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Effect of fluoride in drinking water on children's intelligence in high and low fluoride areas of Delhi

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ABSTRACT:

Introduction: Fluoride is one of the indispensable elements for the living being. However, the intake of F above the threshold level can affect the central nervous system even before causing dental or skeletal fluorosis. **Aim:** The aim was to assess the effect of fluoride in drinking water on the intelligence quotient (IQ) of 8–12 years old school going children residing in high and low Fluoride (F) areas of Delhi. **Materials and Methods:** A total of 200 school children were selected, 100 from low F area and 100 from high F area. The IQ of the children was assessed using Ravens Standardized Progressive Matrices Test. Information for each child's sociodemographic data, mother's diet during pregnancy, duration of residency in the village, source of drinking water, and duration of drinking water from the source was entered on a specially designed proforma from mothers of children. Height and weight were also recorded for each child to assess the nutritional status. Independent *t*-test and Chi-square test was used to compare mean IQ scores in high and low fluoridated areas. Pearson's correlation and multivariate linear regression were used to appraise the issue of all the study variables on IQ. **Results:** Comparison of mean IQ of children in both high (76.20 ± 19.10) and low F (85.80 ± 18.85) areas showed a significant difference ($P = 0.013$). Multiple regression analysis between child IQ and all other independent variables revealed that mother's diet during pregnancy ($P = 0.001$) along with F in drinking water ($P = 0.017$) were the independent variables with the greatest explanatory power for child IQ variance ($r^2 = 0.417$) without interaction with other variables. **Conclusion:** Fluoride in the drinking water was significantly related with the IQ of children. Along with fluoride, mother's diet during pregnancy was also found to be significantly related with IQ of children. Researches in the same field are further advocated with large sample size and over a large geographical area.

Key words:
Diet, fluoride, intelligence quotient, pregnancy, school children

INTRODUCTION

Fluoride (F) although being an essential trace element for health is often called as a double-edged sword. This is because of both its beneficial and damaging effects on teeth. On one hand, the daily supplementation with F is certainly an important preventing factor in protecting teeth from dental caries, has an important mitogenic stimulus for osteoblasts, it may enhance mineral deposition in bone; but on the other hand, F, above a threshold concentration, it has been shown to be toxic.[1] The WHO's drinking water quality guideline value for F is 1.5 mg/L (WHO, 1993). However, WHO emphasizes that in setting national standards for F it is particularly important to consider climatic conditions, volumes of water intake, and intake of F from other sources (e.g., food and air).[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.[3] 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 from the ill effects of the element.[4] The intake

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of F above the threshold level can first affect the central nervous system before causing any dental or skeletal fluorosis.[5] 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.[6] 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.[7]

As of September 2012, a total of 42 studies have investigated the relationship between F and human intelligence, and a total of 17 studies have investigated the relationship F and learning/computer storage in animals. Of these investigations, 36 of the 42 human studies have found that elevated F exposure is linked with reduced IQ, while 16 of the 17 animal studies have found that F exposure impairs the learning and retention capacity of animals. The human studies, which are based on IQ examinations of over 11,000 children, provide compelling evidence that F exposure during the early years of life can damage a child's developing brain. After reviewing 27 of these studies, it was concluded that F effect on the young brain should now be a "high research priority."[8]

India contributes to 12 million of the total 85 million tons of F deposits in the earth's crust.[9] Hence, it is natural that F contamination is widespread, intensive, and alarming in India.[9] Endemic fluorosis is prevalent in India since 1937.[10] About 50% of the groundwater in National Capital Territory of Delhi exceeds the maximum permissible limit for F in drinking water.[11] Various studies conducted in India have found lower IQ in children living in high F areas.[6,12,13] Similarly, many researchers have found that parents, education and mother's diet during pregnancy also cause an event on the IQ of children.[14-16]

Therefore, the present study was conducted to assess the effect of Fluoride (in drinking water) and other factors like mother's diet during pregnancy, mothers and fathers' education, occupation, nutritional status of children on the IQ of 8–12 years old, school going children, residing in high and low Fluoride areas of Delhi in light.

MATERIALS AND METHODS

Study design

A cross-sectional study was designed to compare the effect of fluoride in drinking water on the IQ among 8–12 years old school going children residing in high and low fluoride areas of Delhi.

