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Water fluoridation, tooth decay in 5 year olds, and social deprivation measured by the Jarman score: analysis of data from British dental surveys

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Abstract

Objective: To examine the effect of water fluoridation, both artificial and natural, on dental decay, after socioeconomic deprivation was controlled for.
Design: Ecological study based on results from the NHS dental surveys in 5 year olds in 1991-2 and 1993-4 and Jarman underprivileged area scores from the 1991 census.
Setting: Electoral wards in three areas: Hartlepool (naturally fluoridated), Newcastle and North Tyneside (fluoridated), and Salford and Trafford (non-fluoridated).
Subjects: 5 year old children (n = 10 004).
Intervention: Water fluoridation (artificial and occurring naturally).
Main outcome measure: Ward tooth decay score (score on the "decayed, missing, and filled tooth index" for each electoral ward).
Results: Multiple linear regression showed a significant interaction between Jarman score for ward, mean number of teeth affected by decay, and both types of water fluoridation. This confirms that the more deprived an area, the greater benefit derived from fluoridation, whether natural or artificial ($R^2 = 0.84$, $P < 0.001$). At a Jarman score of zero (national mean score) there was a predicted 44% reduction in decay in fluoridated areas, increasing to a 54% reduction in wards with a Jarman score of 40 (very deprived). The area with natural fluoridation (at a level of 1.2 parts per million—higher than levels in artificially fluoridated areas) had a 66% reduction in decay, with a 74% reduction in wards with a Jarman score of 40.
Conclusion: Tooth decay is confirmed as a disease associated with social deprivation, and the more socially deprived areas benefit more from fluoridation. Widespread water fluoridation is urgently needed to reduce the "dental health divide" by improving the dental health of the poorer people in Britain.

Introduction

Despite over a hundred studies consistently confirming the efficacy, non-discriminatory benefit, safety, and cost effectiveness of adjusting the level of fluoride in the water supply to 1 part per million (ppm), most of the British population does not have a fluoridated water supply, which would halve the amount of tooth decay in British children.[1] The Water (Fluoridation) Act 1985, now consolidated in the Water Industry Act 1991, has been ineffective: no new water fluoridation schemes have been implemented since the act came into force over 10 years ago. The wording of the act has been interpreted by the privatised water companies as giving them discretion to ignore the legitimate requests of health authorities.[2] This unfortunate situation has serendipitously allowed a "natural experiment" to arise in Britain. An estimated five million British people have had water fluoridation for at least 10 years.[1] The rest still carry the burden of a disease, which could be halved in 5 year old children,[3] and they acted as a non-fluoridated control group for our ecological study.

Dental decay, as with many diseases, is strongly associated with socioeconomic deprivation,[4 5] and the use of indices of material deprivation to identify children at risk has been reported.[6 7] Dental decay is not uniformly distributed through the population, and recent surveys of 5 year olds have shown increased polarisation of the disease.[8 9] In 1993-4, only 45% of 5 year olds in Great Britain had dental decay.[10]

Dental decay in 5 year olds is recorded by the "decayed, missing, and filled tooth" index (for the number of teeth affected by decay regardless of whether they are still decayed, have been extracted, or have been successfully filled) in each individual subject. A mean score can then be calculated for each electoral ward's population of 5 year olds.

Although all studies have consistently reported that water fluoridation reduces tooth decay, the literature seems equivocal about a differential effect associated with deprivation. Two studies, for example, showed that water fluoridation was more effective in reducing dental decay in social classes IV and V than in classes I, II, and III.[11 12] The use of an index of deprivation has confirmed this differential benefit to poorer groups.[6] In contrast, two studies from the early 1980s showed no differential benefit for more deprived groups, although they were not based on random samples, and the authors stated that the results should not be generalised.[13 14]

In another study the authors concluded that the relation between fluoridation, socioeconomic status, and decay was equivocal.[15] They sampled 1661 5 year olds, of whom 923 had a dental examination; 709 questionnaires were returned by parents with the reported fluoride history of their children. This response rate of 43% was unsatisfactory, and the authors did not say how representative these respondents were. The children were categorised into three socioeconomic groups, but only 61 of these children had not been exposed to water fluoridation; the authors stated that this would limit the conclusions that could be drawn from the study. On the basis of the original figures reported in the study, a power calculation for a comparison between the group that had been exposed to water fluoridation and the group that had not, gave an α level of 0.21.[16] A type II statistical error, where there is only a 21% chance that the null hypothesis has been incorrectly rejected, is therefore likely.

