Original Article

Effect of fluoridated water on intelligence in 10–12-year-old school children

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Abstract

Aim: The aim of the present study was to evaluate the relationship of drinking water fluoride levels with children's intelligence quotient (IQ). **Materials and Methods:** Water was collected from initially identified endemic fluoride regions according to the geological research of Government of India. Fluoride concentration of the water was assessed by utilizing fluoride ion selective electrode, Orion 9609BN, and categorized on the basis of fluoride concentration into low, medium, and high-fluoride regions, i.e., Virajpet (low fluoride level < 1.2 ppm), Banavara (Medium fluoride level 1.2–2 ppm), and Mastihalli (High fluoride levels > 3 ppm). Government school from all three villages were selected randomly and IQ levels were assessed by using Raven's Standard Progressive Matrices. This test was conducted on each child in the study sample. **Results:** A significant inverse relationship was found between the fluoride concentration in drinking water and IQ (r value = –0.204; $P < 0.000$). It was observed that IQ level was negatively correlated with fluoride concentration in drinking water. **Conclusion:** It is concluded that IQ level was negatively correlated with fluoride level in drinking water. Factors that might affect children's IQ need to be considered, and it is necessary to devise solutions for preventing the harmful effects of excessive intake of fluoride ion to the body.

Key words: *Dental fluorosis, drinking water, fluoride, intelligence quotient*

INTRODUCTION

Fluoride has both favourable and harmful effects on human beings. Induction of topical and systemic fluorides for the inhibition and prevention of dental caries is a significant problem in dentistry. Fluorides have brought an appreciable reduction in the dental caries prevalence, especially in advanced economic countries. However, in the 1980s, it was found that fluoride prevents caries mainly through its topical action. Drinking water is a common vehicle for fluoride intake. Increased concentration of naturally available fluoride in drinking water is an international concern. Concentration of fluoride level in most of the Asian countries including India is more than the World Health Organization (WHO) guidelines values. Sixty million Indians are residing in approximately 200 districts of 20 states categorized as the endemic areas of fluorosis.[1]

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One of the ten most crucial public health achievements of the 20th century is community drinking water fluoridation to reduce dental caries (Achievements in Public Health, 1900-1999: Fluoridation of Drinking Water to Prevent Dental Caries, 1999). Historically, millimolar (mM) concentration of fluoride has been used by biochemists and protein chemists as an enzyme inhibitor.[2]

According to Dr. A. K. Susheela, fluoride badly damages bone matrix formation and prevents hardening of bones. She discovered that, in approximately 20 countries of the world, serious health problems exist due to increased fluoride. She also found out that the increased levels of fluoride in drinking water were interconnected with early infant mortality, still births, and birth defects. Increased fluoride can cause detrimental neurologic effects. Rats injected sodium fluoride in their drinking water, which produces the same plasma level concentration of fluoride as that of humans consuming water with 4 ppm of fluoride was found to have similar symptoms as that of attention deficit-hyperactivity disorder.[3]

In humans, dental and skeletal problems interconnected with fluoride are well documented. Guan *et al*. found that the contents of phospholipid and ubiquinone in the rat brains were affected by chronic fluorosis, and that these changes in membrane lipids could be involved in the pathogenesis of this disease. Other studies by Yang *et al*. and Pang *et al*. 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 Hu *et al*. and Spittle *et al*. did not show any trend or association between fluoride and the intelligence quotient (IQ) of children.[4]

This study was conducted because there is a contradiction regarding the association of fluoride concentration in drinking water and IQ and because there are no studies from India comparing IQ levels of 10–12-year-old school children residing in three villages of Karnataka state with difference in drinking water fluoride concentration.