Study area

National Capital Territory of Delhi lies between 28.6100°N latitude and 77.2300°E longitude with a total area of 1483 km^2. The total population of the study area is 13.783 million (Ministry of Finance 2008), with a population density of 9344 individuals/km^2. The Delhi region is a part of the Indo Gangetic Alluvial Plains, at an elevation ranging from 198 to 220 m above mean sea level. The climate of Delhi is semiarid, with an average yearly rainfall of around 612 mm and an annual potential evaporation of nearly 2565 mm. The annual average temperature is 25°C.[17] There are various high fluoride areas in Delhi which include Palam village (1.2–32.5 ppm), Nangloi (1.7–13.6 ppm), Sagarpur (3.4–24.6 ppm) and Najafgarh where except for the control part whole block is polluted.[18,19] All these areas come in South West Delhi with a population of 115,382 in Palam village, 205,497 in Nangloi, approximate 10,000 houses in Sagarpur and 1,365,152 in Najafgarh as per census 2011.[20]

Sampling

Convenient sampling was used to include 1 high (Najafgarh) and 1 low fluoride area (Defence Colony). There are a total of 12 government schools in Najafgarh (high fluoride area) and 4 schools in Defence Colony (low fluoride area)[21] from which, using convenient sampling, 1 government school was selected from both the areas respectively. All the children from 8 to 12 years of age present on the day of examination who gave consent and satisfied the following inclusion and exclusion (100 from low and 100 from high fluoride area) were included in the study.

Inclusion criteria

- Children who were permanent/continuous residents of the areas and drinking ground water since birth
- Children who shared similar socioeconomic status
- Only biological children were included in the study.

Exclusion criteria

- Children with birth defects, any form of neurological injury, brain wound, injury to the brain or any systemic medical problem.

Ethical clearance and permission

The ethical clearance for the present study was obtained from the Institutional Review Board. Written permission was sought from the school offices. Before the study, prior information was sent to the principal and class teachers of the concerned classes to call the mothers of the selected children for the study.

Training and calibration

Two-day training sessions for standardization and calibration of the data collection methods were organized in the Department of Public Health Dentistry. The training session consisted of a revaluation of the criteria outlined, followed by an examination of children based on simulation of field technique for reliability. Dental fluorosis was assessed using Deans fluorosis index 1942 index. Intra-examiner reliability was assessed through Cohen's Kappa which came to be 0.85.

Fluoride estimation

Drinking water (bore well water) from both the areas was collected in polypropylene bottles (nonreactive) and were brought to the laboratory (National Test House, Ghaziabad) in an icebox to preserve majority of its physical, chemical and biological characteristics. 4 samples of water collected from 4 different bore wells from both the areas were analyzed on the same day in national test house using Ion-Selective electrode method.

Clinical examination

The children were made to sit on the chair and the oral examination of study subjects was conducted in respective schools using a plane mouth mirror under natural light and Dental fluorosis was assessed by Deans fluorosis index - Modified (1942).[22] Two most severely affected teeth were assessed and the score was given for the less severely affected tooth.

Sociodemographic information

Information for each child's sociodemographic data (age, sex, mothers and fathers' education), mother's diet during pregnancy (routine or any special diet as suggested by the doctor during pregnancy), duration of residency in the village, source of drinking water, and duration of using the water from that origin was entered on a specially designed proforma collected from mothers of the children. Socioeconomic status was recorded using Modified Prasad's classification.

Anthropometric measurements

Height and weight were used to assess children's nutritional status. Height was measured by the principal investigator, with the child standing erect against a wall mounted measuring tape in centimeters. Weight was also assessed by the principal investigator using a weighing balance in kilograms.

Centers for Disease Control classification of body mass index (BMI) for children was used:

- Underweight = <5th percentile
- Healthy weight = 5th percentile to <85th percentile
- Overweight = 85–95th percentile
- Obese = ≥95th percentile.

