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USING THE RAVEN'S STANDARD PROGRESSIVE MATRICES TO DETERMINE THE EFFECTS OF THE LEVEL OF FLUORIDE IN DRINKING WATER ON THE INTELLECTUAL ABILITY OF SCHOOL-AGE CHILDREN

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[SUMMARY: Children, aged 9–10½, from 22 villages in Jing County, Hubei Province, China, with different levels of fluoride in the drinking water were tested for their IQs according to the revised version of *Raven's Standard Progressive Matrices*. Among 141 children in villages with 2.1–4.0 ppm F in the drinking water, 34 (24.11%) had IQ scores in the top three categories (1–3) of intelligence; among 147 children in the villages with 0.1–0.2 ppm F, the number was 40 (27.21%), and among 159 children in villages with a "normal" 0.5–1.0 ppm F, the number was 92 (57.86%). For the lowest two IQ categories (4 and 5), the percentages were, respectively, 75.89, 72.79, and 42.14%. The reasons for this non-monotonic pattern are not clear.]

[Keywords: Children and fluoride; Fluoride in water; IQ in Chinese children; Raven's Standard Progressive Matrices.]

INTRODUCTION

There have been relatively few reports on the effects of fluoride on child intelligence. In order to investigate whether fluoride has an effect on child intelligence, we carried out intelligence testing between July and November 1988 on children ranging in age from 9 to 10½ years using the revised version of *Raven's Standard Progressive Matrices*.[1] The 447 subjects were drawn from 22 villages in eight townships of Jing County, Hubei Province, China. Each village had varying concentrations of fluoride in the drinking water. The results are reported here.

SUBJECTS AND METHODS

Test Subjects:

The fluoride ion selective electrode method was used to determine the fluoride content of the well water (in each case the main local water source for at least 10 years). Based on the results of the testing, the various villages were divided into the normal group (0.5-1.0 mg/L of fluoride), the high fluoride group (2.1–4.0 mg/L), and the low fluoride group (0.1–0.2 mg/L). The children were further divided into groups based on their age: the 9 year-old group (8 years, 9 months, 1 day to 9 years, 2 months, 30 days), the 9½ year-old group (9 years, 3 months, 1 day to 9 years, 8 months, 30 days), the 10 year-old group (9 years, 9 months, 1 day to 10 years, 2 months, 30 days), and the 10½ year-old group (10 years, 3 months, 1 day to 10 years, 8 months, 30 days). All test subjects were elementary school students who had grown up drinking the well water in their home village; there were a total of 228 boys and 219 girls.

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Testing method:

The standardized procedure used for the determination of intellectual ability was the revised version of *Raven's Standard Progressive Matrices*,[1] edited by Zhang Houcan and Wang Xiaoping from Beijing Normal University, suitable for the measurement of intellectual ability and for various kinds of comparative research.[1] The testing was administered individually, in strict compliance with the guidelines of that standard, by a single tester who was given professional training which included the awarding of a certificate. The testing was done blind, i.e., the tester did not know the fluoride content of water consumed by particular subjects tested. After testing was complete, the subjects were divided based on the number of days since their birth, then a percentage score determined using the smoothed scale for percentage conversion of *Raven's Standard Progressive Matrices* scores, and the final intellectual ability ranking assigned by reference to the Raven intellectual ability rankings, i.e., rank 1: a standardized score greater than 95% of children in the same-age theoretical norm group high intelligence; rank 2: a standardized score less than 95% but greater than 75%, above average intelligence; rank 3: a standardized score of between 25% and 75%, average intelligence; rank 4: a standardized score of between 5% and 25%, below average intelligence; rank 5: a standardized score of less than 5%, intellectually deficient.

TESTING RESULTS

Comparison of the average percentage scores for subjects with varying concentrations of fluoride in their drinking water:

A previous correlation of scores on the *Raven's Standard Progressive Matrices* with the IQ scores resulting from verbal, performance, and full scale testing using the *Wechsler Intelligence Scale for Children*[2] shows concurrent validity coefficients of 0.54, 0.70, and 0.71, respectively ($p<0.01$ for all). For the 5 villages (in 3 townships) that formed the high fluoride group in this study, the average intelligence score was 21.17%; the 8 villages (in 4 townships) that formed the low fluoride group had an average intelligence score of 23.03%. The normal group, made up of 9 villages (in 3 townships), had an average intelligence score of 28.14%. Statistical analysis shows that the difference between the high and low fluoride groups is not significant ($p>0.05$), and differences between the high and normal groups and the normal and low groups are both very significant ($p<0.01$).

Distribution of the intelligence ranking for subjects with varying concentrations of fluoride in their drinking water:

According to Raven score ranking methods, the percentage of subjects in the high fluoride group whose score put them in rank 1, 2, or 3 was 24.11%. In the low fluoride group, 27.21% of the subjects were ranked 1, 2, or 3. In the normal group, the subjects ranked 1, 2, or 3 made up 57.86% of the total (see Table 1).