MATERIALS AND METHODS

A cross-sectional study was conducted to evaluate the relationship of drinking water fluoride levels with children's IQ over a period of 3 months from August 2014 to October 2014. Ethical clearance was taken from the Institutional Ethical Committee of CIDS, Virajpet. An official permission was obtained from the DDPI and school authorities. Parental consent was obtained by explaining the details and purpose of the study. A total sample of 96 from each group was selected using the formulae $N = z_{\alpha}^{2} P q/d^{2}$. Purposive sampling was used to determine the villages. 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). Government school children who were permanent residents of the three different villages with different fluoride levels in the drinking water and who consumed drinking water from a single source and fulfilled the inclusion and exclusion criteria were included in the study. Residents of the selected villages aged between 10 and 12 years were included in the study. Children suffering from any developmental disorder related to psychiatric illness and children with defective audio, speech, or visual activity were excluded.

Initially, endemic fluoride areas were recognized according to the geological research of Government of India. Water was collected from these areas and three villages were selected according to the drinking water fluoride concentration. These places were then categorized into low, medium, and high fluoride regions for the purpose of the study, i.e., Virajpet (low fluoride level < 1.2 ppm), Banavara (medium fluoride level ranging from 1.2–2 ppm), and Mastihalli (high fluoride levels > 3 ppm).

Water sample collection and analysis

A plastic bottle with a tight stopper was washed at least 2–3 times with water from the source. The bottle was then filled with 200 ml of drinking water and capped. Date and time of water collection and the location of water source (nearest postal address with pin code) was noted. The type of water source (e.g. open well/ borewell/tubewell) was also noted. The water fluoride levels was measured using a fluoride ion selective electrode, Orion 9609BN [Graph 1] at Malnad college of Engineering Consultancy Centre, Hassan, and categorized on the basis of fluoride concentration.

Assessment of intelligence

Intelligence level was assessed by conducting the Raven's Standard Progressive Matrices test.[5] Ravens test consists of 60 multiple- choice questions, which are arranged in the order of difficulty. This test was initially developed by John C. Raven 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%).

Government school from all three villages were selected randomly. Official permission was taken from DDPI and school authorities. On predetermined dates, government schools were visited. The purpose of the study was explained and verbal consent was taken from children. Before starting the test, the nature of the test and instructions for the test were explained to the children along with the method of providing answers in the record form. The test was performed by each child in the classroom under the direction of an investigator. Time allotted to complete the test was 40 mins. No chance for copying was allowed.

Statistical analysis

Analysis of the obtained results was carried out by four statistical tests. Analysis of variance (ANOVA) was done to test the significant difference in IQ levels based on fluoride concentration. Student's *t*-test was done to test the significant gender-based difference in IQ levels of three villages with three different fluoride concentrations in drinking water. Kruskal–Wallis ANOVA was done to test the significant difference in distribution of IQ grades with children in the low, medium, and high-fluoride areas. Correlation was evaluated using Spearman's rank correlation coefficient.

Graph 1: Water sample analysis for fluoride Using Orion 9609BN

RESULTS

Based on fluoride concentration level in drinking water, three villages were assigned into three groups – low, medium, and high (<1.2 ppm, 1.2–2 ppm, and > 2 ppm, respectively). There was almost an equal distribution of male and female children among areas with low, medium, and high concentration of fluoride in drinking water. In low fluoride concentration area, 49% of the study participants were males and 51% were females; in medium fluoride concentration area, 48% were males and 52% were females; and in high fluoride concentration area, 49% were males and 51% were females.

Table 1 shows the mean IQ level of study participants based on fluoride concentration. The mean IQ level was more in the region with medium fluoride concentration in drinking water (56.68) compared to areas with low fluoride concentration (41.03) and high fluoride concentration (31.59). When mean IQ levels were compared based on fluoride concentrations, a highly significant statistical association was found (0.0001 HS).

Table 2 shows the mean IQ level of boys based on fluoride concentrations. The mean IQ level of boys was more in areas with medium fluoride concentration (56.30) compared to regions with low fluoride concentration (41.47) and high fluoride concentration (30.92). When mean IQ levels of boys were compared based on fluoride concentration, a highly significant statistical association was found (0.0001 HS).