A fifth study, which used individual "decayed, missing, and filled tooth surface" scores in 14 year olds and a deprivation index for the enumeration district, suggested that fluoridation has no differential benefits for deprived children.[17] Possible reasons for this include the use of fibreoptic transillumination of teeth for diagnosing decay (with which more decay can be detected), the use of an unusual tooth decay index, and a suboptimal level of fluoride in the study area (Anglesey) of only 0.7 ppm. Although significant differences were reported, the correlation coefficients were low ($r=0.13$, non-fluoridated enumeration districts; $r=0.14$, fluoridated districts).

We aimed to clarify the situation by examining the association between dental decay and social deprivation, as measured by the Jarman underprivileged area score, using populations without water fluoridation, with artificial fluoridation, and with natural water fluoridation.

Method

This ecological study was based on data from electoral wards in parts of the north and north west of England. We used the Jarman underprivileged area score as the indicator of social deprivation and explored its relation to dental decay. We used the results from the NHS dental epidemiological surveys of 5 year old children in 1991-2 and 1993-4, coordinated by the British Association for the Study of Community Dentistry.[10 18]

The Jarman underprivileged area score is used in the NHS for planning and to weight capitation payments to general medical practitioners. It is readily available by electoral ward from the public health common dataset.[19] The score is the weighted total of eight transformed and standardised census variables and can be used to rank areas in order of deprivation; a score of 0 is the mean for England. The eight variables are the ward percentages of (*a*) elderly people living alone; (*b*) households with children under 5 years; (*c*) one parent families; (*d*) unskilled manual workers; (*e*) unemployed people; (*f*) overcrowded households; (*g*) residents who have changed address in the previous year; and (*h*) head of household born in the new commonwealth. An area with a larger score is more deprived than one with a lower (including negative) score.[20] We used the score as a proxy for social deprivation.

Collection of electoral ward data

We collected data for electoral wards in three areas: the 41 non-fluoridated wards in Salford and Trafford District Health Authorities in 1993-4; the 26 artificially fluoridated wards in Newcastle District Health Authority and eight wards in North Tyneside District Health Authority that had received consistent artificial water fluoridation (1 ppm fluoride) in 1991-2; and the 17 naturally fluoridated wards in Hartlepool (1.2 ppm fluoride) in 1991-2. The district surveys of 5 year olds for this study included all children in state primary schools in the sampling frame. We calculated the ward tooth decay score (score on the decayed, missing, and filled tooth index for each electoral ward) directly from the raw data, using the home postcode of the subjects to allocate them to the correct ward. We then calculated a mean ward tooth decay score using the individual scores. Table 1 shows the number of subjects in each ward in the three study areas.

A multiple linear regression model was fitted to the dependent variable (mean ward tooth decay score of 5 year olds) with independent variables, the ward Jarman score (Jarman underprivileged area score for each ward), fluoridation status (adjusted or unadjusted), and interaction terms between the two independent variables.[17] Pearson's correlation coefficients were also calculated. Significance was taken as $P<0.05$.

Results

In Salford and Trafford and in Newcastle 86% (5137/5964 and 2857/3319 respectively) of 5 year old children on the school role had had a dental examination. In Hartlepool the figure was 83% (1051/1272). In North Tyneside the denominator population was unknown, but 959 children were examined; the response rate for the whole North Tyneside area,

Table 1 Mean values (95% confidence intervals) of ward Jarman scores and tooth decay scores, and range of subjects per ward

Study area (n=10 004)	Jarman score	Tooth decay score	Range of subjects/ward
No fluoridation (n=5137)	10.95 (16.77 to 5.13)	2.36 (2.64 to 2.08)	69-180
Artificial fluoridation (n=3816)	18.59 (24.94 to 12.24)	1.34 (1.50 to 1.18)	25-264
Natural fluoridation (n=1051)	10.43 (21.56 to −0.70)	0.73 (0.84 to 0.62)	13-104

