Community Water Fluoridation and Intelligence: Prospective Study in New Zealand

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Objectives. This study aimed to clarify the relationship between community water fluoridation (CWF) and IQ.

Methods. We conducted a prospective study of a general population sample of those born in Dunedin, New Zealand, between April 1, 1972, and March 30, 1973 (95.4% retention of cohort after 38 years of prospective follow-up). Residence in a CWF area, use of fluoride dentifrice and intake of 0.5-milligram fluoride tablets were assessed in early life (prior to age 5 years); we assessed IQ repeatedly between ages 7 to 13 years and at age 38 years.

Results. No clear differences in IQ because of fluoride exposure were noted. These findings held after adjusting for potential confounding variables, including sex, socioeconomic status, breastfeeding, and birth weight (as well as educational attainment for adult IQ outcomes).

Conclusions. These findings do not support the assertion that fluoride in the context of CWF programs is neurotoxic. Associations between very high fluoride exposure and low IQ reported in previous studies may have been affected by confounding, particularly by urban or rural status. (*Am J Public Health.* 2015;105: 72–76. doi:10.2105/AJPH.2013.301857)

Community water fluoridation (CWF) is a cost-effective,[1,2] safe,[3] and environmentally friendly[4] means of reducing dental caries rates[3] and social inequalities.[5] However, CWF has recently been criticized as a cause of IQ deficits among children,[6] despite a lack of evidence to support that claim. This claim was considered pivotal in the recent rejection of CWF by voters in Portland, Oregon,[7] and by local government politicians in Hamilton, New Zealand. It is likely that such claims may continue to be lobbied against CWF worldwide.

Since the 1960s, about half of New Zealand's population has had access to CWF. Nationally, average fluoride intakes remain below the adequate intake level for dental caries protection, and CWF schemes are only 1 (albeit important) source of exposure to fluoride.[8] The New Zealand Ministry of Health supports CWF in policy, but implementation of that policy is decided upon and undertaken by Territorial Local Authorities (local government) mandated[9] to supply water services to people in their areas (and improve the health of their populations).

Hamilton city (New Zealand's fifth-largest metropolitan area) has had CWF since 1966 and has recently become a target for CWF opponents. Despite a binding 2006 referendum that showed 70% support for CWF among voting Hamiltonians,[10] Hamilton's City Council chose to relitigate CWF and held a tribunal on fluoridation in early 2013. The councilors voted to cease CWF, leading to an outcry from members of the public and health officials. A new referendum was then held (accompanying a local government election), which again showed 70% support for CWF among voting Hamiltonians.[11] The Hamilton City Council elected to await the outcome of a High Court ruling on a challenge to the legality of CWF in another New Zealand city (New Plymouth) before reinstating CWF. Following the release of the ruling in favor of CWF, the Hamilton City Council reversed their previous decision, and voted in February 2014 to reintroduce CWF to Hamilton in April 2014.

In the tribunal submissions and hearings, CWF opponents relied heavily on 2 studies as the basis for linking CWF with IQ deficits. The first was a 2006 review article in which fluoride was included in a list of "compounds known to cause neurotoxicity in man"[12(p2169)]; however, the text of the same article stated that this had been inconclusive.[12(p2173)] The second study was a 2012 meta-analysis that compiled the findings of studies from China and Iran, which related IQ and naturally occurring fluoride in water and other sources of exposure, but none were in the context of CWF. The meta-analysis conceded that the included studies were of low quality and that potential confounders were not investigated.[13] Furthermore, the fluoride levels in the water sources for the high fluoride and low IQ groups had very high and variable fluoride levels. In a majority of the studies that considered fluoride in water, the reference groups had exposure to water with similar or even greater fluoride levels than those used in CWF programs. Selective readings of the meta-analysis generated enough misinformation that a press release issued by the authors in September 2012 had to emphasize the fact that their research was irrelevant to CWF.[14]

The EU Scientific Committee on Health and Environmental Risks has reported on these fluoride–IQ studies and found them to be of simplistic methodological design with no (or at best little) control for confounders such as nutrition, exposure to iodine or lead, or socioeconomic status.[15] A New Zealand review also considered many of the same studies and found them to be of low quality and with a high risk of bias.[16]

Despite these problems, several public anti-CWF submissions that were made to the Hamilton City Council Fluoridation Tribunal cited these studies; for example, one submission stated "recent research findings show that fluoride can be toxic to children's brain development"[17]; another stated "The decrease in average IQ results in a significant drop in the number of geniuses in society and an equally disproportionate increase in the number of mentally handicapped people"[18]; yet another stated "fluoride is a known neurotoxin" and suggested a relationship with fictional World War II "mental numbing" experiments.[19] These statements

were presented as valid evidence at the Hamilton Water Fluoridation Tribunal, illustrating that these assertions continue to be cited extensively as conclusive proof that CWF causes IQ deficits, despite irrelevance of that work to CWF, and other limitations.