Table 1. Intelligence rankings for tested subjects

Intelligence rank	High fluoride (2.1–4.0 ppm F)		Low fluoride (0.1–0.2 ppm F)		Normal fluoride (0.5–1.0 ppm F)	
	No.	%	No.	%	No.	%
Rank 1	1	0.71	0	0	2	1.26
Rank 2	3	2.13	6	4.08	9	5.66
Rank 3	30	21.28	34	23.13	81	50.94
Rank 4	53	37.59	67	45.58	46	28.93
Rank 5	54	38.30	40	27.21	21	13.21
Total	141	100.00	147	100.00	159	100.00

Comparison of intelligence scores among the various subject age groups with varying concentrations of fluoride in their drinking water (see Table 2):

After statistical analysis, the various age groups within the high fluoride group show no significant differences in average intelligence ($p>0.05$), the age groups with the normal fluoride group show no significant differences in average intelligence ($p<0.05$), however the low fluoride group does show very significant differences in intelligence based on age ($p<0.01$).

Table 2. Comparison of average intelligence by age

Age groups	High fluoride (2.1–4.0 ppm F)		Low fluoride (0.1–0.2 ppm F)		Normal fluoride (0.5–1.0 ppm F)	
	No.	%	No.	%	No.	%
9 year olds	36	21.44	34	18.82	31	26.14
9½ year olds	36	18.33	38	19.02	44	26.88
10 year olds	37	22.40	43	27.62	41	29.07
10½ year olds	32	22.62	32	25.05	43	29.76

Effects of varying levels of fluoride on average intelligence within age groups:

Taking the 9 year-old age group as an example, the intelligence difference between 9 year-olds in the normal fluoride group as compared with the low group is very significant ($p<0.01$), the difference between the normal and high groups is significant ($p<0.05$), and the difference between high and low groups is not significant ($p>0.05$).

DISCUSSION

By testing the intellectual ability of 447 elementary school students ranging in age from 9 to 10½, it was discovered that both high and low fluoride had an effect on child intelligence. Fluoride levels greater than 2.0 mg/L or less than 0.2 mg/L can disrupt intellectual development.

Using the Raven ranking scale, the children ranked 1, 2, or 3 in the normal fluoride group made up 57.86% of the total; this was by far the largest percentage among the three groups, with 24.11% and 27.21% of similarly ranked children in the high and low fluoride groups, respectively. The difference between the high and low groups was not statistically significant; however, the differences between normal and high as well as normal and low are both very significant. This indicates that the children whose drinking water has a fluoride content of above 2 mg/L or below 0.2 mg/L manifest intellectual deficits as compared to a "normal" control group.

Looking at the effects of fluoride content on intellectual ability across the various age groups, there are no significant differences between the intelligence scores of the different age groups in the high fluoride region. This result is in line with the basic principles of *Raven's Standard Progressive Matrices*. That the low fluoride area showed significant differences between the average intelligence scores of the different age groups may be attributable to changes in fluoride needs with age, but the mechanisms involved require further research.

Different levels of fluoride clearly affected children within the same age group. For instance, the 9 year-olds, where the intelligence difference between the normal fluoride group as compared with the low group was very significant, the difference between the normal and high groups significant, and the difference between high and low groups not significant. This further illustrates the effects of drinking water fluoride on child intelligence; both high fluoride and low fluoride influence intellectual ability.

To eliminate the effects of non-experimental factors, we selected students of the same age, all currently attending elementary school, and a single tester carried out all the testing. The proportion of each gender and all other relevant factors was essentially the same across subject groups, so that the testing could objectively reflect the effects of fluoride drinking on child intelligence. Fluoride is a protoplasmic poison; in excess amounts it has definite toxic effects on the cells of animals, including humans.[3,4] It enters the cells of various organ systems and binds with protoplasm inside, ultimately causing damage to protoplasm. Protoplasm is a mixture of biological substances with a protein base that can exist in a colloidal or gelatinous state. Fluoride, after entering a nerve cell, can damage the protoplasmic structure and its function, leading to a disruption of normal brain function. Under normal circumstances, fluoride ions maintain equilibrium within the body, a matter of primary importance for the normal physiological function of the organism. Fluoride is a key element with regard to teeth and bones, giving them increased mechanical strength; low fluoride areas have high cavity rates among children, and with older segments of the population more prone to osteoporosis. Child intellectual development also appears to show varying degrees of influence according to the seriousness of the fluoride deficit. Fluoride poisoning in humans can affect the activation of the central nervous system, typical sufferers of fluoride poisoning present with symptoms such as headache, dizziness, memory deficits, lethargy, fatigue, insomnia, upper respiratory inflammation, stomach pain, joint pain, rhinitis, dermatitis, and gingivitis. Animal studies have observed shedding of the myelin sheath and a decrease in the number of Purkinje cells, with irregularities in the Nissl bodies.[3] Other studies have demonstrated the effects of fluoride on the bioelectrical activity in the cerebral cortex of mice, with a clear drop in activity within the cerebral cortex after six months of exposure.[5] All of these finding serve to indicate that both high and low fluoride can affect the normal development and function of the cerebrum as well as the entire nervous system, causing a decrease in intellectual ability.

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