of dentists, less dental care received for both adults and children, and greater tooth loss for adults. The percentage of children with caries, and parental rating of the condition of the teeth, were not significantly different between rural and urban areas.

Table 6: Rural-Urban Comparisons, NSCH Sample.

	Children in Rural Areas	Children in Urban Areas	P-value*
Number of counties	2406	739	
Number of individuals	33,576	52,968	
	Mean or % (95% CI)	Mean or % (95% CI)	
% with caries	19.8 (18.6, 21.0)	19.3 (18.2, 20.4)	0.5626
% with less than very good teeth	28.8 (27.5, 30.1)	29.4 (27.7, 31.2)	0.5715
% with dental care delayed or not received	3.4 (2.8, 3.9)	2.8 (2.4, 3.1)	0.0640
Number of visits (Percent)			0.0043
0	23.6 (22.2, 25.0)	21.0 (19.9, 22.1)	
1	28.0 (26.6, 29.4)	27.7 (26.7, 28.8)	
2 or more	48.4 (46.9, 49.9)	51.3 (50.0, 52.7)	
Dentists per 1,000 population (Mean (95% CI))	0.33 (0.32, 0.34)	0.51 (0.48, 0.53)	< 0.0001
Mean percent population with fluoridated water (Mean (95% CI))	64.6 (63.2, 66.1)	72.6 (70.2, 75.1)	< 0.0001

*p value for t-test for group mean differences, or chi-square for percent difference.

Table 7: Rural-Urban Comparisons, BRFSS Sample.

	Adults in Rural Areas	Adults in Urban Areas	P-value*
Number of counties	473	671	
Number of individuals	60,089	183,297	
	Mean or % (95% CI)	Mean or % (95% CI)	
% with tooth loss	51.5 (50.3, 52.7)	43.5 (42.6, 44.3)	<0.0001
% with dental care within last two years	64.4 (63.4, 65.3)	70.5 (69.5, 71.5)	<0.0001
Dentists per 1,000 population (Mean (95% CI))	0.33 (0.32, 0.34)	0.51 (0.48, 0.53)	< 0.0001
Mean percent population with fluoridated water (Mean (95% CI))	64.6 (63.2, 66.1)	72.6 (70.2, 75.1)	< 0.0001

*p value for t-test for group mean differences, or chi-square for percent differences.

CONCLUSIONS

Rural populations have significantly poorer access to adequately fluoridated public drinking water compared to urban populations. Population access to fluoridated water is lowest in the most rural areas of the country.

Controlling for covariates, greater availability of water fluoridation was related to better adult dental health outcomes in metropolitan counties. However, when models were run for non-metropolitan counties, greater fluoridation was not statistically associated with dental health measures for adults or children. This was unexpected and may be due to a number of possible factors. The measure of fluoridation at the county level may have been too crude to detect individual level variation in access to and use of fluoridated water. It also may be the case that rural populations are more likely to compensate for unfluoridated drinking water by taking individual protective measures such as using fluoride rinses. There may also be present a confounding of fluoridation rates with other unmeasured risks of poor dental health. Regarding the adult effects, the limited results in this study are consistent with another recent study that found that public water fluoridation was related to lower rates of adult tooth loss based on fluoridation levels present when those adults were children, but not for fluoridation they received as adults.[24]

Despite some concerns about possible harmful effects of fluoridation,[25-26] the CDC strongly recommends that public water be fluoridated at 0.7 parts per million.[8] Previously, the CDC recommendation was 0.7 to 1.2 parts per million, but this was reduced to allow for the fact that people currently have access to fluoride through other sources such as toothpaste or fluoride rinses that were less widely available to populations in earlier years. Recent reviews confirm the benefits of fluoridation on dental health while concluding that no clear links exist between fluoride in drinking water at 0.7 ppm and cancer, bone fractures, or other health risks, the only exception being overuse of fluoride toothpaste among children less than two and increased fluorosis risk.[27-30]

Health services variables showed potentially important rural-urban differences for both adults and children. Children in rural areas had fewer dental visits than urban children, and were marginally more likely to have dental care that was delayed or not received ($p<.07$). Adults in rural areas were more likely than urban adults to have gone without dental care in the last two years. The per capita supply of practicing dentists was significantly lower in rural versus urban areas.

Policy Recommendations: Water fluoridation is clearly beneficial to improved dental health, especially for children. The limited evidence in the current study linking fluoridation to dental health likely reflects poor sensitivity to detect these benefits because of the limits of the county-level fluoridation measure. The single question that was asked of parents regarding the presence of caries in their children is not the most accurate method of caries identification relative to clinical assessment. Rural populations have significantly less access to adequately fluoridated water, and policy efforts to improve access to fluoridated drinking water for rural populations should be undertaken. These efforts may occur primarily through increasing the percent of the population with access to clean, publicly treated water that has protective, safe levels of fluoride. For rural populations that rely on domestic wells, efforts to educate people about the safety and efficacy of fluoride are indicated, so that they may undertake personal protection behaviors to ensure that their children receive topical fluoride.

Other policy initiatives may be undertaken to address additional risk factors for poor dental health identified in this study. These risks include lower supplies of dentists in rural areas, and the receipt of less dental care for rural versus urban populations. Children in rural areas may be at greater risk than urban children for inadequate caries preventive dental care. Appropriate policy responses may include efforts to improve dental health insurance coverage, and to improve the supply of dentists practicing in rural areas. Supply shortages may be addressed through loan repayment programs or other strategies to encourage dentists to practice in rural areas. Encouraging better dental care in underserved areas may also be addressed by improving reimbursement levels for dentists to treat children on public assistance programs such as Medicaid. Other policy initiatives may include programs to encourage pediatricians and family physicians at wellness visits to refer infants to a dental home at the eruption of the first tooth, expanding the Women, Infants and Children program to include a dental education component on brushing children's teeth, and strengthening the Head Start program to allow caregivers to brush the children's teeth rather than letting the children brush their teeth independently. To the extent that access to preventive dental care for children may be more problematic in rural versus urban areas, these policy initiatives may be fruitfully targeted to underserved rural areas.

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