ORIGINAL ARTICLE

Impact of Fluoridated Water on Intelligence Quotient Levels of School Children - A Exploratory Study

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ABSTRACT

Background: In humans, dental and skeletal problems interconnected with fluoride are well documented. Disturbances of normal neurological functions of the central nervous system are of great concern among various biological effects associated with fluoride. Hence, the present study was conducted with an aim to assess the impact of fluoridated water on intelligence quotient (IQ) levels of school children.

Materials and Methods: A cross-sectional study comprised 88 school children in each group. Three villages were selected according to the concentrations of naturally obtained fluoride in drinking water, i.e., fluoride level <1.2 ppm (low), fluoride level ranging 1.2–2 ppm (medium), and fluoride levels >2 ppm (high). The fluoride concentration in the water sample was then estimated using fluoride ion selective electrode method. IQ was estimated using the Raven's Standard Progressive Matrices test. The independent *t*-test, one-way analysis of variance, and *post hoc* analysis were utilized to associate the mean marks of children in low, medium, and high-fluoride regions.

Results: Mean IQ level of school children was more (58.96 ± 11.65) in medium fluoride concentration of water, followed by low fluoride concentration of water (45.65 ± 12.40) and high fluoride concentration of water (32.98 ± 16.99) and there was a highly significant difference between the mean IQ levels and fluoride concentration. The maximum school children belonging to Grade III level (89.77%) in medium fluoride concentration and there was a highly significant difference between the fluoride concentration and IQ grades.

Conclusion: Fluoride concentration in drinking water is negatively correlated with IQ level of school children.

Keywords: Fluoride, Intelligence quotient, Raven's standard progressive matrices, School children.

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INTRODUCTION

Elevated concentration of naturally occurring fluoride (F) or arsenic (As) in drinking water is a worldwide problem. Many Asian and Latin American countries have reported concentrations of either F or As often exceeding the World Health Organization guideline values of 1.5 mg/L and 10 μg/L, respectively, or their prevailing national standards.[1] In many communities in the central and northern states of Mexico, people are exposed to either F and/or As in drinking water.[2]

Throughout decades of research and more than 60 years of virtual experience, fluoridation of public water supplies has been responsible for dramatically improving the public's oral health. In 1994, the U.S. Department of Health and Human Services released a report which reviewed its public health achievements. However, as every element has its pros and cons, we cannot overlook the cons of this element. Studies have shown that in those endemic F areas where most of the people, depend on groundwater for their survival, are at serious threat to get affected by the ill effects of the element. The intake of F above the threshold level can first affect the central nervous system before causing any dental or skeletal fluorosis.[3]

Disturbances of normal neurological functions of the central nervous system are of great concern among various biological effects associated with fluoride. It is observed in studies that if the mother has taken in an excessively high amount of F during pregnancy, she can transmit that through the placenta to the fetus thus affecting the intelligence quotient (IQ) of the child. The reason could be attributed to the fact that F can penetrate the fetal blood–brain barrier and accumulate in cerebral tissue before birth, thereby affecting the child's mental capacity and mental development.[4]

In humans, dental and skeletal problems interconnected with fluoride are well documented. Other

studies by Yang *et al*.[5] and Pang *et al*.[6] identified adverse effects of fluoride 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 fetal cerebral function and neurotransmitters. A study conducted by Spittle B *et al*.[7] did not show any trend or association between fluoride and the IQ of children.

The present study was conducted because there is a contradiction regarding the association of fluoride concentration in drinking water and IQ and because there are limited studies from Karnataka comparing IQ levels of school children with the difference in drinking water fluoride concentration.

MATERIALS AND METHODS

Study Design

A cross-sectional study was designed to compare the effect of fluoride in drinking water on the IQ among 12–15-year-old school going children in Mysore district. Parental consent was obtained by explaining the details and purpose of the study. A total sample of 88 children from each group was selected. Purposive sampling was used to determine the villages. 3 villages were selected according to the concentrations of naturally obtained fluoride in drinking water, i.e., fluoride level <1.2 ppm (low), fluoride level ranging 1.2–2 ppm (medium), and fluoride levels >2 ppm (high).

Inclusion Criteria

The following criteria were included in the study:

- Children who shared similar socioeconomic status
- Children who were permanent/continuous residents of the areas and drinking groundwater since birth
- Mothers having lived in the same village since their pregnancy.

Exclusion Criteria

The following criteria were excluded from the study:

- Children with birth defects, any form of neurological injury, brain wound, injury to the brain, or any systemic medical problem
- Children having a history of long-term living at places other than the place of birth.

Fluoride Estimation

Water samples were collected in pre-cleaned polyethylene (nonreactive) bottles from different villages surrounding Mysore district from the hand pumps noted to be the source of consumed water for the inhabitants. The bottles were coded which represented a particular village and were then stored in an icebox to preserve the majority of its physical, chemical, and biological characteristics. The fluoride concentration in the water sample was then estimated using fluoride ion selective electrode method (Thermo-Scientific Orion 4 star).

Intelligence Quotient Estimation

IQ was estimated using the Raven's Standard Progressive Matrices test.[8] This test consists of 60 multiple-choice questions, which were arranged in the order of difficulty. Raven *et al.* initially developed this test in 1936. Each test item consists of a missing element which the student has to identify and complete the pattern from the options. The total scores were transformed into percentile and specific grades were given as follows.

Grade I: Intellectually superior (IQ score ≥95%)
Grade II: Definitely above average (IQ score >75%)
Grade III: Intellectually average (IQ score 75–25%)
Grade IV: Definitely below average in intellectual capacity (IQ score ≤25%)
Grade V: Intellectually impaired (IQ score ≤5%).

