EFFECT OF HIGH-FLUORIDE WATER ON INTELLIGENCE IN CHILDREN

Y Lu,[a] ZR Sun,[a] LN Wu,[a] X Wang,[a] W Lu,[a] SS Liu[b]
Tianjin, China

SUMMARY: The Intelligence Quotient (IQ) was measured in 118 children, aged 10-12 years, who were life-long residents in two villages of similar population size and social, educational and economic background but differing in the level of fluoride in drinking water. The children in the high-fluoride area (drinking water fluoride 3.15 ± 0.61 mg/L [ppm]) (mean ± S.D.) had higher urinary fluoride levels (4.99 ± 2.57 mg/L) than the children in the low-fluoride area (drinking water fluoride 0.37 ± 0.04 mg/L) (urinary fluoride 1.43 ± 0.64 mg/L). The IQ of the 60 children in the high-fluoride area was significantly lower, mean 92.27 ± 20.45, than that of the 58 children in the low-fluoride area, mean 103.05 ± 13.86. More children in the high-fluoride area, 21.6%, were in the retardation (<70) or borderline (70-79) categories of IQ than children in the low fluoride area, 3.4%. An inverse relationship was also present between IQ and the urinary fluoride level. Exposure of children to high levels of fluoride may therefore carry the risk of impaired development of intelligence.

Keywords: Fluoride and IQ, Fluoride excretion in urine, Fluoride in water, Intelligence and fluoride.

INTRODUCTION

In view of reports of increased fluoride levels in many foods and water supplies, it is urgent that further studies be conducted to examine whether there is a link in animals and humans between fluoride and disturbances of the development and function of the central nervous system.

High-fluoride levels may occur in artesian well water when the water passes through strata with a high fluoride content, food may become contaminated when stored in contact with the smoke from a poorly ventilated indoor fire burning high-fluoride coal, and fluoride may be added to water supplies with the practice of fluoridation.

Despite Roholm[1] noting that “man is much more sensitive to fluorine than the rat”, rats have been used in animal studies disclosing significant changes from fluoride effects on the central nervous system. Mullenix *et al*[2] found neurotoxicity in rats with fluoride exposure causing sex- and dose-specific behavioural deficits. Isaacson *et al*[3] and Varner *et al*[4] found that the chronic administration of aluminium fluoride and sodium fluoride in the drinking water of rats resulted in distinct morphological alterations in the brain, including effects on neurones and cerebrovasculature. Guan *et al*[5] found that the contents of phospholipid and ubiquinone are modified in the brains of rats affected by chronic fluorosis, and these changes in membrane lipids could be involved in the pathogenesis of this disease.

[a]For correspondence: Dr Yan Lu, Department of Environmental Health, Tianjin Medical University, Tianjin, China. Emai: yan_lv@hotmail.com.
[b]Tianjin Xiqing District Anti-Epidemic Station, Tianjin, China.

Other studies by Yang *et al*[6] and Pang *et al*[7] have noted the adverse effects that fluoride has on the brain and explored the actions of protective agents. Human maternal exposure to high-fluoride levels was found to have an adverse effect on foetal cerebral function and neurotransmitters.[8-11] Reduced intelligence in children is associated with exposure to high-fluoride levels in food or drinking water.[12-15] This area is examined further in the present study of the intelligence of Chinese school children exposed to a high-fluoride level in drinking water.

MATERIALS AND METHODS

The study was undertaken on 118 children, aged 10-12 years, attending school in the Tianjin Xiqing District in China. The children were life-long residents of two villages of similar population size which differed in the fluoride content of the drinking water. Using a random cluster sampling method, 60 children were chosen from the high-fluoride area with 3.15 ± 0.61 mg/L (ppm) of fluoride in the drinking water and 58 children were chosen from the low-fluoride area with 0.37± 0.04 mg/L of fluoride in the drinking water. Children affected by congenital or acquired neurological disorders were excluded.

The Intelligence Quotient (IQ) was measured with the Chinese Combined Raven's Test, Copyright 2 (CTR-C_2).[16] The seven categories distinguished by the IQ were: <70 retarded (low); 70-79 borderline (below average); 80-89 dull normal (low average); 90-109 normal (average); 110-119 bright normal (high average); 120-129 superior (good); >129 very superior (excellent).

