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Original Research Article

Relationship between intelligence quotient and water fluoride levels of school-going children aged 6-12 years in and around Mahbubnagar district – a cross-sectional study

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ABSTRACT

Background: Excess fluoride exposure during childhood leads to dental fluorosis and, according to some studies, has also been associated with lower neurocognitive test scores. This study assessed the intelligence quotient (IQ) of school-going children aged with aged with 6-12 years in villages of the Mahbubnagar district with varying levels of fluoride in drinking water.
Methods: A cross-sectional study was conducted among the permanent residents of Mahbubnagar district, Telangana state, India. A total of 480 government school-going children aged 6-12 years were selected through stratified random sampling from 3 different areas with varying levels of naturally occurring fluoride in drinking water. The IQ levels of the children were assessed using Ravans standard progressive matrices test (1991, edition).
Results: The mean IQ levels were higher in villages with low fluoride concentration in drinking water (15.26) compared to those with medium fluoride content (12.91) and high fluoride content (9.10). A statistically significant association was observed ($p<0.01$).
Conclusions: The overall IQ levels of children exposed to high fluoride concentration were significantly lower than those in low-fluoride areas, indicating that high levels of fluoride in drinking water adversely affect children's intelligence.

Keywords: Drinking water, Fluoride, Intelligence quotient, School children

INTRODUCTION

Fluoride, a mineral found in water, soil, and food, is known for preventing dental caries. Many countries, including India, add fluoride to drinking water to combat tooth decay.[1]

Mahabubnagar district is geographically region situated in Telangana state along the border with Karnataka state, is predominantly inhabited by populations of lower-socio-economic status. Several areas in Telangana state are known to have elevated fluoride concentrations in their drinking water sources. Mahbubnagar district is one such are where a significant portion of the population is affected by both dental and skeletal fluorosis.

While effective for dental health, concern about its potential neurological effects, especially on children's developing brains, have emerged.[2]

Fluoride acts as a protoplasmic poison, and when present in excessive amounts, it produces toxic effects on animal cell including human. It enters the cells of various organ systems, binds with the protoplasm, and ultimately causes damages to cellular structures. After entering nerve cells, fluoride can damage the protoplasmic structure and impair its function, leading to disruption of normal brain activity. Under normal circumstances, however, fluoride ions help maintain equilibrium with in the body, which is of primary importance for the normal physiological functions of the organisms.[3]

Fluoride poisoning in humans can impair central nervous system (CNS) activity. Typical clinical manifestations include headache, dizziness, memory defects, lethargy, fatigue, insomnia, upper respiratory tract inflammation, abdominal pain, joint pain, rhinitis, dermatitis, and gingivitis.[4]

Experimental animal studies have further demonstrated neurotoxic effects, such as demyelination, a reduction in the number of Purkinje cells, and irregulates in Nissl bodies.[5]

India's diverse fluoride concentration, influenced by natural and industrial sources, offer a unique context to investigate its cognitive impacts.[6]

Since a review of the scientific literature indicated a scarcity of such studies in the Mahbubnagar district, the present study was undertaken to assess the intelligence quotient (IQ) levels of school-going children aged 6-12 years in villages of Mahbubnagar district with the varying fluoride concentration in drinking water.

METHODS

Study design

A cross-sectional study was assessed the IQ of school going children aged 6-12 years in villages of Mahbubnagar district with different levels.

Study area

Mahbubnagar district lies between 15^0 55 and 17^0 15^0 North latitudes and 77^0 15^1 and 79^0 15^0 East longitudes. The district covers an area of 18,432 km and lies an average elevation of 498 metres above sea level, with a population of 4,042,191. The annual average temperature is around 32^0. The district has a predominantly rural population, with about 85%, living in rural areas. The literacy rate is around 65.21% for males and 44.72 for females.

It contains about 6 revenue division, 90 mandals, 370 villages, 1230 panchayats, primary school 3031, upper primary schools 528, high schools 1117, and high secondary school were 2.[7]

Sampling technique/section of sample/sample size

The sampling procedure involved multistage sampling was used, where the entire Mahbubnagar district was divided into 5 strata based on different levels of naturally occurring fluoride in drinking water supply, fluoride levels in the drinking water supply.[8] Fluoride levels in the drinking water for stratifying the district were obtained from the documented records of district rural water supply department, Mahabubnagar.

Fluoride level low in Balanagar (low 0.6 PPM). Areas with medium fluoride levels Ramayyabowli (1.2 ppm) and high fluoride levels (>2 ppm) Kosghi. Were identified from each area, are school was selected using the simple random sampling method, resulting in a total of approximately 20 government schools being selected from the specified areas.

A total of 480 eligible were randomly selected from the lists obtained from school going records. Age eligibility requires that the subjects fall in to the approximate age at the time of sampling. All 6-12 years old children present on the day of clinical examination were included in the study.

