Effect of fluoride exposure on Intelligence Quotient (IQ) among 13-15 year old school children of known endemic area of fluorosis, Nalgonda District, Andhra Pradesh.

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ABSTRACT

Background: Waning controversy over fluoride and water fluoridation is rekindling with the findings released from certain fluoride studies which reported an inverse association between fluoride exposure and intelligence.

Objective: To assess the relationship between exposure to different drinking water fluoride levels and children's Intelligence Quotient (IQ) among 13-15 year old school children of Nalgonda District, Andhra Pradesh.

Methodology: An analytical cross sectional study was conducted among the permanent residents of Nalgonda District of Andhra Pradesh. A total of 1000 school children aged 13-15 years were selected by stratified random sampling from four different areas with different levels of naturally occurring fluoride in drinking water. Raven's standard progressive matrices (1992 Edition) were used for assessment of Intelligence Quotient (IQ) of children.

Results: Intellectually superior (Grade 1) scores for individual IQ assessment were absent in all the 4 different fluoride levels. Only 0.8% of children were present in Grade 1(definitely above the average in intellectual capacity) scores except in 4th level (>4.1ppm). Number of intellectually impaired children were gradually increased with the increase in fluoride concentration in the drinking water.

Conclusion: Findings of this study suggest that overall IQ levels in children's exposed to high fluoride level were significantly lower than the low fluoride areas.

In view of many endemic Fluorosis areas in India, it is needed that further studies be conducted to examine the link in humans between fluoride & disturbances of the development & function of the central nervous system.

Key words: Fluoride, Intelligence quotient (IQ), Raven's standard progressive matrices.

INTRODUCTION

The waning controversy over fluoride and water fluoridation is rekindling with the findings released from certain fluoride studies which reported an inverse association between the fluoride exposure and intelligence[1,2,3,4,5,6].

It has been reported that fluoride can penetrate the fetal blood brain barrier and accumulate in cerebral tissue before birth, there by apparently affecting children's intelligence[2].

Human maternal exposure to high-fluoride levels was found to have an adverse effect on fetal cerebral function and neurotransmitters. Reduced intelligence in children was associated with exposure to high fluoride levels in food or drinking water[1].

Endemic fluorosis continues to remain as a challenging national health problem. Over more than three decades of continuing epidemiological studies on the prevalence of endemic fluorosis indicated that over 60 million children's are affected with endemic fluorosis in India[7].

Nalgonda district of Andhra Pradesh, India consist of various levels of fluoride in drinking water starting from below optimal to optimum and above optimal levels[8]. In view of the above mentioned reports of increased fluoride levels in water, it is needed that studies be conducted to examine whether there is a link in humans between fluoride and disturbances of the development and function of the central nervous system.

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With the study in recent years of endemic fluorosis, attention has been given to the effects of fluoride on intelligence in children.

AIMS AND OBJECTIVES

To assess the relation between exposures to different drinking water fluoride levels and children's intelligence quotient (IQ) among 13-15 year old school going children of Nalgonda district of Andhra Pradesh, India.

MATERIAL AND METHODS

Study Design

A cross-sectional Analytical study was conducted among 13-15 year old school children of Nalgonda district, Andhra Pradesh.

Study population/ Source of Data

Data was collected from the 13-15 year old school going children who were life long residents of Nalgonda district, Andhra Pradesh and who consumed drinking water from a same source in the initial 10 years of their life.

Sampling technique / Selection of sample, Sample size

A stratified random sampling technique was used. The entire geographical area of Nalgonda district was divided into 4 strata based on different levels of naturally occurring fluoride in drinking water supply. Fluoride levels in the drinking water for stratifying the district was obtained from the documented records of District Rural Water Works Department, Nalgonda. Level 1 or the first strata consisted of villages with water fluoride levels less than 0.7 ppm, Level 2 or the second strata consisted of villages with water fluoride levels ranging from 0.7- 1.2 ppm, Level 3 or the third strata consists of villages with water fluoride levels ranging from 1.3-4ppm, and the Level 4 or the fourth strata consists of villages with fluoride level more than 4.0 ppm. So in each strata or Levels several villages were involved from which children were randomly selected from schools. Sample size was divided equally among all four strata and representation from both the sex was included in the sampling.