Table 3 shows the mean IQ level of girls based on fluoride concentrations. The mean IQ level of girls was more in areas with medium fluoride

Table 1: Mean IQ levels of study participants based on fluoride concentration

Fluoride	Mean IQ levels	*F*	*P*
Low (<1.2 PPM)	41.03±16.36	60.726	0.0001***
Medium (1.2-2 PPM)	56.68±14.51		
High (>2 PPM)	31.59±16.81		

*** *Highly significant*

Table 2: Mean IQ levels of boys based on fluoride concentration

Fluoride	Mean IQ	*F*	*P*
Low (<1.2 PPM)	41.47±14.93	34.527	0.0001 ***
Medium (1.2-2 PPM)	56.30±13.14		
High (>2 PPM)	30.92±16.09		

*** *Highly significant*

concentration (57.03) compared to regions with low fluoride concentration (40.62) and high fluoride concentration (32.24). When mean IQ levels of girls were compared based on fluoride concentration, a highly significant statistical association was found (0.0001 HS).

Table 4 shows the mean IQ level of boys and girls based on fluoride concentration. When mean IQ levels of boys and girls in low fluoride areas were compared, it was found to be statistically nonsignificant (0.800). When mean IQ levels of boys and girls in medium fluoride areas were compared, it was found to be statistically nonsignificant (0.808). When mean IQ levels of boys and girls in high fluoride areas were compared, it was found to be statistically nonsignificant (0.702).

Table 5 shows the IQ grades of the children in regions with low, medium, and high fluoride concentration in drinking water. In high fluoride areas, percentage of children with below average IQ, i.e., grade IV (25-5) was larger (59.37%) compared to low fluoride areas (15.6%) and medium fluoride areas (0). The proportion of children with IQ grades II and III was larger in regions with low fluoride concentration level in drinking water (3.12%, 81.25%) and regions with medium fluoride concentration in drinking water (8.3%, 81.25%) compared to high fluoride areas (0, 40.62%), and the difference was statistically significant (ANOVA = 97.344; $P < 0.0001$).

Table 3: Mean IQ levels of Girls based on fluoride concentration

Fluoride	Mean IQ	*F*	*P*
Low (<1.2 PPM)	40.62±17.77	27.028	0.0001***
Medium (1.2-2 PPM)	57.03±15.78		
High (>2 PPM)	32.24±17.62		

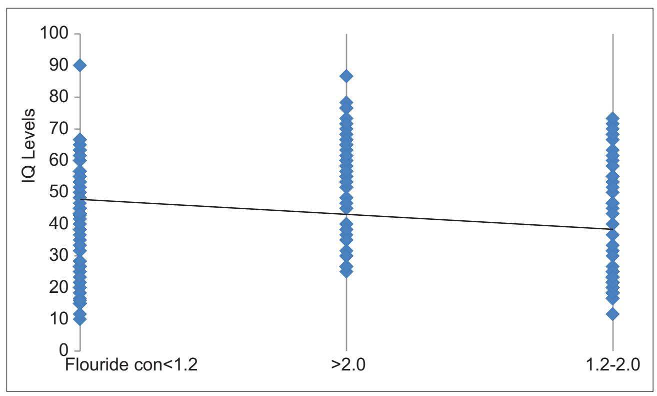
*** *Highly significant*

Graph 2 (r value = −0.204, $P < 0.0001$). It was observed that IQ level was negatively correlated with fluoride concentration level in drinking water and was highly significant ($P < 0.0001$).

DISCUSSION

The study was conducted in government school children aged 10–12 years. The study involved almost equal numbers of male and female children. The present study showed that there was no significant association between the mean IQ level and gender. These results are similar to the studies done by Poureslami *et al*.[6] and Seraj *et al*.[7] In a study conducted by Xian *et al*.,[8] only one village out of two villages considered had a significant relationship between IQ and gender. In a psychological book written by Beirne-Smith *et al*., gender is mentioned as a non-related factor to IQ.

The present study showed low mean IQ in high fluoride concentration areas (31.59 ± 16.81) compared to low fluoride concentration areas (41.03 ± 16.36).



