Original Article

A cross-sectional study to assess the intelligence quotient (IQ) of school going children aged 10-12 years in villages of Mysore district, India with different fluoride levels

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ABSTRACT

Introduction: Besides dental and skeletal fluorosis, excessive fluoride intake can also affect the central nervous system without first causing the physical deformities associated with skeletal fluorosis. With the existence of widespread endemic fluorosis in India, the possible adverse effect of elevated fluoride in drinking water on the Intelligence Quotient (IQ) level of children is a potentially serious public health problem. **Aims and Objectives:** This study assessed the Intelligence Quotient (IQ) of school going children aged 10-12 years in villages of Mysore district with different fluoride levels. **Materials and Methods:** In this cross-sectional study, 405 school children aged 10-12 years were selected from three villages in Mysore district with normal fluoride (1.20 mg F/l), low fluoride (0.40 mg F/l) and high fluoride (2.20 mg F/l) in their water supplies. A pre designed questionnaire was used to collect the required data for the survey which included socio demographic details, oral hygiene practices, diet history, body mass index and dental fluorosis. Intelligence Quotient was assessed using Raven's colored Progressive Matrices Test. **Results:** In bivariate analysis, significant relationships were found between water fluoride levels and Intelligence Quotient of school children ($P < 0.05$). In the high fluoride village, the proportion of children with IQ below 90, i.e. below average IQ was larger compared to normal and low fluoride village. Age, gender, parent education level and family income had no significant association with IQ. **Conclusion:** School children residing in area with higher than normal water fluoride level demonstrated more impaired development of intelligence when compared to school children residing in areas with normal and low water fluoride levels. Thus, children's intelligence can be affected by high water fluoride levels.

KEYWORDS: Intelligence Quotient; Fluoride; Drinking Water, School children, Mysore District

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Introduction

For decades a major concern in India has been and remains the supply of safe drinking water. By early 2004, the rural drinking water supply program in India was estimated to have 3.7 million hand pumps dependent on ground water. While this has lowered the incidence of waterborne diseases, it has led to the emergence of other problems such as depletion of drinking water sources due to excessive withdrawal by irrigation wells and contamination by, for example fluorides and arsenic. The principal source of these fluoride contaminants being the soil.[1]

Fluoride has a significant mitigating effect against dental caries, if the concentration is approximately 1mg/l. However, continual consumption of higher concentrations can cause dental fluorosis and, in extreme cases, skeletal fluorosis. The guideline for fluoride in drinking water is 1.5mg/l. High fluoride concentrations are especially critical in developingcountries, largely because of lack of suitable infrastructure for treatment.[1] Apart from these, there are reports that excess fluoride consumption promotes cancer, hip fracture, leads to still birth or birth defects, and has detrimental neurological effects.[2]

Besides dental and skeletal fluorosis, excessive fluoride intake can also affect the central nervous system without first causing the physical deformities associated with skeletal fluorosis. Thus as an extreme example, toxic neuronal injury in the form of tetaniform convulsions in a 12-year old boy from ingestion of 1-ppm fluoridated drinkingwater was described in detail and found to subside with nonfluoridated water. Over the last 2 decades, more subtle injury from fluoride in the form of lower intelligence has been reported in China, India, and Iran.[3]

According to current research findings, fluoride produces neuronal dysfunction and synaptic injury by a mechanism that involves free radical production and lipid peroxidation. A recent study revealed that a high fluoride level in drinking water depressed learning-memory ability of brain in Wistar rats, in agreement with earlier findings of Mullenix *et al*., showing that fluoride exposure caused a common pattern of sex and dose-specific behavioral deficits in rats. Brain histology of Sodium fluoride-intoxicated rabbits revealed loss of molecular layer and glial cell layer, and Purkinje neurons exhibited chromatolysis and acquired a 'ballooned' appearance. Reduction and even complete loss of Nissl substance was observed in rabbit and rat brain.[4]

With the existence of widespread endemic fluorosis in India, the possible adverse effect of elevated fluoride in drinking water on intelligence quotient (IQ) level of children is a potentially serious public health problem. Mysore district in Karnataka state, India, is considered to be naturally fluoridated area according to Sachetana Drinking Water Project; Karnataka, undertaken by BAIF Institute for Rural Development.[5]

Hence, it provides what would appear to be an ideal locale to investigate the relationship between fluoride level in drinking water and IQ of children. Since a review of scientific literature indicated a scarcity of such studies in Mysore district, the current study was conducted to assess the IQ of school going children aged 10-12 years in villages of Mysore district with different fluoride levels.