Inclusion criteria

All the participants aged 6-12 years enrolled in selected primary schools, resident in the area >1 year, and parental/guardian consent and child assets illness were included.

Exclusion criteria

Children suffering from chronic conditions affecting cognition (eg. untreated epilepsy, severe malnutrition, children on chromic medication cognition), children who had migrated from other areas or were not permanent residents of the study area, children with orthodontic brackets, and children with severe stains on their teeth, for whom assessment was not possible were excluded.

Collection water sample analysis

Water sample collection was carried out following the methodology outlined in the National Oral Health Survey and fluoride mapping (2002-03).[9]

A sufficient number of clean plastic bottles (Tenkobyte Pvt Ltd, India) were taken to the selected schools for water sample collection. The date, time and location of each water source were recorded, along with water source were recorded, along with the type of water source.

The fluoride concentration in the collected water samples was measured using the Alzarin visual method.[10]

Data collection, ethical clearance and informed consent

Prior to commencement of the study, an ethical clearance was obtained from the ethical committee of S. V. S. Institute of Dental Sciences, Mahabubnagar. An official permission was obtained from the district educational office, Mahabubnagar.

Informed consent was obtained from the school head masters on behalf of the students before the onset of study.

Scheduling

The study was carried out over a period of 4 years, from 2009-2013.

Study tools

Data were collected using a self-administered questionnaire and clinical examination. The questionnaire included information on demographic details, permanent residential address, sources of drinking water, duration of use of the current water sources, staple foods routinely consumed, beverages, and aids used for maintaining oral hygiene.

Socio-economic status was considered as one of the confounding variables. The modified Kuppaswamy socio-economic status scale was used to assess the socio-economic status of each child.[11] It consisted of a questionnaire that included information on parental education, family in come, fathers' occupation, and other relevant factors.

Dental examinations

An ADA specified type III dental examinations was carried out by the investigator in accordance with WHO (1997) guidelines.[12]

All the teeth of the participants were examined for the presence and severity of dental fluorosis. Subsequentially, the results were compared to assess the diagnostic variability among the examinations.

Assessment of intelligence

Intelligence level was assessed by conducting the Ravens standard progressive matrices test. (SPM). Ravens test consists of sets A, B, C, D and E each set having a multiple-choice question. Participants were instructed to answer all questions on a specifically designed answer sheet.

This test was initially developed by John C. Raven in 1936. Each test item includes items, with a missing element that the participants must identify to complete. A visual pattern from the given options. There were allotted a time limit of 30 minutes according to the specification of the test manual.

The total scores were transformed in to percentile and specified grades were given as follows - grade 1: 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 intellectually impaired. (IQ score <75%), and grade V: intellectually impaired (IQ score <5%).

RESULTS

Table 1 shows the children analysed according to the different levels of fluoride the mean IQ score were more in the villages with low fluoride concentration in drinking water (mean raw score 15.26) compared to villages with medium fluoride concentration (mean raw score 9.1).

Table 1: Children analyzed according to the different levels of fluoride.

F levels	Area	Number of children per area
Low	Kothur (0.6 ppm)	160
Medium	Ramayya Bowli (1.2 ppm)	160
High	Kosghi (2.2 ppm)	160

When the mean IQ levels of boys were combined, higher scores were observed in villages with low fluoride concentration (mean raw score 16.23) compared to those with medium (mean raw score 13.60) and high fluoride concentration (mean raw score 9.43) (Table 2).

Table 2: Mean IQ levels of total children.

F levels	Mean IQ levels (mean±SD)	F	P value
Low	15.26±3.40	25.41	<0.001
Medium	12.91±8.14		
High	9.18±6.65		

ANOVA test, SD=standard deviation, IQ=intelligence quotient

The mean IQ levels of girls were based on fluoride concentration of girls were more in the villages with low fluoride concentration (mean raw score 14.25). Compared to villages with medium fluoride concentration (mean raw score 8.91) (Table 3).

Table 4 shows the mean IQ levels of girls were compared based on fluoride concentration, a significant statistical association was found ($p<0.01$).

Table 3: Mean intelligence quotient levels of boys.

F levels	Mean IQ levels (mean±SD)	F	P value
Low	16.23±8.23	16.361	<0.001
Medium	13.60±8.16		
High	9.43±6.48		

ANOVA test, SD=standard deviation, IQ=intelligence quotient

Table 4: Mean IQ levels of girls.

F levels	Mean IQ levels (mean±SD)	F	P value
Low	14.25±8.51	9.308	<0.001
Medium	12.17±10		
High	8.91±6.67		

ANOVA test, SD=standard deviation, IQ=intelligence quotient

DISCUSSION

The mean IQ score levels of children in low, medium and high fluoride villages are 15.26, 12.91 and 9.18 respectively with a p<0.01, indicating a statically significant. The mean IQ score levels of boys in low, medium, and high fluoride villages are 16.23, 13.6 and 9.43 respectively, and when mean IQ levels in low, medium, and high fluoride villages, it was 14.25, 12.17, and 8.91 respectively.