Levels/ Strata	Fluoride content in ppm
Level 1	< 0.7 ppm
Level 2	0.7 – 1.2 ppm
Level 3	1.3 – 4.0 ppm
Level 4	> 4.0 ppm

Inclusion criteria

1. School going children aged 13-15 years who were life-long residents of that region are included in this study.

Exclusion criteria

1. Children who had a history of brain disease and head injuries.
2. A child whose intelligence had been affected by congenital or acquired disease.
3. Children who had migrated from some other place or who were not the permanent residents of that particular area were excluded.
4. Children with orthodontic brackets.
5. Children with severe extrinsic stains on their teeth, in whom assessing fluorosis is not possible, are excluded in this study.

Collection and analysis of water sample

Collection of water samples was done based on the methodology followed in National Oral Health Survey and Fluoride Mapping 2002-2003. During the initial visits to the schools, the children were interviewed regarding history of their residence and the source of drinking water from birth to 10th year of life. Water samples were collected from those who satisfied the inclusion criteria. Sufficient number of plastic bottles of 200ml capacity were carried to schools.

A bottle was given to the 1st child of the school who was interviewed and satisfied the inclusion criteria. Another bottle was given to the next child, only if the source of drinking water was different from the previous one. If the source of drinking water of a child is same as collected previously, water was not collected from the child. Children were asked to collect the sample of water from the source which was used in initial 10 years of their life.

Water bottles were collected on the next day. All bottles were assigned serial number and identification particulars of the individuals including village, mandal and source. All assigned a serial number, the serial number of the bottles indicate the serial number of source of drinking water and thus number was recorded in the questionnaires of all the children who consumed water from that particular source.

The water samples collected were subjected to water fluoride analysis using ion specific electrode Orion 720A fluoride meter at District Water

Works, Nalgonda to confirm the fluoride levels in the water before commencement of clinical examination.

Data collection: Ethical Clearance and Informed Consent:

Ethical clearance: Before start of the study, an ethical clearance was obtained from the Ethical Committee of College of Dental Sciences, Davanagere. An official permission was obtained from the District Educational officer (DEO), Nalgonda.

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

Scheduling

The study was conducted between the months of 1st August 2006 to 31st October 2006.

Study tools

Data was collected using a self administered questionnaire and clinical examination. Self administered questionnaire consisted of information on demographic data, permanent residential address, information on source of drinking water, duration of use of present source of drinking water, staple food, liquids routinely consumed, aids used for oral hygiene maintenance (fluoridated or nonfluoridated).

Socio-economic status was considered as one of the confounding variable so, Kakkar socio-economic status scale (KSESS)[9] was used to assesses socio-economic status of the each children. It consisted of questionnaire, with 8 closed ended questions related to parental education, family income, fathers occupation etc. All the children were asked to fill the form and the answers obtained were scored using kakkar socio-economic status scoring keys, finally all the children were divided into 3 groups i.e lower class, middle class and upper class.

Assessment of IQ levels

The Raven's standard progressive matrices 1992 Edition[10] was used to assess the IQ levels of each child at the age of 13-15years, it's a non verbal questionnaire consisting of sets A, B, C, D & E each set having 12 questions. Each student was given a questionnaire and was asked to answer all the questions in a separately designed answer paper. They were allotted a time limit of 30 min according to specification of the test manual. The results obtained were converted into percentile and then overall score in individual assessment of child was given as Grades, so 1000 children were graded as follows.

Grade 1: "intellectually superior", if a score lies at or above 95th percentile for people of the same age-group.

Grade 2: "definitely above the average in intellectual capacity", if score lies at or above the 75th percentile.

Grade 3: "intellectually average", if a score lies between the 25th and 75th percentile.

Grade 4: "definitely below average in intellectual capacity" if a score lies at or below the 25th percentile.

Grade 5: "intellectually impaired", if score lies at or below the 5th percentile for that age group.

Clinical examination

Finally clinical examination was carried out for each child to assess dental fluorosis using Dean's fluorosis index under the adequate natural light in school premises or corridors. The subjects present on the day of examination were made to sit on a chair or stool as per availability in upright position with proper head rest (wall). The examiner stood on right side, slightly in front of the patient during the examination.