Recently, the authors of the first review have repeated the claim that children exposed to fluoride experience "IQ deficits,"[20] based on the meta-analysis.[13] They also assert that "confounding from other substances seemed unlikely in most of these studies."[20(p332)] This is in spite of concerns about confounding from other environmental exposures, a lack of consideration of the comparability of sizes of villages and other village characteristics such as proximity to school facilities, nature of local industry, and lack of relevance of the studies included in the meta-analysis to the use of CWF or fluoride toothpastes.

A prospective, longitudinal investigation of the association between early life exposure to artificially fluoridated water and IQ in childhood and in adulthood could redress many of the limitations of the studies included in the meta-analysis mentioned previously. It is also important that such studies should also investigate the relationship of fluoride in water with reasoning ability, problem solving, and memory, not just IQ.[16] Genetic effects can influence IQ,[20] but because environmental factors are more likely to cause variation in mental development in the early years than at older ages,[21] this study focuses upon early life exposure to fluoride during the first 5 years of life—a critical period in mental development.

We sought to test the hypothesis that spending childhood in an area with CWF is associated with lower IQ in childhood and adulthood. We hypothesized that any observed difference might be explained by confounding.

METHODS

Participants were members of the Dunedin Multidisciplinary Health and Development Study, a longitudinal investigation of the health and behavior of a complete birth cohort of consecutive births between April 1, 1972, and March 31, 1973, in Dunedin, New Zealand. The cohort of 1037 children (91% of eligible births; 52% boys) was constituted at age 3 years. Cohort families represent the full range of socioeconomic status (SES) in the general population of New Zealand's South Island and are primarily of white European ancestry. We conducted follow-up assessments with informed consent at 5, 7, 9, 11, 13, 15, 18, 21, 26, 32, and most recently at 38 years of age, when 95.4% of the 1007 living study members underwent assessment in 2010 to 2012. Because individuals with missing data at one wave tend to return to the study at some later wave(s), the attrition in the Dunedin Study has not been cumulative, and reasons for missing assessments seem to be idiosyncratic rather than systematic.

Variables and Data Sources and Measurement

Preschool fluoride exposure was used in these analyses because this is when brain development is rapid and vulnerable, and thereafter the IQ is known to be relatively stable. Studies of twins indicate that environmental effects on IQ are greatest in the early years, and genetic effects are least during that period.[22] Thus, we report history of use of 0.5-milligram fluoride tablets (response options: ever, never) and use of fluoridated toothpaste (response options: always, sometimes, never, unknown) by age 5 years, according to parental interviews (n = 922). At that time, virtually all study members still resided in the Dunedin metropolitan area. Most suburbs of Dunedin have had CWF since 1967, but certain suburbs remain unfluoridated. We report residence in an area with or without CWF (0.7–1.0 ppm and 0.0–0.3 ppm fluoride, respectively) coded from residential address data to age 5 years (n = 922), or to age 3 years (n = 103) where residence data from age 5 years were unavailable (area of residence for 2 study members could not be coded at either age).

We assessed childhood IQ for each study member at ages 7, 9, 11, and 13 years by means of the Wechsler Adult Intelligence Scale-Revised (WISC-R).[23] The IQs determined at these 4 ages were averaged into 1 measure and standardized. Adult IQ was individually assessed at age 38 years by means of the Wechsler Adult Intelligence Scale–Fourth Edition (WAIS-IV).[24] Both the WISC-R and the WAIS-IV tests comprise a series of subtests that yield indices standardized to population norms (mean = 100; SD = 15). Tests were administered in the morning by trained psychometrists who were blind to the study members' previous IQ data. In addition, examiners were unaware of the CWF status of participants' area of residence.

