Community Water Fluoridation and Intelligence: Prospective Study in New Zealand

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Community water fluoridation (CWF) is a cost-effective,1,2 safe,3 and environmentally friendly4 means of reducing dental caries rates5 and social inequalities.6 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 lobbed 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) mandated9 and elected to await the outcome of a High Court ruling on a challenge to the legality of CWF in Hamilton, New Zealand.10 Hamiltonians,10 Hamilton’s City Council chose to relitigate CWF and held a tribunal on fluoridization 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.10 Hamilton’s 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”129(p2169); however, the text of the same article stated that this had been inconclusive.129(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 Fluoridization 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

**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 significant 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. Published online ahead of print May 15, 2014: e1–e5. doi:10.2105/AJPH.2013.301857)
were presented as valid evidence at the Hamil-
ton Water Fluoridation Tribunal, illustrating that these assertions continue to be cited ex-
tensively 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 fluo-
ride 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.”20,32 This is in spite of concerns about confounding from other environmental
exposures, a lack of consideration of the compa-
rability of sizes of villages and other village
characteristics such as proximity to school facili-
ties, nature of local industry, and lack of rele-
ance 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 arti-
cially fluoridated water and IQ in childhood and
in adulthood could redress many of the limita-
tions of the studies included in the meta-analysis
mentioned previously. It is also important that
such studies should also investigate the relation-
ship 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,24 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 spend-
ing 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 consec-
tutive births between April 1, 1972, and March
31, 1973, in Dunedin, New Zealand. The co-
hort of 1037 children (91% of eligible births;
52% boys) was constituted at age 3 years. Co-
hort families represent the full range of socio-
economic 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 assess-
ment 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 develop-
ment 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
tables (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 (0.85 ppm and 0.0–0.3 ppm fluoride, re-
spectively) 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 resi-
dence 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 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 Edi-
tion (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 admin-
istered 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 investigat-
ing 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 in-
come 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 pre-
viously cited, together with education achieve-
ments. 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 child-
hood and adulthood, after adjusting for poten-
tial confounders. All statistical analyses were
conducted in Intercooled Stata 10.0 (StataCorp
LP, College Station, TX). The models were
fitted using the built-in glm function of Stata.
Model assumptions were assessed by the re-
sidual diagnostics via various plots of residuals.

RESULTS

Data on IQ were available for 992 and 942
study members in childhood and adulthood, re-
spectively. 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 sta-
tistically significant. Association of educational
attainment (F = 123.44; n = 924; P < .001)
with adult IQ was also statistically significant.

In childhood, no statistically significant dif-
ference 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).

**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, but this difference was nonsignificant.

**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. 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. 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; 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. 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 that children who had been breastfed had higher IQs than those who were not breastfed (bottle-fed), regardless of the exposure of either group to CWF.

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

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**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**

<table>
<thead>
<tr>
<th>Variable</th>
<th>IQ at Age 7–13 Years</th>
<th>IQ at Age 38 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>No.</td>
</tr>
<tr>
<td>Area of residence (age 5 y)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CWF area</td>
<td>100.0 (13.5)</td>
<td>891</td>
</tr>
<tr>
<td>Never lived in CWF area</td>
<td>99.8 (13.0)</td>
<td>99</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Fluoride toothpaste (age 5 y)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always</td>
<td>100.2 (13.4)</td>
<td>634</td>
</tr>
<tr>
<td>Sometimes</td>
<td>98.7 (12.4)</td>
<td>240</td>
</tr>
<tr>
<td>Never</td>
<td>100.2 (18.4)</td>
<td>22</td>
</tr>
<tr>
<td>Unknown</td>
<td>101.8 (15.0)</td>
<td>96</td>
</tr>
<tr>
<td>Fluoride tablets (age 5 y)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>100.2 (13.5)</td>
<td>139</td>
</tr>
<tr>
<td>No</td>
<td>99.7 (13.2)</td>
<td>763</td>
</tr>
<tr>
<td>Unknown</td>
<td>90</td>
<td>91</td>
</tr>
<tr>
<td>IQ known</td>
<td>100.0 (14.4)</td>
<td>992</td>
</tr>
</tbody>
</table>

Note. CWF = community water fluoridation. At age 13 years, 1032 study members were living; at age 38 years, 1007 study members were living.
with Choi,13 Grandjean and Landrigan claimed that children exposed to fluoride experience "an average IQ decrement of about seven points."