Method of calibration of examiner

All the examination was carried out by a single examiner (i.e., investigator himself) and recording was done by another person, who was familiar with the local language and assisted the examiner in recording the details.

Calibration of the examiner was done before the study was conducted and in the middle of the study by doing duplicate examination of 5% (1 in 20) of the total population and intra examiner agreement was assessed with Kappa statistics for dental fluorosis with Kappa levels above 75%.

STATASTICAL ANALYSIS

The Data was subjected to statistical analysis, since the data are ordinate type, non parametric method were used for analysis, Chi-square test was used to test the association between different variables i.e. Fluoride levels, Deans score & socio-demographic factors with IQ levels.

Spearmen's rank co-relation was used for measuring the relationship between the two variables using 'SPSS for windows' software.

RESULTS

A total of 1000 children were involved in the study (Males- 549 and Females- 451). The sample of 1000 children were proportionately divided into 4 different fluoride levels, 247 in level < 0.6 ppm, 243 in level 0.7-1.2 ppm, 267 in level 1.3-3.1 ppm and 243 in level > 4.1.

Table 1 shows the demographic characters of the study population including number of respondents, their age, and sex.

Table 2 shows distribution of children IQ scores from areas with differing fluoride levels in drinking water. The intellectually superior (Grade 1) scores for individual IQ assessment were absent in all the 4 different fluoride levels. Only 0.8% of children were present in Grade 2(definitely above the average in intellectual capacity) scores except in 4th level (> 4.1 ppm).

At fluoride level ≤ 0.6 ppm about 29.1% of children had an IQ score Grade 3(intellectually average). 70.8% of the children with fluoride level > 4.1 ppm had an IQ score Grade 5 (intellectually impaired).

So the number of intellectually impaired children were gradually increased with the increase in fluoride concentration in the drinking water. So more number of intellectually average children were found in low drinking water fluoride areas.

Chi-Square test used to test the association between different fluoride levels with IQ scores & Spearmen's rank co-relation used for measuring the relationship between the two variables showed a statistically significant inverse association between the two with $P < 0.001$.

Table: 1 Demographic Data

		SEX		Total
		Male	Female	
AGE In Years	13%	106	115	221
		19.3%	115	25.5
	14%	235	263	498
		42.8%	58.3%	49.8%
	15%	208	73	281
		37.9%	16.2%	28.1%
Total%		549	451	1000
		100.0%	100.0%	100.0%

Table 2: The distribution of child IQ scores from areas with differing fluoride levels in drinking water

IQ Grades	Fluoride Levels				Total
	< 0.6(%)	0.7 – 1.2(%)	1.3 – 3.9(%)	> 4.1(%)	
Grade 2	2 (0.8)	1(0.4)	1(0.4)	0	4(0.4)
Grade 3	72(29.1)	33(13.6)	43(16.1)	19(7.8)	167(16.7)
Grade 4	82(33.2)	74(30.5)	70(26.2)	52(21.4)	278(27.8)
Grade 5	91(36.8)	135(55.6)	153(57.3)	172(70.8)	551(55.1)
Total	247	243	267	243	1000

(Comparing IQ Grades with different water Fluoride levels the $\chi 2 - 63.969$, $P < 0.001$ Spearmen's rho- 0.23, $P < 0.001$ statistically significant difference was found)

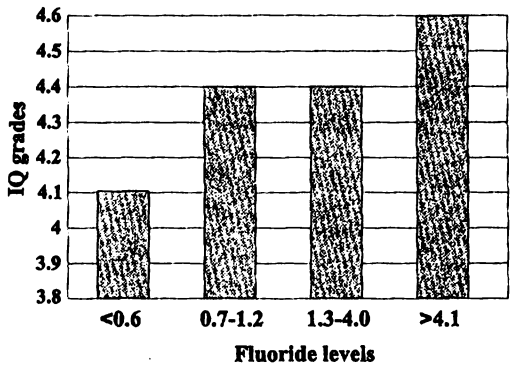

Fig. 1: IQ grades in relation to fluoride levels

Fig 1 clearly indicates, as the level of fluoride increases the mean IQ scores also increase i.e., the number of intellectually impaired children also increase gradually with increase in fluoride levels in drinking water.