Many factors affect IQ, and studies investigating fluoride exposure and IQ must consider potential confounders.[16] Variables considered as prior causes common to both low IQ and adult mental disorders were included as confounders in our models, as done in previous research.[25]

Childhood measures included SES, birth weight, and breastfeeding. SES was based on parental occupation (and the educational level and income associated with that occupation in the New Zealand census)[26] and categorized into 3 groups. Low birth weight was defined as birth weight below 2.50 kilograms. Breastfeeding was defined as breastfeeding for 4 weeks or more.

Confounders for adult IQ included those previously cited, together with education achievements. Education achievements were defined as no school qualifications, school certificate, high school graduation, or university degree by age 38 years.

Data analysis

We used General Linear Models to assess the association between CWF and IQ in childhood and adulthood, after adjusting for potential confounders. All statistical analyses were conducted in Intercooled Stata 13.1 (StataCorp LP, College Station, TX). Model assumptions were assessed by the residual diagnostics via various plots of residuals.

RESULTS

Data on IQ were available for 992 and 942 study members in childhood and adulthood, respectively. Sex was not significantly associated with IQ. Associations of childhood SES ($F = 83.94$; n = 987; $P < .001$), breastfeeding ($F = 51.23$; n = 990; $P < .001$) and low birth weight ($F = 5.14$; n = 992; $P = .024$) with childhood IQ were statistically significant. Association of educational attainment ($F = 123.44$; n = 924; $P < .001$) with adult IQ was also statistically significant.

In childhood, no statistically significant difference in IQ existed between participants who had or had not resided in areas with CWF, used fluoride toothpaste, or used fluoride tablets, both before (Table 1) and after (Table 2) adjusting for potential confounding variables. An interaction term for breastfeeding and CWF status was considered, but was excluded from the model

because it did not improve the model fit. Breastfeeding was associated with higher child IQ irrespective of residence in CWF areas (Table 3). Mean IQ subscale scores for verbal comprehension, perceptual reasoning, working memory, and processing speed did not significantly differ by exposure to CWF, use of fluoride toothpaste, or fluoride tablet consumption (Table 4).

TABLE 1—Mean Weschler IQ Scores in Childhood and Adulthood by Sources of Fluoride Exposure: Dunedin Multidisciplinary Health and Development Study; Dunedin, New Zealand; 1972–2012

Variable	IQ at Age 7–13 Years			IQ at Age 38 Years		
	Mean (SD)	No.	*P*	Mean (SD)	No.	*P*
Area of residence (age 5 y)			.92			.18
CWF area	100.0 (15.1)	891		100.2 (15.1)	847	
Never lived in CWF area	99.8 (14.5)	99		98.1 (14.4)	93	
Unknown		2			2	
Fluoride toothpaste (age 5 y)			.32			.51
Always	100.2 (14.9)	634		100.0 (15.0)	608	
Sometimes	98.7 (13.8)	240		98.8 (15.1)	217	
Never	100.2 (20.5)	22		101.1 (11.5)	20	
Unknown		96			97	
Fluoride tablets (age 5 y)			.71			.83
Ever used	100.2 (15.0)	139		100.0 (15.4)	136	
Never used	99.7 (14.7)	763		99.7 (14.8)	715	
Unknown		90			91	
IQ known	100.0 (15.0)	992		100.0 (15.0)	942	

Note. CWF = community water fluoridation. At age 13 years, 1032 study members were living; at age 38 years, 1007 study members were living.

DISCUSSION

The findings do not support the assertion that fluoride exposure in the context of CWF can affect neurologic development or IQ. Study members who lived in areas with CWF before age 5 years had slightly higher IQs (on average) in adulthood than those who had not.

Strengths and Limitations

This study has numerous strengths, including the robust IQ measures used, the presence of prospective data on use of fluoride tablets and fluoridated toothpaste, and the ability to link each child's address with historical administrative records of CWF. A limitation is that we did not ask how much water study members drank. Individual water-intake level was not directly measured, meaning that the CWF exposure variable is an ecological one. Other sources of fluoride are also important in assessment of total intake. Prior to age 5 years, water intake is thought to account for less than half of total fluoride intake among children.[8] Dietary fluoride was not considered, although we did consider exposure to fluoride from dentifrices and fluoride tablets. Virtually all study members were living in the Dunedin metropolitan area up to age 5 years, so in this study we found it unnecessary to control for confounding by differences in IQ associated with urban or rural area of residence. However, suburbs with CWF were mostly located in central Dunedin, and those without CWF were satellite suburbs.