Table 2 Regression lines and Pearson's correlation coefficients for social deprivation and tooth decay

Study area	No of wards	Slope	Intercept	Coefficient	
				R	R^2
No fluoridation	41	0.0426	1.89	0.88*	0.77
Artificial fluoridation	34	0.0144	1.07	0.57*	0.33
Natural fluoridation	17	0.0068	0.665	0.68*	0.46

*P<0.01.

including non-fluoridated wards (which were not considered in this study) was 94% (2171/2317). The lowest possible response rate in the fluoridated wards in North Tyneside can be calculated if we assume a 100% response rate for the non-fluoridated wards. The total number of children examined (2171), minus the numerator population in the fluoridated wards (959) is 1212. If this is subtracted from the total population of 2317, and the resulting figure of 1105 is used as the denominator for the fluoridated wards, then the lowest possible response rate is 87% (959/1105). Children who were not examined were absent from school on the day the dental examinations were carried out.

The ward Jarman scores were −22.9 to 48.65 for Salford and Trafford, −17.18 to 56.59 for Newcastle and North Tyneside, and −30.7 to 40.65 for Hartlepool. The mean ward tooth decay scores were 0.24 to 4.32 for Salford and Trafford, 0.35 to 2.54 for Newcastle and North Tyneside, and 0.23 to 0.9 for Hartlepool. Table 1 shows the mean values and 95% confidence intervals of these ward scores.

The weighted mean district tooth decay scores reported nationally for Salford and Trafford (2.48)[10] and Hartlepool (0.81)[18] lie within the 95% confidence limits derived from the mean of the ward tooth decay scores (table 1). The reported score for Newcastle and North Tyneside is not comparable as the non-fluoridated wards are included in the district score. The confidence intervals of the mean tooth decay scores do not overlap, confirming a significant difference between the study areas, although the effect of social deprivation is not controlled for in this analysis. Multiple linear regression analysis showed significant differences between (*a*) the slopes of the regression lines for both the artificially fluoridated areas (B weight = −0.83, $P<0.001$) and the naturally fluoridated areas (B weight = −1.21, $P<0.001$) and (*b*) the slope of the regression line for non-fluoridated areas. The difference in the slopes relating to the artificially fluoridated and naturally fluoridated areas was not significant. Significant differences between interactions of fluoridation status (both artificial (B weight = 0.01, $P<0.001$) and natural (B weight = 0.04, $P<0.001$)) and the ward Jarman score for the ward were found, confirming a differential benefit to the more deprived electoral wards (overall $R^2=0.84$, $P<0.001$).

Figure 1 shows the best fit linear regression lines for the ward Jarman scores and the ward tooth decay scores in non-fluoridated Salford and Trafford in 1993-4, artificially fluoridated Newcastle and North Tyneside in 1991-2, and naturally fluoridated Hartlepool in 1991-2. Correlation coefficients were significant in the three study areas, confirming that the mean ward tooth decay score is associated with social deprivation as indicated by the Jarman score (table 2).

Using the regression line equations to predict levels of dental decay, we found a 44% reduction in the mean tooth decay score of 5 year olds in artificially fluoridated wards with a Jarman score of 0 (the national mean score); this increased to a predicted 54% reduction in wards with a score of 40 (very deprived). In an area with natural fluoridation at a level of 1.2 ppm we found a 66% reduction, rising to 74% in similarly deprived wards.

Discussion

The results show that dental decay in 5 year old children has a strong positive association with deprivation as measured by the Jarman underprivileged area score at an electoral ward level, in both naturally and artificially fluoridated areas and also in non-fluoridated areas. The wards were all in the north of England, and therefore the mean Jarman underprivileged area scores are higher than the national mean score. The 95% confidence intervals of the mean Jarman scores for the three study areas show that differences in the scores existed between the artificially fluoridated and non-fluoridated wards (table 1). However, the regression analysis would control for this. The electoral wards in each area covered a wide range of socioeconomic status, from very deprived wards with a score of 40 or more, to affluent wards with scores of −20 or less. The range of Jarman scores in each area was similar, at over 70. It was reported that many people, especially young adults, chose not to participate in the 1991 census, from which the Jarman scores are calculated. Any effect this may have had on the ward Jarman scores would be to increase deprivation.