Table 3 shows the association between Deans fluorosis index scores and IQ Grades of children. Children with Dean's index score 1 about 31.8% of children had an IQ score of Grade 3 (intellectually average) on the other hand 11.7% of the children with Dean's score 4 had IQ score Grade 3 (intellectually average) and 67.1% of the children with Dean's fluorosis score 4 had an IQ score of Grade 5 (intellectually impaired).

Chi-Square test used to test the association between Deans index scores with IQ scores & Spearmen's rank co-relation used for measuring the relationship between the two variables showed a statistically significant association with $P < 0.001$.

Table 4 & Table 5 shows that age and sex are the other two variables which were associated with IQ which did not show any significant association with IQ levels. (Chi-Square and spearmen's rank co-relation showed $P > 0.05$ NS)

Table 6 depicts one of the confounding variable socio-economic status and IQ which did not show any statistically significant association.

Table 3: The Distribution of child IQ grades with deans index scores

IQ Grades	Deans Index Scores					Total
	0.5(%)	1(%)	2(%)	3(%)	4(%)	
Grade 2	1(10.0)		1(0.6)	1(0.2)	1(0.4)	4(0.4)
Grade 3	4(40.0)	57(31.8)	37(23.6)	41(9.9)	28(11.7)	167(16.7)
Grade 4	5(50.0)	44(24.6)	39(24.8)	140(33.8)	50(20.8)	278(27.8)
Grade 5		78(43.6)	80(51.0)	232(56.0)	161(67.1)	551(55.1)
Total	10(100)	179(100)	157(100)	414(100)	240(100)	1000(100)

(Comparing IQ Grades with different Deans Index scores the $\chi 2 - 63.497$, $P < 0.001$ Spearmen's rho- 0.18, $P < 0.001$ statistically significant difference was found)

Table 4: The Association between IQ grades with age of children

IQ Grades	Age in Years			Total
	13(%)	14(%)	15(%)	
Grade 2	1(0.5)	2(0.4)	1(0.4)	4(0.4)
Grade 3	36(16.3)	80(16.1)	51(18.1)	167(16.7)
Grade 4	68(30.8)	140(28.1)	70(24.9)	278(27.8)
Grade 5	116(52.5)	276(55.4)	159(56.6)	551(55.1)
TOTAL	221(100)	498(100)	281(100)	1000(100)

(Comparing IQ Grades with different socio-economic status the $\chi 2 - 3.340$, $P > 0.05$ Spearmen's rho- 0.01, P-0.63 statistically significant difference was not found)

Table 5: The association between IQ grades with sex of children

IQ Grades	Sex		Total
	Male (%)	Female (%)	
Grade 2	2(0.4)	2(0.4)	4(0.4)
Grade 3	92(16.8)	75(16.6)	167(16.7)
Grade 4	165(30.1)	113(25.1)	278(27.8)
Grade 5	290(52.8)	261(57.9)	551(55.1)

(Comparing IQ Grades with different socio-economic status the $\chi 2 - 4.420$, $P > 0.05$ Spearmen's rho- 0.04, P-0.13 statistically significant difference was not found)

Table 6: The association between IQ grades with socio-economic status of children

IQ Grades	Socio-Economic Status			Total
	Low (%)	Middle (%)	High (%)	
Grade 2	1(0.4)	1(0.2)	2(0.8)	4(0.4)
Grade 3	44(17.2)	85(17.6)	38(14.6)	167(16.7)
Grade 4	65(25.4)	148(30.6)	65(24.9)	278(27.8)
Grade 5	146(57.0)	249(51.6)	156(59.8)	551(55.1)
TOTAL	256(100)	483(100)	261(100)	1000(100)

(Comparing IQ Grades with different socio-economic status the $\chi 2 - 6.722$, $P > 0.05$ Spearmen's rho- 0.02, P-0.46 statistically significant difference was not found)

(Chi-Square test and Spearmen's rank co-relation both showed $P > 0.05$ NS)

DISCUSSION

This study was conducted with a afford to assess the relation between exposures to different drinking water fluoride levels and children's intelligence quotient (IQ) among 13-15 year old school going children of Nalgonda district of Andhra Pradesh, India.