An important oversight in past studies of exposure to naturally occurring water fluoride by IQ is the fact that the average IQ of rural dwellers is often lower than that of those who dwell in urban areas.[27,28] In New Zealand, natural levels of fluoride in water are generally less than 0.2 parts per million, and in areas with CWF, fluoride levels in the water are artificially adjusted upwards to the 0.7 to 1.0 parts per million range. Conversely, in many parts of China, fluoride levels in water are naturally high (and variable), and in many areas with treatment facilities, fluoride levels are artificially adjusted downward. The urban and rural distribution of high and low fluoride areas is likely to be opposite in countries with naturally high levels of fluoride that are artificially reduced by water treatment plants when compared with countries that have naturally low levels which add fluoride through CWF programs. Investigation of the villages compared in the studies reviewed by Choi et al. reveals marked differences in their size and apparent affluence (while many included such little detail that it is not possible to identify from the text where the studies were actually conducted). Water improvement plants are also likely to remove lead from drinking water, and areas with such facilities are more likely to be urban or affluent. It is likely that differences in IQ observed may be attributable to urban–rural or socioeconomic differences, or removal of lead from drinking water.

Causation

A previous report noted that a plausible biological link for an association between fluoridated water and IQ has not been established[15]; no plausible biological mechanism exists. However, we suggest that any observed link may be attributed to covariance by urban–rural status (and exposure to lead, in some past studies). Because more education opportunities may be available for central city dwellers than those in satellite suburbs, this might explain the slightly higher IQ at age 38 years observed among those from areas with CWF. The urban–rural distribution of high and low fluoride areas in New Zealand runs counter to China and other countries that have high levels of natural fluoride. Regional differences in IQ are more likely related to urban–rural effects than to CWF status.

Breastfed children are known to have higher IQs than formula-fed babies, and previous research has indicated that genetic variations in fatty acid metabolic pathways may be responsible for variation in the effect of breastfeeding on IQ.[29] The relative fluoride content of breast milk and formula is unlikely to have any effect on IQ outcomes. In New Zealand, infant formulas are manufactured without added fluoride, so the fluoride in formula would be sourced from water. We found a tendency for children who had been breastfed to have higher IQs than those who were not breastfed (bottle-fed), regardless of the exposure of either group to CWF.

The Flynn Effect[30] is relevant but has not been considered by the previous studies, including the recent *Lancet Neurology* article.[20]

TABLE 2—Unstandardized Parameter Estimates From General Linear Models of Childhood and Adulthood IQ: Dunedin Multidisciplinary Health and Development Study; Dunedin, New Zealand; 1972–2012

	IQ at Age 7–13 Years (n = 983)		IQ at Age 38 Years (n = 929)	
	b (95% CI)	*P*	b (95% CI)	*P*
Unadjusted estimates				
Area of residence in childhood				
Area with CWF	0.15 (−2.96, 3.28)	.92	2.18 (−1.04, 5.39)	.18
Area without CWF	Ref		Ref	
Fluoride toothpaste in childhood				
Always	0.64 (−1.31, 2.59)	.52	0.01 (−2.00, 2.01)	.99
Sometimes/never/unknown	Ref		Ref	
Fluoride tablets in childhood				
Ever	0.26 (−2.43, 2.96)	.85	−0.02 (−2.72, 2.71)	.99
Never/unknown	Ref		Ref	
Adjusted estimates[a]				
Area of residence in childhood				
Area with CWF	−0.14 (−3.49, 3.20)	.93	3.00 (0.02, 5.98)	.05
Area without CWF	Ref		Ref	
Fluoride toothpaste in childhood				
Always	0.83 (−0.96, 2.63)	.36	0.19 (−1.42, 1.80)	.82
Sometimes/never/unknown	Ref		Ref	
Fluoride tablets in childhood				
Ever	−0.25 (−3.18, 2.68)	.87	1.61 (−0.97, 4.19)	.22
Never/unknown	Ref		Ref	

Note. CI = confidence interval; CWF = community water fluoridation.
[a]Adjusted estimates for childhood IQ by CWF and other fluoride exposures controlled for sex, socioeconomic status in childhood, low birth weight, and breastfeeding. Analyses for adult IQ by CWF also controlled for educational achievements.