Graph 2: Correlation between IQ and fluoride concentration in total patients

Table 4: Mean IQ levels based on fluoride concentration among boys and girls

Fluoride concentration	Mean IQ levels (Boys)	Mean IQ levels (Girls)	*t*	*P*
Low (<1.2 PPM)	41.47±14.93	40.62±17.77	0.254	0.800 NS
Medium (1.2-2 PPM)	56.30±13.14	57.03±15.78	0.244	0.808 NS
High (>2 PPM)	30.92±16.09	32.24±17.62	0.384	0.702 NS

Table 5: Distribution of IQ grades of the children based on fluoride concentration

Fluoride concentration	Grade I (<95%)	Grade II (75-95%)	Grade III (25-75%)	Grade IV (25-5%)	Grade V (>5%)	K ANOVA	*P*
Low (<1.2 PPM)	0 (0)	3 (3.12%)	78 (81.25%)	15 (15.6%)	0 (0)	97.344	0.0001***
Medium (1.2-2 PPM)	0 (0)	8 (8.3%)	88 (81.25%)	0 (0)	0 (0)		
High (>2 PPM)	0 (0)	0 (0)	39 (40.62%)	57 (59.37%)	0 (0)		

*** *highly significant*

The study results are similar to the study reported by Eswar *et al*., where mean IQ in high fluoride areas was 86.3 ± 12.8 and in low fluoride areas was 88.8 ± 15.3,[9] and in a study conducted by Karimzade *et al*., where the IQ of the 19 students in the high-fluoride areas was lower than 20 students in the low-Flouride areas.[10] According to Eswar *et al*., lack of IQ in children exposed to high levels of fluoride is mainly due to functional and biochemical harm to the nervous system during the prenatal and development periods of infancy and childhood because fluoride can cross the blood brain barrier; however, it is also due to factors involving variation in biological susceptibility, environmental conditions, and measurement errors.[11] During pregnancy, fluoride plays a major role in in determining IQ development such as freedom from disease, parental IQ, nutrition, prenatal care, breast feeding, physical trauma, and good schooling.[12] In addition, the present study results are consistent with the study of Sebastian and Sunitha[13] who demonstrated a higher percentage of children with above the normal IQ range in the normal and low-fluoride group compared to high-fluoride group. This was in line with the findings of Trivedi *et al*.,[14] who reported that an elevated fluoride level would affect higher levels of intelligence more vigorously than normal and low intelligence levels. There was a statistically significant difference in IQ levels of children belonging to high, medium, and low fluoride areas, which was in accordance with studies reported by Khan *et al*.[15] and Mondal *et al*.[16] The present study is in contrast with Broadbent *et al*.[17] 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, significant negative correlation was found between IQ and fluoride concentration level in drinking water (r value = -0.204, $P < 0.0001$), in which the results were contrary to the research conducted by Kundu *et al*.,[18] which showed a positive correlation of fluoride in drinking water with IQ (r = 0.417). Our study results were in accordance with those of Das *et al*.,[19] where IQ values were plotted against the urinary fluoride concentration, and it was found that they have a significant negative correlation (r = 0.751, $P < 0.01$). Further investigations are required with larger sample size considering all the confounding factors to clarify the nature of the relationship between intelligence and fluoride are clearly desirable.

CONCLUSION

Fluoride has been advised since a long time as the ideal preventive, therapeutic agent for dental caries. However, like a coin that has two sides, fluoride has both favorable and harmful effect. In the present study, it was observed that IQ level was negatively correlated with fluoride concentration level in drinking water and it is highly significant ($P < 0.0001$). Therefore, it is necessary to devise solutions for preventing the harmful effects of excessive intake of fluoride ion in the body. Because fluoride has the capability to be toxic to many organ systems, further toxicity studies must be conducted to evaluate this further. It is essential to evaluate the current situation and control the drinking water fluoride level if the fluoride concentration in a community's water supply is significantly above the permissible level of 1.5 mg/L.

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Conflicts of interest

There are no conflicts of interest.

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