It was a cross sectional analytical study conducted on an stratified random sample of 1000 school going children selected from 4 regions with different levels of naturally occurring fluoride in drinking water supply.

In this study, it was noted that about 70.8% in Grade 5 (intellectually impaired) 7.8% in Grader 3(intellectually average) & no children in Grade 2 were present from fluoride level 4 which was comparable to study conducted by Li et.al, (1995)[1] in which 47.5% in severe & 49.1% in medium fluorosis area had low or borderline IQ < 79.No children with IQ > 120 were present in both areas, there was a statistically significant difference between 4 different fluoride levels and IQ scores ($P < 0.05$)(S). So the high fluoride environment adversely affects the development of intelligence in children.

It appears that the influence of a high fluoride environment on the development of intelligence may occur early in development such as during the stages of embryonic life or infancy when the differentiation and growth of the nervous system is most rapid. A higher concentration of fluoride has been found in embryonic brain tissue obtained from termination of pregnancy operations in areas where fluorosis due to coal burning was prevalent. Stereological and ultramicroscopic study of this tissue showed the differentiation of brain nerve cells was poor, and brain development was delayed. This suggests that developing brain tissues are sensitive to the toxic effects of fluoride[1].

In the present study no one was reported from Grade 1 (intellectually superior) in any of the 4 different fluoride levels. 29.9% were in Grade 2 & 3 (definitely above average & intellectually average) in fluoride level < 0.6 ppm. Only 7.8% were in Grade 2 & 3 in fluoride level > 4.1 in the present study, thus indicating that less number

of children with intellectually above average and average were present in the high fluoride areas which was similar to studies conducted by Zhao et.al, (1996)[2] in which IQ scores of 120 or higher (superior intelligence) was 17% in Xiaoyi (low fluoride area) but was only 12% in sima (high fluoride area). Average IQ of 97.69 in Sima which was lower than Xiaoyi with average IQ 105.21 was significant with $P < 0.01$ (S), Lu et.al, (2000)[10] where Mean IQ of high fluoride level children was significantly lower than children living in low fluoride level in drinking water ($P < 0.05$) (S) and Xiang et.al.,(2003)[5] in two villages Wamiao & Xinhuai Shanghai province China, Xinhuai (low fluoride) 27% of children tested as bright normal or high IQ, where as Wamiao (high fluoride) only 8.11% were in that category $P < 0.05$(S). Possible mechanisms for such a relationship have been suggested. The ability of fluoride to enter the brain is enhanced by its ability to form a lipid soluble complex with Aluminum. Aluminofluoride complexes are able to stimulate guanine nucleotide binding protein (G proteins) and can produce pharmacological and toxicological effects in animal and human cells, tissues and organs[4].

There was no co-relation between age and IQ ($P > 0.05$) (NS) in the present study which was similar to the study conducted by Li et.al, (1995)[1].

There was no co-relation between sex and IQ ($P > 0.05$) (NS) in the present study which was similar to the study conducted by Li et.al, (1995)[3] and Zhao et.al, (1996)[2].

In the present study, socio-economic status variables like Family income, parental education did not show any significance with IQ levels P>0.05(NS) which was in agreement with findings of the study conducted by Xiang et.al.,(2003)[5].

CONCLUSION & RECOMMENDATIONS

The findings of this study suggest that an overall IQ level in children exposed to high fluoride level was significantly lower than the low fluoride areas.

In India according to the reports of National Oral health Survey and Fluoride Mapping 2002-2003 report overall prevalence of severe fluorosis in children between 12-15 years is 6%. Haryana, UP & AP are the three states having prevalence of severe fluorosis which was higher than the national average. In view of this report of increased prevalence of fluorosis, it is needed that further studies should be conducted in these high fluoride areas to examine the link in humans between fluoride & disturbances of the development & function of the central nervous system.

Further studies to clarify the nature of the relationship between fluoride and intelligence are clearly indicated.

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