Intelligence quotient estimation

The IQ of the school going children was assessed using Ravens Standardized Progressive Matrices (SPM) test prepared by John C Raven (1998). Prior to administering the test, an explanation of the nature of the test and instructions was given to the children regarding the method of writing the answers in the required form. The trial was administered to each child individually in the school classroom under the supervision of the police detective. No opportunity of copying was allowed. Answer sheets were held back from the students after 20 min. Raw score obtained by children was converted into the standard score (based on the age of the children) by the psychologist and comparison was done on the basis of these standard scores.

Statistical analysis

The information collected was subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) version 19. (SPSS Inc., Chicago, IL, USA). The independent *t*-test was used to compare mean IQ scores in low and high F areas, Chi-square test was used to compare dental fluorosis scores in both the fluoridated areas, Pearson's correlation and multivariate linear regression was used to appraise the issue of all the study variables on IQ.

RESULTS

The study was conducted in school children with a mean age of 10.38 ± 1.52 years in high F areas and 10.28 ± 1.57 years in the low F area with a mean weight of 61.04 lbs (27.68 kg) and 64.94 lbs (29.45 kg) in high and the low F area, respectively [Table 1]. Equal numbers of male and female children were included in the study. Most of the parents were illiterate or read up till primary or middle primary level. Majority of the fathers of children residing in high F area were unskilled and those in low F area were occupied in skilled nonmanual occupations.

Comparison of mean IQ of children in both High and Low F areas showed a significant difference ($P = 0.013$). IQ of children in a high F area was found to be significantly less when compared to those in low F areas [Table 2]. No dental fluorosis (score 0) was found among 10 children in high fluoride area as compared to 94 in low fluoride area. Very mild (Score 1) dental fluorosis was found among 20 children in high fluoride and 6 in low fluoride area. None of the subject in either of the area had questionable dental fluorosis. Mild, moderate and severe (score 2, 3, and 4) dental fluorosis was found among 24 (24%), 21 (21%) and 25 (25%) children in high fluoride area as compared to none among the low fluoride area. This comparison showed a significant difference among both the groups for dental fluorosis ($P = 0.001$) [Table 3]. Of all the variables taken; area, mothers education and mothers diet during pregnancy were found to be positively correlated with IQ [Table 4]. As these factors were found to be positively correlated; to confirm their relation, multivariate regression was applied to them.

Table 1: Sociodemographic variables

Variables	High F area	Low F area
Mean age (in years)	10.38±1.52	10.28±1.57
Gender		
Male	50	50
Female	50	50
Mean weight in lbs (kg)	61.04 (27.68)± 18.24 (8.27)	64.94 (29.45)± 27.08 (12.28)
Mean height (in cm)	119.54±19.65	122.83±22.44
Mean BMI±SD	19.44±4.72	19.21±4.49
Nutritional status (%)		
Underweight	48 (48)	44 (44)
Healthy weight	38 (38)	46 (46)
Overweight	12 (12)	10 (10)
Obese	2 (2)	0 (0)
Fathers' education (%)		
Illiterate	12 (12)	16 (16)
Primary education	54 (54)	48 (48)
Middle primary education	24 (24)	18 (18)
Higher school	4 (4)	10 (10)
Intermediate	6 (6)	8 (8)
Mothers' education (%)		
Illiterate	38 (38)	38 (38)
Primary education	38 (38)	28 (28)
Middle primary education	24 (24)	22 (22)
Higher school	0 (0)	12 (12)
Father's occupation (%)		
Unskilled	36 (36)	24 (24)
Partly skilled	8 (8)	12 (12)
Skilled manual	32 (32)	24 (24)
Skilled nonmanual	24 (24)	40 (40)

BMI: Body mass index, SD: Standard deviation

Table 2: Comparison of mean IQ scores in both low and high F areas

Area	*n*	Mean IQ standard score	Standard deviation	Standard error mean	*P**
High F area	100	76.20	19.101	2.701	0.013
Low F area	100	85.80	18.854	2.666	

*Significance level <0.05, statistical test used - Independent *t*-test. IQ: Intelligence quotient

Table 3: Dental fluorosis scores in both regions

Area	Dental fluorosis score					Total	χ^2	*P**
	0	1	2	3	4			
High F area (%)	10 (10)	20 (20)	24 (24)	21 (21)	25 (25)	100	72.692	0.001
Low F area (%)	94 (94)	6 (6)	0 (0)	0 (0)	0 (0)	100		

*Significance level <0.05

Multiple regression analysis between child IQ (dependent variable) and F in drinking water, mothers diet during pregnancy, nutritional status of children, mothers and fathers education, and occupation (independent variables) revealed that mother's diet during pregnancy (*P* = 0.001) along with F in drinking water (*P* = 0.017) were the independent variables with the greatest explanatory power for child IQ variance (r^2 = 0.417), without interaction with other variables [Tables 5 and 6].