Materials and Methods

Sampling methodology

Information regarding the fluoride levels in different places of Mysore district was obtained from Rajiv Gandhi National Rural Drinking Water Program (RGNRDWP) which showed low (<0.5 ppm), optimum (0.5-1.5 ppm), and high (>1.5 ppm) fluoride areas.[6] Based on these different levels of fluoride, three village panchayaths were randomly selected; namely, Nerale (2.0 ppm) which belonged to high fluoride area, Belavadi (1.2 ppm) which belonged to optimum fluoride area, and Naganahally (0.40 ppm) which belonged to low fluoride area. From each panchayath one school was selected for the study purpose. Each school was considered as a cluster and all school children in the age group of 10-12 years who fulfilled the eligibility criteria were included in the study.

Study population

Four hundred and five participants aged 10-12 years living in three villages in Mysore district were recruited for this cross-sectional study. The three selected rural areas were similar in their general demographic and geographic characteristics with the inhabitants having a comparable level of socioeconomic status and similar occupations. All participants were long-life residents of the villages under study, with their mothers having lived in the area during their pregnancies. The exclusion criteria included a history of genetic disease, systemic disorders, or brain trauma in the family. A written informed consent was obtained from the parents of all subjects after explaining the nature and aim of the study. A detailed questionnaire was completed including information about child's demographic status, parent's education, and family income.

Dental examinations

The dental examinations were carried out by the investigator itself according to the World Health Organization (WHO)-recommended Dean's index.[7] Prior to conducting the study, the investigator was trained in the Department of Public Health Dentistry, JSS Dental College and Hospital, Mysore under the supervision of an expert. Calibration was done on 20 subjects who were examined twice using diagnostic criteria on successive days, and then the results were compared to know the diagnostic variability. Agreement for assessment was 87%.

IQ evaluation

The intellectual ability of each child was calculated using Raven's Coloured Progressive Matrices (RCPM). The models were presented in the form of matrices. In each test item, the child was asked to identify the missing part that completes the model. The test was administrated in a convenient school classroom under the supervision of a trained psychologist following the procedures laid down in the manual of Raven's Progressive Matrices.[8] The average time taken to complete the test was 30 min. The test comprised of 36 problems, beginning with easy problems and ending with difficult ones. Each question contained a matrix of geometric design with six alternatives for one removed cell. Only one of the options fitted correctly.

The children's IQ scores were divided according to the Current Wechsler classification in six groups: Superior (120-129), high average (110-119), average (90-109), low average (80-89), border line (70-79), and extremely low (<70).

Statistical analysis

All analyses were performed by Statistical Package for Social Sciences (SPSS) version 17.0 for Windows. The

data were subjected to analysis of variance (ANOVA), post-hoc test, and binary logistic regression. The significance level was fixed at 0.05.

Results

Four hundred and five 10–12-year-old children took part in this study.Dental examination revealed that 74% children in high-fluoride group demonstrated mild to severe fluorosis. In comparison, only 20% of the subjects in the normal and 8% subjects in low fluoride groups showed very mild to severe fluorosis and the remaining were unaffected [Table 1]. An increase in water fluoride content above the standard level was associated with the incidence of more severe dental fluorosis ($P < 0.001$).

IQ evaluation results from the three groups are shown in Table 2. Although IQ scores for children with normal and low fluoride content were significantly higher than high fluoride level ($P < 0.01$), there was no statistically significant difference between the IQ of children residing in normal and low fluoridated areas ($P > 0.05$). Furthermore, we did not observe any significant difference between the scores of girls and boys in any of the groups examined ($P > 0.05$). IQ scores of children living in areas with various water fluoride content (normal, medium, and high) have been demonstrated in Table 3, exhibiting that more children residing in the normal and low fluoride area showed normal IQ levels.