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

<table>
<thead>
<tr>
<th>Area of residence in childhood</th>
<th>IQ at Age 7–13 Years (n = 983)</th>
<th>IQ at Age 38 Years (n = 929)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b (95% CI)</td>
<td>P</td>
</tr>
<tr>
<td><strong>Unadjusted estimates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area with CWF</td>
<td>0.15 (-2.83, 3.14)</td>
<td>.92</td>
</tr>
<tr>
<td>Area without CWF</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td>Fluoride toothpaste in childhood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always</td>
<td>0.61 (-1.25, 2.47)</td>
<td>.52</td>
</tr>
<tr>
<td>Sometimes/never/unknown</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td>Fluoride tablets in childhood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0.25 (-2.32, 2.83)</td>
<td>.849</td>
</tr>
<tr>
<td>No/unknown</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td><strong>Adjusted estimates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area with CWF</td>
<td>-0.01 (-3.22, 3.20)</td>
<td>.996</td>
</tr>
<tr>
<td>Area without CWF</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td>Fluoride toothpaste in childhood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always</td>
<td>0.70 (-1.03, 2.43)</td>
<td>.428</td>
</tr>
<tr>
<td>Sometimes/never/unknown</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td>Fluoride tablets in childhood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.55 (-0.38, 3.49)</td>
<td>.116</td>
</tr>
<tr>
<td>No/unknown</td>
<td>Ref</td>
<td>Ref</td>
</tr>
</tbody>
</table>

Note. CI = confidence interval; CWF = community water fluoridation.

*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.

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

<table>
<thead>
<tr>
<th>Status</th>
<th>Mean (SD)</th>
<th>No.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas With CWF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breastfed</td>
<td>103.2 (12.5)</td>
<td>429</td>
<td>.049</td>
</tr>
<tr>
<td>Not breastfed</td>
<td>97.0 (13.8)</td>
<td>460</td>
<td>.001</td>
</tr>
<tr>
<td>Overall</td>
<td>100.0 (13.5)</td>
<td>889</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Status</th>
<th>Mean (SD)</th>
<th>No.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas Without CWF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breastfed</td>
<td>101.8 (11.8)</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Not breastfed</td>
<td>97.5 (14.2)</td>
<td>45</td>
<td>.049</td>
</tr>
<tr>
<td>Overall</td>
<td>99.8 (13.9)</td>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>

Note. CWF = community water fluoridation.

### Table Note

**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 policymakers.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.

### About the Authors

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design, data collection, data management and interpretation.

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We are indebted to previous researchers for collecting the early life data reported here, and to Study founder, Phil Silva. The Dunedin Study would not be possible but for the ongoing participation of the Study members, their families and friends.

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.

References


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

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Verbal Comprehension Index</th>
<th>Perceptual Reasoning Index</th>
<th>Working Memory Index</th>
<th>Processing Speed Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>P</td>
<td>Mean (SD)</td>
<td>P</td>
</tr>
<tr>
<td>Area of residence in childhood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area with CWF</td>
<td>100.1 (17.2)</td>
<td>.257</td>
<td>100.2 (12.6)</td>
<td>.089</td>
</tr>
<tr>
<td>Area without CWF</td>
<td>98.9 (16.5)</td>
<td>.485</td>
<td>98.2 (13.5)</td>
<td>.522</td>
</tr>
<tr>
<td>Fluoride toothpaste in childhood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always</td>
<td>100.0 (16.6)</td>
<td>.707</td>
<td>100.0 (14.0)</td>
<td>.432</td>
</tr>
<tr>
<td>Sometimes/never/unknown</td>
<td>100.0 (16.6)</td>
<td></td>
<td>100.0 (13.3)</td>
<td>.462</td>
</tr>
<tr>
<td>Fluoride tablets in childhood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>99.3 (16.3)</td>
<td>.707</td>
<td>100.2 (14.0)</td>
<td>.432</td>
</tr>
<tr>
<td>No/unknown</td>
<td>100.1 (16.6)</td>
<td>.707</td>
<td>100.1 (14.7)</td>
<td>.707</td>
</tr>
</tbody>
</table>

Note. CWF = community water fluoridation.