Possible confounding factors were investigated by assessing the questionnaires that the children's parents completed. This was done under the direction of the examiners. The categories covered in the questions about the children were: past history of illness, age, sex, and residential history. The questions about the parents' background included information on past history of illness, social status, economic status, level of education, income, smoking, and the use of alcohol.

Fluoride levels were measured using a fluoride ion selective electrode for the drinking water and urine of the children.

Statistical analysis of the results was done with Fisher's exact test, Welch's alternate t-test, the rank sum test, and multiple regression analysis.

RESULTS

The residents of the two areas studied were similar in their social, educational and economic backgrounds.

The urinary fluoride levels of the children living in the area with a high-fluoride level in drinking water were significantly higher than those of the children living in the area with a low-fluoride level in drinking water (Table 1).

The mean IQ of the children living in the area with a high-fluoride level in drinking water was significantly lower than that of the children living in the area with a low-fluoride level in drinking water (Table 1).

Table 1. Urinary fluoride levels and IQs of children living in areas with high and low levels of fluoride in drinking water.

Level of drinking water fluoride (mean ± S.D.)	No. of children examined	Urinary fluoride level (mean ± S.D.)	Mean IQ (mean ± S.D.)
High (3.15±0.61 mg/L)	60	4.99 ± 2.57 mg/L*	92.27 ± 20.45†
Low (0.37±0.04 mg/L)	58	1.43 ± 0.64 mg/L	103.05 ± 13.86

*comparing the urinary fluoride levels with Welch's alternate t-test, which does not assume equal variances, t = 10.40 with 66 degrees of freedom, P<0.0001.

†comparing the mean IQs with Welch's alternate t test, t = 3.36 with 104 degrees of freedom, P <0.005.

The proportion of children in the retardation or borderline categories of IQ was significantly higher for the children living in the area with a high-fluoride level in drinking water than for the children living in the area with a low-fluoride level (Table 2).

Table 2. The distribution of IQ scores for children living in areas with high and low levels of fluoride in the drinking water.

Water fluoride	IQ <70 retarded (low)	IQ 70-79 borderline (below avg)	IQ 80-89 dull normal (low avg.)	IQ 90-109 normal (average)	IQ 110-119 bright normal (high avg.)	IQ 120-129 superior (good)	IQ >129 very superior (excellent)
High	5* (8.3%)	8* (13.3%)	12 (20.0%)	26 (43.3%)	5 (8.3%)	3 (5.0%)	1 (1.7%)
Low	0 (0.0%)	2 (3.4%)	6 (10.3%)	30 (51.7%)	13 (22.4%)	5 (8.6%)	2 (3.4%)

*comparing the proportions of children in the retarded and borderline categories of IQ (<70-79) with those in the dull normal, normal, bright normal, superior and very superior categories (80->129) with Fisher's exact test, P<0.005.

A significant inverse relationship was found between the urinary fluoride level and the IQ (Table 3).

Table 3. Relationship between urinary fluoride levels and the IQ for 118 children

Statistical test	Result
Simple correlation method	r = - 0.32, P<0.01
Multiple correlation coefficient	R = 0.3172, P<0.01
Decision coefficient	R = 0.1006, P<0.05
Partial regression coefficient of urinary fluoride	b = - 1.9520, P<0.05

DISCUSSION

Fluoride can produce detrimental biochemical and functional changes in the developing human brain. Exposure may commence with fluoride in the maternal blood passing through the placenta to the foetus and continues during childhood from fluoride in food and drinking water. In the present study, a high-fluoride level in drinking water resulted in a greater intake of fluoride which was confirmed by higher urinary fluoride levels. Intelligence was, in turn, inversely related to the level of fluoride in both drinking water and urine. No confounding factors such as population size or differences in social, educational, or economic background explained the relationship.