DISCUSSION

The present study revealed a positive correlation of IQ with fluoride in drinking water along with other significant factors like mothers diet during pregnancy. Low IQ among children living in high fluoride area was also observed in the studies conducted by Trivedi *et al.*,[23] Yun *et al.*,[24] Poureslami *et al.*,[5] Shivaprakash *et al.*[13] and contrary to the results of Eswar *et al.*[7]

The precise mechanism of the action of F in reducing IQ is not well-defined. Guan *et al.*[25] demonstrated that the contents of phospholipids and ubiquinone are altered in the brain of rats affected by chronic fluorosis, and therefore changes in membrane lipids could be a cause of this disorder.[25] A principal ground for reduced intelligence in human children exposed to high levels of F is the ability of F to cross the blood brain barrier, producing biochemical and functional impairment of the nervous system during prenatal and development periods of early childhood and childhood. IQ, however, is known to be influenced by many factors, including differences in biological susceptibility, environmental conditions, and measurement errors.[17]

Variables like nutritional status, mother's diet during pregnancy, parental education, occupation, and maternal exposure to F during pregnancy also play a large role in determining IQ development.[26] In the present study, positive correlation was found between IQ and F level in drinking water, mother's diet during pregnancy, and mothers' education (*P* = 0.015, 0.001, and 0.004, respectively). To assess the direction of association multivariate linear regression was applied, which showed a significant association of IQ with F levels in drinking water and the mother's diet during pregnancy. Although almost 50% of the children in our study were underweight; no significant relation was found between nutritional status and IQ. However, several studies in the past have found a significant impact of low weight on low IQ of children. This was primarily attributed to malnutrition (reflected by child's weight/BMI) which effects IQ and causes poor cognitive performance.[26]

Pregnancy diet impacts the long-term health, wellbeing, brain development, and mental performance of the children, according to researchers from a research project funded by the European Commission through its 7th Framework Program (NutriMENTHE) who assessed diet during pregnancy in a 5-year study of European

Table 4: Correlation between various variables in both high and low F areas

Pearson correlation significant (two-tailed)	Area	IQ	Fathers education	Mothers education	Occupation	Nutritional status	Mothers' diet during pregnancy
Area	1						
IQ	0.242*	1					
Fathers education	0.088	−0.097	1				
Mothers' education	0.041	0.283**	0.040	1			
Occupation	−0.148	0.031	−0.101	−0.281**	1		
Nutritional status	−0.014	0.062	−0.150	−0.048	0.250*	1	
Mothers' diet during pregnancy	0.063	0.586**	−0.072	0.257**	0.029	−0.102	1

*Correlation is significant at the 0.05 level (two-tailed), **Correlation is significant at the 0.01 level (two-tailed). IQ: Intelligence quotient

Table 5: Multivariate linear regression analysis of IQ (dependent variable) with the independent variables

Model summary							
Model	R	R^2	Adjusted R^2	SE of the estimate	Change statistics		
					R^2 change	F change	Significant F change
1	0.645	0.417	0.379	1.112	0.417	11.068	0.001

SE: Standard error, IQ: Intelligence quotient

Table 6: Multivariate linear regression analysis of IQ (dependent variable) with the independent variables

Model	Unstandardized coefficients		Standardized coefficients	*t*	*P*
	B	*SE*	*B*		
Area-high F and low F	7.720	3.169	0.199	2.437	0.017
Mothers diet during pregnancy (routine and special)	22.264	3.450	0.548	6.454	0.001

Dependent variable: IQ standard score. SE: Standard error, IQ: Intelligence quotient

households. The researchers specifically studied the influence of B-vitamins, folic acid, breast milk versus formula milk, iron, iodine, and omega 3 fatty acids. They analyzed how these nutrients affected cognitive, emotional, and behavioral development in children from prebirth to age 9. A positive correlation was found between the inadequacy of all these critical nutrients during gestation and low IQ of the child.[27]