Statistical Analysis

The data obtained were compiled systematically and were subjected to statistical analysis using Statistical Package for the Social Sciences (SPSS) version 20 (SPSS Inc., Chicago, IL, USA). The independent *t*-test, one-way analysis of variance, and *post hoc* analysis were utilized to associate the mean marks of children in low, medium, and high-fluoride regions.

RESULTS

Table 1 shows the mean IQ levels and fluoride concentration of study subjects. Mean IQ level of school children was more (58.96 ± 11.65) in medium fluoride concentration of water, followed by low fluoride concentration of water (45.65 ± 12.40) and high fluoride concentration of water (32.98 ± 16.99) and there was a highly significant difference between the mean IQ levels and fluoride concentration.

Mean IQ level of girls (59.03 ± 12.18) was more in medium fluoride concentration of water compared to boys (58.90 ± 11.12). In low and high fluoride

Table 1: Mean IQ levels and fluoride concentration of study subjects

Fluoride	Mean IQ levels	F value	*P* value
Low (<1.2 ppm)	45.65±12.40	54.365	0.0001***
Medium (1.2–2 ppm)	58.96±11.65		
High (>2 ppm)	32.98±16.99		

***Highly significant, IQ: Intelligence quotient

concentration of water, boys mean IQ level was more (48.87 ± 10.24 and 34.01 ± 18.15) compared to girls (42.44 ± 14.57 and 31.96 ± 15.84), respectively. However, there was no statistically significant difference between the groups [Table 2]. Table 3 reveals that the maximum school children belonging to Grade III level (89.77%) in medium fluoride concentration, followed by low fluoride concentration (68.18%). Moreover, there was a highly significant difference between the fluoride concentration and IQ grades.

DISCUSSION

Outcome measures revealed that exposure to higher levels of F determined by dental fluorosis status of child inferred higher IQ deficit. This designates that early and long-term contact with excess F causes deficits in memory attention, which was contrary to the results of Eswar *et al*.[4] who concluded that F level in drinking water was not significantly associated with IQ levels of 12–14-year-old school children in a high and low F village of Davangere, Karnataka, India. However, on the other side, studies on human fetuses have already shown that developing brain is the ripest targets for disruption by fluoride poisoning. Given that, at early stages of life, i.e., before the age of 6 years, the human brain is in its fastest stage of development, and that around seven and eight basic structural development is completed; therefore, the brain is most vulnerable to damage from excess F intake before this age.[9] The basis of abridged intelligence in children contacted with high levels of F is the ability of F to pass the blood–brain barrier, bringing about a functional impairment of the nervous system throughout the pre- and post-natal development.

The present study results showed a higher percentage of children with intellectually average IQ range in the entire fluoride group compared. This was in contrast to the findings of a study done Trivedi *et al*.[10] who reported that an increased fluoride concentration would affect the higher levels of intelligence more vigorously than normal and low intelligence levels.

Even several animal studies[11,12] explained the possible mechanisms for the neurotoxic effect of fluoride. Fluoride can pass through the placenta by maternal exposure to elevated fluoride levels during the prenatal period, or it may be ingested through the child's diet. High levels of absorbed fluoride in children (80–90%) and adults (60%) are retained in the body.[13] Once absorbed in the blood, fluoride forms lipid-soluble complexes which cross the blood–brain barrier and accumulate in cerebral tissues. The penetrated fluoride complexes adversely affect the *central nervous system* development by different neurotoxic mechanisms, such as free radical generation, inhibition of antioxidant and mitochondrial energy enzymes, and inhibition of glutamate transporters.

The present study is in contrast with Broadbent et al.[14] study results, where there was no apparent difference in IQ because of fluoride exposure. In the present study, certain factors were not taken into consideration such as exposure to school environment and freedom from physical trauma; the possible effects of the abovementioned confounding factors including the parental education and difference in socioeconomic status between the villages. Therefore, it is not possible to explain the IQ of children based on the effects of exposure to high or low-fluoride water alone.

In the present study, we found a negative correlation between IQ and fluoride concentration level in drinking water; these results were contrary to the research conducted by Kundu *et al*.[15] which showed a positive correlation of fluoride in drinking water with IQ (r = 0.417).

CONCLUSION

Fluoride concentration in drinking water is negatively correlated with IQ level of school children. Further studies required for exploring the other factors that might affect children's IQ need to be considered, and it is

Table 2: Mean IQ levels and fluoride concentration among boys and girls

Fluoride concentration	Mean IQ levels (boys)	Mean IQ levels (girls)	*t* value	*P* value
Low (<1.2 ppm)	48.87±10.24	42.44±14.57	0.268	0.601
Medium (1.2–2 ppm)	58.90±11.12	59.03±12.18	0.412	0.624
High (>2 ppm)	34.01±18.15	31.96±15.84	0.388	0.810

IQ: Intelligence quotient

Table 3: Fluoride concentration and IQ grades of school children

Fluoride concentration	Grade I (<95%)	Grade II (75–95%)	Grade III (25–75%)	Grade IV (25–5%)	Grade V (>5%)	F value	*P* value
Low (<1.2)	0 (0)	8 (9.09)	60 (68.18)	20 (22.72)	0 (0)	83.467	0.0001***
Medium (1.2–2.0)	0 (0)	5 (5.68)	79 (89.77)	4 (4.54)	0 (0)		
High (>2)	0 (0)	0 (0)	46 (52.27)	42 (47.72)	0 (0)		

***Highly significant

necessary to devise solutions for preventing the harmful effects of excessive intake of fluoride ion to the body.

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