The findings of this study thus replicate those of earlier studies[12,13] and suggest that a real relationship exists between fluoride exposure and intelligence. Possible mechanisms for such a relationship have been suggested. The ability of fluoride to enter the brain is enhanced by its ability to form a lipid-soluble complex with aluminium. Aluminofluoride complexes are able to stimulate guanine nucleotide binding proteins (G proteins) and can produce pharmacological and toxicological effects in animal and human cells, tissues and organs.[17]

In the low-iodine area of Xinjiang, high-fluoride levels have also been associated with an impairment in intelligence in children, and may occur through the development of hypothyroidism or subclinical cretinism.[18] Further studies to clarify the nature of the relationship between fluoride and intelligence are clearly indicated. Pending completion of such studies, exposure of children to high-fluoride levels may run the risk of impaired intelligence.

REFERENCES

1 Roholm K. Fluorine intoxication: a clinical-hygienic study with a review of the literature and some experimental investigations. London: HK Lewis; 1937. p. 281.

2 Mullenix PJ, Denbesten PK, Schunior A, Kernan WJ. Neurotoxicity of sodium fluoride in rats. Neurotoxicol Teratol 1995;17:169-77.

3 Isaacson RL, Varner JA, Jensen KF. Toxin-induced blood vessel inclusions caused by the chronic administration of aluminium and sodium fluoride and their implications for dementia. Neuroprotective Agents. Ann NY Acad Sci 1997;825:152-664.

4 Varner JA, Jensen KF, Horvath W, Isaacson RL. Chronic administration of aluminium-fluoride or sodium-fluoride to rats in drinking water: alterations in neuronal and cerebrovascular integrity. Brain Res 1998;784;284-98.

5 Guan ZZ, Wang YN, Xiao KQ, Dai DY, Chen YH, Liu JL, et al. Influence of chronic fluorosis on membrane lipids in rat brain. Neurotoxicol Teratol 1998; 20:537-42.

6 Yang W, Yu Y, Liu J. Protective effect of a SOD inducer on the brain changes of chronic fluorosis. Chinese Journal of Endemiology 1998;17:101-4.

7 Pang Y, Zhu P, Zhang S, et al. Protective effect of magnesium and selenium on the damage caused to brain cells by fluoride. Chinese Journal of Endemiology 1994;13:329-30.

8 Yu Y, Yang W, Dong Z, et al. Changes in neurotransmitters and their receptors in human foetal brain from an endemic fluorosis area. Chung Hua Liu Hsing Ping Hsueh Tsa Chih 1996;15:257-9.
9 Zhang A, Zhu D. Effect of fluoride on the human foetus. Chinese Journal of Endemic Prevention and Treatment 1998;13:156-8.
10 Shi J, Dai G, et al. A study of the effects of fluoride on the human foetus in an endemic fluorosis area. Chung Hua Liu Hsing Ping Hsueh Tsa Chih 1990;9:10-2.
11 Chen Z, Liu W, Su G. A study of the effects of fluoride on foetal tissue. Chinese Journal of Endemiology 1990;9:345-6.
12 Li XS, Zhi JL, Gao RO. Effect of fluoride exposure on intelligence in children. Fluoride 1995;28:189-92.
13 Zhao LB, Liang GH, Zhang DN, Wu XR. Effect of a high fluoride water supply on children's intelligence. Fluoride 1996;29:190-2.
14 Ren DL, Liu Y, An Q. An investigation of intelligence development of children aged 8-14 years in high fluoride and low iodine areas. Chinese Journal of Control of Endemic Diseases 1989;4:251-4. .
15 Li Y, Li X, Wei S. Effect of excessive fluoride intake on mental work capacity of children and a preliminary study of its mechanism. Hua His I Ko Ta Hsueh Hsueh Pao 1994;25:188-91.
16 Wang D, Qian M. Report on the village use of the Recension Chinese Combined Raven's Test. Information of Psychological Science 1989;(5):23-7.
17 Strunecká A, Patočka J. Pharmacological and toxicological effects of aluminofluoride complexes. Fluoride 1999;32:230-42.
18 Lin FF, Aihaiti, Zhao HX, Lin J, Jiang JY, Maimaiti, et al. The relationship of a low-iodine and high-fluoride environment to subclinical cretinism in Xinjiang. Iodine Deficiency Disorder Newsletter 1991;7.

Published by the International Society for Fluoride Research
Editorial Office: 727 Brighton Road, Ocean View, Dunedin 9051, New Zealand