It has also seen that dieting tendency among expectant mothers predispose their babies to risk of low IQ and behavioral problems. A study[28] found that cutting back on vital nutrients and calories in the first half of pregnancy stunts the development of an unborn child's brain. It supports the view that poor diets in pregnancy can alter the development of fetal organs, in this case, the brain, in ways that will have lifetime effects on offspring, potentially lowering IQ and predisposing to behavioral problems. Studies performed in the past have indicated that severe diets, famines, and food shortages during pregnancy can harm unborn babies in terms of retarded brain development.[28]

The SPM test by Raven used to measure IQ[29] of children is a "culture-fair" test which is suitable to compare people with respect to their immediate capacities for observation and clear thinking. Though SPM test was designed to encompass the broadest possible scope of mental ability, several possible shortcomings of the test need to be studied. The scores represent relative intelligence, not absolute intelligence. Intelligence is an encompassing term that includes attributes such as creativity, persistent curiosity, logical reasoning, problem-solving skill, critical thinking, and adaptation. These different aspects of intelligence are independent of one another.[6] The SPM test measures only observation, clear thinking, and logical reasoning and hence it is a poor indicator of other attributes of intelligence. One cannot get a balanced picture of an individual from the IQ test since the other categories of IQ are not considered. Aside from the shortcomings of the IQ test itself, other factors like emotional stress, anxiousness, and unfamiliarity with the testing procedure can also greatly affect test performances.[29]

Considering these factors and the fact that this was a preliminary study done on a small scale further research should be done in the same field which will assist in formulating appropriate preventive and defluoridation programs along with spreading awareness for the same such that the long-term outcome of higher fluorides can be neutralized.

CONCLUSION

Fluoride has been long advocated as the ideal preventive, therapeutic agent for dental caries. However, like a coin has two sides, it also has both beneficial and harmful effects. High F concentration in the drinking water was found to have marked systemic effects on the IQ of children. Though the precise mechanism by which F crosses the blood brain barrier is still not clean-cut; enough evidence survives for the influence of F intake via drinking water and low IQ of the child. Apart from fluoride there are other factors which also affect IQ of children. In the present study, mothers diet during pregnancy also significantly affected the IQ of the children.