Binary regression model was used to adjust the relationship between IQ score and the other potential confounders in the study. The dependent variable was IQ score. The independent variables included were age, gender, parental education, family income, and water fluoride level. After adjusting the variables, it was found that the IQ scores were increasing as the education level of parent increases. However, this association was not found to be significant. Significant association was found between the IQ score and water fluoride level when the variables like age, gender, parental education, and family income were controlled [Table 4].

Table 1: Fluorosis distribution in the three groups

Dental fluorosis index	Nerale, *n* (%)	Belavadi, *n* (%)	Naganahally, *n* (%)
Normal	17 (12.6)	98 (72.6)	121(89.6)
Questionable	18 (13.3)	10 (7.4)	3 (2.2)
Very mild	24 (17.8)	14 (10.4)	7 (5.2)
Mild	25 (18.5)	5 (3.7)	3 (2.2)
Moderate	13 (9.6)	7 (5.2)	0
Severe	38 (28.1)	1(0.7)	1(0.7)
Total	135 (100)	135 (100)	135 (100)

Discussion

Here we demonstrated that the average IQ of children living in the area with high fluoride content in the drinking water was significantly lower than children with normal and low water fluoride levels. Since all potentially confounding factors were adjusted, the difference in IQ scores may reveal the potential effect of high fluoride exposure on the intellectual development of children. These results are consistent with findings reported by Xiang *et al*., who confirmed a decrease in children's neurobehavioral ability when exposed to elevated fluoride levels.[9]

Furthermore, the current study compared three fluoride levels to evaluate the effect of different concentrations of fluoride on children's IQ and dental fluorosis. In addition, our results 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*., who reported that an elevated fluoride level would affect the higher levels of intelligence more vigorously than normal and low intelligence levels.[4]

Possible mechanisms for the neurotoxic effect of fluoride may be explained by several animal studies.[10-13] 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.[7,14] Once absorbed in the blood, fluoride forms lipid-soluble complexes which cross the blood-brain barrier and accumulate in cerebral tissues.[7,10,15] The penetrated fluoride complexes adversely affect

Table 2: Children's IQ in three areas in Mysore district

Place name	Mean IQ	Standard deviation	Significance	Water fluoride level	Post-hoc test		
					Group	Groups	Significance
Nerale(Ner)	80.49	12.67	0.01*	2.0 mg F/l	Ner	Bel	0.007 (S)
						Nag	0.03 (S)
Belavadi(Bel)	88.6	14.01		1.2 mg F/l	Bel	Nag	0.361 (NS)
						Ner	0.007 (S)
Naganahally(Nag)	86.37	13.58		0.40 mg F/l	Nag	Bel	0.361 (NS)
						Ner	0.03 (S)

*Statistically significant association using analysis of variance; S = Significant; HS = Highly significant; NS = Not significant; IQ = Intelligent quotient

Table 3: IQ score distribution for children living in areas with low, normal, and high water fluoride content

IQ category	Nerale, *n* (%)	Belavadi, *n* (%)	Naganahally, *n* (%)
Very superior	0	0	0
Superior	5 (3.7)	3 (2.2)	4 (3.0)
High average	1 (0.7)	7 (5.2)	4 (3.0)
Average	30 (22.2)	52 (38.5)	42 (31.1)
Low average	13 (9.6)	16 (11.9)	22 (16.3)
Border line	86 (63.7)	57 (42.2)	63 (46.7)
Total	135 (100)	135 (100)	135 (100)

IQ = Intelligence quotient

Table 4: Binary regression model based on intelligence quotient scores and the variables included in the study