Based on Grandjean's previous collaboration with Choi,[13] Grandjean and Landrigan claimed that children exposed to fluoride experience "an average IQ decrement of about seven points."[20(p332)] If this claim were accurate, then major decrements in IQ in countries that have adopted CWF would be expected, as well as in the many countries where use of fluoride toothpastes is widespread (note that children up to age 5 years often ingest substantial quantities of fluoride during toothbrushing if given excessive quantities of toothpaste or not properly supervised during brushing).[31,32] No dramatic historical decreases in IQ have been seen following widespread implementation of CWF or worldwide introduction of fluoride toothpastes; instead, historical comparisons have documented substantial IQ gains across countries since the mid-1900s.[22,30,33]

TABLE 3—Age 7–13 IQ by Breastfeeding and Fluoridation Status: Dunedin Multidisciplinary Health and Development Study; Dunedin, New Zealand; 1972–2012

	Areas With CWF			Areas Without CWF		
Status	Mean (SD)	No.	*P*	Mean (SD)	No.	*P*
Breastfeeding			< .01			.09
Not breastfed	97.0 (15.3)	460		97.2 (15.8)	45	
Breastfed	103.6 (13.9)	429		102.0 (13.1)	54	
Overall	100.0 (15.1)	889		99.8 (14.5)	99	

Note. CWF = community water fluoridation.

Relevance to the International Context

The participants of the Dunedin Study cohort are reasonably similar in their characteristics to populations in the European and North American context.[34] Where implemented in New Zealand, CWF is set at 0.7 to 1.0 parts per million fluoride, which is similar to the level of used in other countries that use CWF (e.g., United States and Australia at 0.7–1.2 ppm). The findings of this study are therefore likely to be generalizable to similar populations.

Implications

Substantive research and quality data are required for addressing important public health issues. In New Zealand, it has been recommended that New Zealand government departments should employ a designated research-literate staff expert to interpret science for the benefit of politicians,[35] and our study suggests that local government organizations could benefit from the same. Scientists and policy makers should be reminded of the necessity of caution in attributing causality when evidence for it does not exist. ■

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Contributors

All authors contributed to writing, critical review, and final approval of this article. J. M. Broadbent contributed to literature search, research design, data collection, data analysis, and data interpretation. W. M. Thomson contributed to literature search, research design, and data analysis. J. Zeng contributed to data analysis and interpretation. L. A. Foster Page contributed to literature

TABLE 4—IQ Subtest Scores by Fluoride Exposure: Dunedin Multidisciplinary Health and Development Study; Dunedin, New Zealand; 1972–2012

	Verbal Comprehension Index		Perceptual Reasoning Index		Working Memory Index		Processing Speed Index	
Exposure	Mean (SD)	*P*	Mean (SD)	*P*	Mean (SD)	*P*	Mean (SD)	*P*
Area of residence in childhood		.51		.18		.12		.47
Area with CWF	100.1 (14.9)		100.2 (15.1)		100.3 (15.0)		100.1 (15.1)	
Area without CWF	98.9 (15.5)		98.0 (14.1)		97.7 (15.0)		98.9 (14.3)	
Fluoride toothpaste in childhood		.97		.96		.61		.87
Always	100.0 (15.0)		100.0 (15.2)		99.8 (14.8)		100.1 (15.1)	
Sometimes/never	100.0 (15.0)		100.0 (14.7)		100.3 (15.1)		99.9 (14.9)	
Fluoride tablets in childhood		.59		.86		.66		.51
Ever	99.3 (14.7)		100.2 (15.7)		99.5 (15.6)		100.8 (15.5)	
Never	100.1 (15.1)		100.0 (14.9)		100.1 (14.9)		99.9 (14.9)	

Note. CWF = community water fluoridation.

search and data interpretation. S. Ramrakha, T. E. Moffitt, and R. Poulton contributed to literature search, research design, data collection, data management and interpretation.

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Human Participant Protection

The Otago Ethics Committee approved each wave of the study. At each wave, the study protocols were described and study members gave informed consent before participating. Study members were physically examined, interviewed, and completed self-report questionnaires as appropriate.

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