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REFERENCES

1. Gazzano E, Bergandi L, Riganti C, Aldieri E, Doublier S, Costamagna C, *et al.* Fluoride effects: The two faces of janus. Curr Med Chem 2010;17:2431-41.
2. World Health Organisation. Guidelines for Drinking Water Quality. Recommendations. 2nd ed., Vol. 1. Geneva: World Health Organization; 1993.
3. US Department of Health and Human Services. For a Healthy Nation: Returns on Investment in Public Health. Washington, DC: US Government Printing Office; 1994.
4. Marier JR. Some current aspects of environmental fluoride. Sci Total Environ 1977;8:253-65.
5. Poureslami RH, Horri A, Koohbanan BG. A comparative study of the IQ of children age 7-9 on a high and a low fluoride water city in Iran. Fluoride 2011;44:163-7.
6. Jiaao AN, Schuzhen ME, Aiping LIU, Yun FU, Wang Q, Zhizhong Lin L, *et al.* The effects of high fluoride on the intelligence level of primary and secondary students. Chinese J Control Endemic Dis 1992;7:93-94.
7. Eswar P, Nagesh L, Devaraj CG. Intelligence quotients of 12-14 year old school children in a high and a low fluoride village in India. Fluoride 2011;44:168-72.
8. Choi AL, Sun G, Zhang Y, Grandjean P. Developmental fluoride neurotoxicity: A systematic review and meta-analysis. Environ Health Perspect 2012;120:1362-8.
9. Brindha K, Elango L. Fluoride in groundwater: Causes, implications and mitigation measures. In: Monroy SD, editor. Fluoride Properties, Applications and Environmental Management. New York: Nova Publishers; 2011. p. 111-36.
10. Shortt HE, Pandit CG, Raghvachari TN. Endemic fuorosis in Nellore district of South India. Ind Med Gaz 1937;72:396-400.
11. Jacks G, Bhattacharya P, Chaudhary V, Singh KP. Controls on the genesis of some high-fluoride groundwaters in India. Appl Geochem 2005;20:221-8.
12. Saxena S, Sahay A, Goel P. Effect of fluoride exposure on the intelligence of school children in Madhya Pradesh, India. J Neurosci Rural Pract 2012;3:144-9.
13. Shivaprakash PK, Ohri K, Noorani H. Relation between dental fluorosis and intelligence quotient in school children of Bagalkot district. J Indian Soc Pedod Prev Dent 2011;29:117-20.
14. Childhood Nutrition Has a Longstanding Effect on IQ. Available from: http://www.universityworldnews.com/article.php?story=20121011133921198. [Last accessed on 2015 Jan 29].
15. Pregnancy Diet Impacts Child Development And Intelligence. Available from: http://www.naturallysavvy.com/nest/pregnancy-diet-impacts-child-development-and-intelligence. [Last accessed on 2015 Jan 29].
16. Meador KJ, Baker GA, Browning N, Clayton-Smith J, Cohen MJ, Kalayjian LA, *et al.* Relationship of child IQ to parental IQ and education in children with fetal antiepileptic drug exposure. Epilepsy Behav 2011;21:147-52.
17. Dash JP, Sarangi A, Singh DK. Spatial variability of groundwater depth and quality parameters in the National Capital Territory of Delhi. Environ Manage 2010;45:640-50.
18. Susheela AK, Bhatnagar M, Kumar A. Status of Drinking Water in the Mega City Delhi. Reaching the Unreached: Challenges for the 21st Century. 22nd WEDC Conference. New Delhi; 1996. p. 299-301.
19. Singh BR. Urban impacts on groundwater quality in the Delhi region. Vol. 259. UK: International Association of Hydrological Sciences Publications; 1999. p. 227-31.
20. Available from: http://www.census2011.co.in/census/state/delhi.html. [Last accessed on 2015 Apr 10].
21. Available from: http://www.delhi.gov.in/wps/wcm/connect/DOIT_Education/education/home/about+us/list+of+government+schools. [Last accessed on 2015 Apr 16].
22. Dean HT. The investigation of physiological effects by the epidemiological method. In: Fluorine and Dental Health. Vol. 19. Pennsylvania: American Association for the Advancement of Science; 1942. p. 23-32.
23. Trivedi MH, Sangai NP, Patel RS, Payak M, Vyasa SJ. Assessment of groundwater quality with special reference to fluoride and its impact on IQ of schoolchildren in six villages of the Mundra region, Kachchh, Gujarat, India. Fluoride 2012;45:377-83.
24. Yun Li, Xiaoji Li, Siqiong W. Effects of high fluoride intake on child mental work capacity: Preliminary investigation into the mechanisms involved. Fluoride 2008;41:331-5.
25. Guan ZZ, Wang YN, Xiao KQ, Dai DY, Chen YH, Liu JL, *et al.* Influence of chronic fluorosis on membrane lipids in rat brain. Neurotoxicol Teratol 1998;20:537-42.
26. Sandjaja, Poh BK, Rojroonwasinkul N, Le Nyugen BK, Budiman B, Ng LO, *et al.* Relationship between anthropometric indicators and cognitive performance in Southeast Asian school-aged children. Br J Nutr 2013;110 Suppl 3:S57-64.
27. The Effect of Diet on the Mental Performance of Children. Available from: http://www.fensnutrition.eu/docs/news/NUTRIMENTHE%20conference%20flyer.pdf. [Last accessed on 2015 Jan 29].
28. University of Texas Health Science Center at San Antonio. "Reducing Diet Early in Pregnancy Stunts Fetal Brain Development, Study Finds." ScienceDaily. ScienceDaily; 18 January, 2011. Available from: http://www.sciencedaily.com/releases/2011/01/110117152741.htm. [Last accessed on 2014 Dec 12].
29. Raven JC, Court JH, Raven J. Manual for Raven's Progressive Matrices and Vocabulary Scales. Standard Progressive Matrices. Sec. 3. London: HK Lewis and Co.; 1998.

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