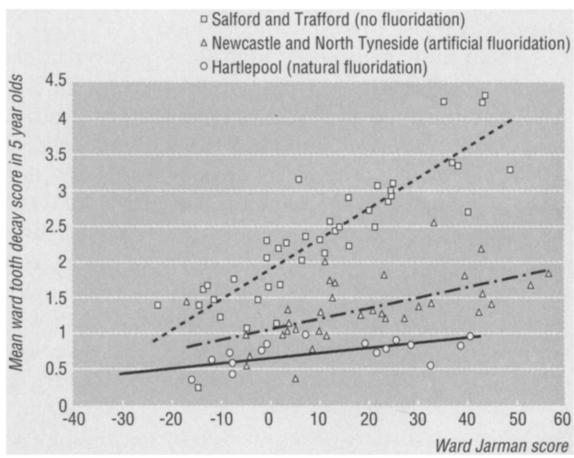

Fig 1 Mean "decayed, missing, or filled tooth" score and Jarman underprivileged area score, by non-fluoridated, artificially fluoridated, and naturally fluoridated electoral wards, with best fit regression lines

Key messages

- Tooth decay in 5 year old children is strongly associated with social deprivation
- Artificial fluoridation of water produced a 44% reduction in tooth decay in 5 year old children in Britain
- The more deprived an area, the greater the benefit derived from water fluoridation

The NHS dental epidemiological surveys of 5 year old children in 1991-2 and 1993-4 were routine surveys, and the trained, local, dental epidemiologists were not blind to the likely fluoride status of the local water supply, so there is the potential for bias in their diagnosis of decay. They did not know, however, that their results would be used in this study. The diagnosis of dental decay for these surveys was carried out at the "D_3" diagnostic threshold—decay extending into the dentine of the tooth—when dentists agree that the tooth should be filled. Variation between dental examiners is also reduced.[21]

Most of the children on the school roles had had a dental examination (83%, 86%, 87% for the three areas). The effect of missing the children who were absent on the day of the examination, on the level of tooth decay is unknown. (Anecdotally, children with high absentee rates are thought to have higher levels of tooth decay.)

The study did not consider the fluoride history of the children—some will have moved from fluoridated to non-fluoridated areas and vice versa, potentially reducing any effect attributable to water fluoridation.[8] Despite this the results were still significant.

The regression analysis clearly shows that the more deprived an area is, the greater benefit 5 year old children derive from water fluoridation. Five year old children in England today would therefore have 44% less tooth decay (54% less in very deprived wards) if water fluoridation had been introduced nationally in the 1970s.

The data from Hartlepool, whose natural fluoridation is higher than the level recommended for artificial fluoridation,[1] show a 66% reduction in decay at a Jarman score of 0, rising to 74% in deprived wards. The shallow slope of the regression lines for both artificial and natural fluoridation shows how water fluoridation reduces the effect of social deprivation on tooth decay in 5 year old children.

Recent surveys also suggest an increase in tooth decay in 5 year olds, which may reflect increasing levels of child poverty.[10] Deprivation per se does not cause tooth decay, and the proved determinants of dental decay include an unwillingness to follow or an inability to afford a non-cariogenic diet and an increase in behavioural risk factors such as high frequency of sugar intake and less frequent toothbrushing with a fluoride toothpaste.[5] Few interventions, however, have been shown to influence these behavioural factors.

Pain, misery, embarrassment, and disfigurement are associated with poor dental health. Widespread water fluoridation is urgently needed as the cost effective, primary preventive measure capable of reducing the "dental health divide" by improving the dental health of the poorer people in Britain.

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Conflict of interest: None.

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Endpiece

Problems of adolescence

I would there were no age between ten and three-and-twenty, or that youth would sleep out the rest; for there is nothing in the between but getting wenches with child, wronging the ancientry, stealing, fighting.

Shakespeare, *The Winter's Tale,* III.iii