The correlation between boys and girls in low, medium, and high villages is not significant with p=0.138, 0.268, and 0.612 respectively. The percentage of children with grade II score in low, medium, and high fluoride villages are 6.25%, 3.75% and 1.875 respectively.

The percentage of children with grade III score in low, medium, and high fluoride villages are 61.25, 56.87, and 36.25 respectively. The percentage of children with grade IV score in low medium, and high villages are 32.5, 39.37 and 6.87 respectively.

The results are consistent with the findings of Haripriya et al, Till et al and Wang et al in high fluoride areas, percentage of children with below average IQ i.e. grade IV was larger (59.37%) compared to low fluoride areas (15.37%) compared to low fluoride areas (15.6%) and medium fluoride areas (0%).[13-15] 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 low regions with medium fluoride concentration in drinking water (8.3%, 81.25%) compared to high fluoride areas (0%, 40.62%) and the difference in percentage is due to variations in sample size and variations in concentration of fluoride levels in these studies.

In the present study, the percentage of children with below average IQ i.e. grade IV was larger (61.87%) in high fluoride villages compared to low fluoride villages (32.5%), and medium fluoride village (39.37%).

The proportion of children with IQ grade II and III was larger in villages with low fluoride fluoride level in drinking water (6.25%, 61.25%) compared to villages with medium fluoride concentration in drinking water (3.75%, 36.87%) and the difference was statically significant (p<0.01).

The result of present study was not in agreement with those of Ahmad et al who found no difference in IQ related to fluoride exposure.[16] This discrepancy may be attributed to various factors, such as difference in school environment and the control of potential confounding variables, including parental education and socio-economic status between the villages.

According to Veneri et al the lower IQ observed among the children exposed to elevated fluoride levels may be attributed to the neurotoxic effects of fluoride on the developing nerves system during prenatal and early childhood periods, as fluoride is capable of crossing the blood-brain barrier.[17]

Studies conducted on human fetes from endemic fluorosis regions have demonstrated that fluoride accumulation in brain tissue can disrupt neurotransmitter activity and neural receptor function, accompanied by a decrease in the numerical density, and volume of neurons and undifferentiated neuroblasts.[18,19]

A possible mechanism explaining this association has been proposed. Fluoride ability to cross the blood-brain barrier is facilitated by the formation of lipid-soluble complexes with aluminium. These alumino fluoride complexes are known to stimulate guanine-nucleotide binding protein (G-proteins), there by eliciting various pharmological and toxicological effects in animal and human cells, tissues, and organs.[20]

According to Guth et al, this association was attributed to the high levels of fluoride absorbed to the high levels of fluoride absorbed in to the blood, which form lipid -soluble complexes capable of crossing the blood-brain barrier and accumulating in cerebral tissues.[21]

The penetrating fluoride complexes adversely affect the development of CNS system through various neurotoxic and ecotoxic mechanisms, such as free radical generations, inhibitions of antioxidant and mitochondrial energy enzymes, and suppression of glutamate transporters.

The structural and functional alternations in the CNS, particularly during the fetal period and 1st 8 year of life, may use to leaving difficulties, intellectual deficits, and neurological dysfunctions.

According to Feng et al the reduced IQ observed in children exposed to high levels of fluoride is primarily due to functional and biochemical damage to the functional and biochemical damage to the nervous system during to the developmental periods of infancy and childhood, as fluorides of infancy and childhood, as fluoride can cross the blood -brain barrier.[22]

Stereological and ultramicroscopic studies of this tissue revealed poor differentiation of brain nerve cells and delayed brain development. This suggests that developing brain is highly sensitive to the toxic effects of fluoride.[20]

Limitations

The limitation of the study was the cross-sectional study design and the limited sample size. Since fluoride compounds are bio degradable, they tend to accumulate gradually in the environment, including the food chain, soil, plants, and in the bones and teeth of human beings.

The findings of the present study highlight that the consumption of fluoride-containing water in fluorosis - endemic areas can be considered a potential risk factor affecting the IQ levels of children.

CONCLUSION

In light of the facts discussed above, the present study, which included 480 subjects aged 6-12 years, concludes that dental fluorosis and IQ levels were not significantly influenced by age or gender. The findings of this study suggest that the overall IQ level in children exposed to high fluoride was significantly lower than in low fluoride areas.

The data from this research may support the hypothesis that excessive fluoride exposure through drinking water may have adverse effects on the nervous system. Millions of children worldwide are exposed to elevated concentrations of fluoride in drinking water, and many may therefore be potentially at risk of neurodevelopmental effects.

Therefore, close monitoring of fluoride levels in local water supplies, particularly in areas with endemic fluorosis, is essential. Implementing appropriate public health measures, such as water defluoridation, is necessary to reduce fluoride concentration in high-fluoride regions and minimise potential health risks.

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