Independent variables	Odd's ratio	95% confidence interval		*P*-value
		Lower bound	Upper bound	
Age	0.993	0.941	1.049	0.812
Gender				
Male	Reference			
Female	0.915	0.586	1.427	0.694
Parent education				
Primary school	Reference			
Middle school	1.091	0.378	3.148	0.872
High school	1.260	0.310	5.120	0.747
Intermediate/post high school	1.280	0.234	7.011	0.776
Family income				
1,533-2,556	Reference			
2,557-5,112	0.797	0.336	1.891	0.606
>5,113	0.259	0.037	1.792	0.171
Water fluoride level				
Naganahally (0.40 mgF/l)	Reference			
Belavadi (1.20 mgF/l)	1.740	1.016	2.980	0.044
Nerale (2.2 mgF/l)	0.590	0.293	1.188	0.140

the CNS development by different neurotoxic and exciotoxic mechanisms, such as free radical generation, inhibition of antioxidant and mitochondrial energy enzymes, and inhibition of glutamate transporters.[16]

Our findings showed that the prevalence and severity of dental fluorosis was greater among children with high water fluoride content. As a probable result of "the halo effect", we found a 20% prevalence of fluorosis in children living in the village with a standard fluoride level, which was in accordance with WHO guidelines explaining that at an optimal fluoride level (1 ppm), about 20% of the population demonstrate fluorosis.[7,17] However, in village with a higher than standard fluoride level, 83% children demonstrated dental fluorosis with a severity index of very mild to severe.

In this study, we administrated RCPM test to evaluate the child's intellectual development, a validated test for basic cognitive abilities and widely used to evaluate the normal development of brain functions. It consists of problems containing a matrix of geometrical design, with a part removed. The child has to select the missing cell from six given alternatives. Owing to the high correlation of this test in evaluating children's IQ (ranging from 0.7 to 0.92) compared to the conventional IQ test, RCPM is recommended for measuring the intellectual and conceptual ability of young children. Furthermore, due to the nonverbal characteristics of the test, it is successfully administrated in preschool children, as it does not require any verbalization or reading skills.[18,19]

As it is well accepted, the neurobehavioral development may be influenced by many genetical, socioeconomical, and geographical factors. Thus, we have recruited our samples from a homogenous population in Mysore district, diminishing the effect of some environmental and inherited factors, yet it is obvious that complete exclusion of such factors is impossible. In the present study, the education level of the parent appears to play a definite role. Yongxiang *et al*., discovered that the IQs of children born into an "employed" household was higher than those born into a farming household, and that the IQ levels of the children increased along with the education level of their parents.[20] This indicates that a positive educational influence from the family is a benefit to child's intellectual development. Therefore, strict uniformity requirements must be enforced when selecting an area for study, determining the test subjects, etc. The present study paid special attention to this aspect; and the occupation and education levels were basically matched in all the three villages.

In a previous study, the urinary fluoride level was implemented as the basic indicator for the child's fluoride exposure.[21] However, since urinary fluoride excretion may vary from one subject to the other or even in the same person, and because drinking water was typically the greatest single contributor to daily fluoride intake in this area; we have evaluated the effect of different amounts of fluoride in drinking water. In the present study, the effect of fluoride concentration on the child's IQ was assessed; however, it is possible that other trace elements in drinking water may have some neurological side effects. Thus, further studies are required to investigate the effect of other environmental or geological contaminants.

Srikanth, in 2009, pointed out that in India about 62 million people are suffering from various levels of fluorosis, of which 6 million are children below the age of 14 years.It should not come as a surprise that excess fluoride is one of the three major hurdles according to tenth 5-year plan in India.[22] Although the biomechanism of fluoride in reducing IQ is not clear;but

on the basis of the data from this study, it is evident that excess fluoride in drinking water has neurological toxic effects. Therefore, a close monitoring of fluoride levels in local watersupplies from areas with endemic fluorosis and implementing public health measures to reduce the fluoride exposure levels in high fluoridated regions seem necessary.

Conclusion

The IQ scores of children living in areas with above the standard water fluoride levels were lower compared to children living in normal and low fluoride level regions. In the high fluoride village, the proportion of children with IQ below 90, that is, below average IQ was larger compared to normal and low fluoride village. Age, gender, parent's educational level, and family income had no significant association with the IQ scores.

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