Original Articles

Biology versus Environment in Low Birth Weight Children

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Manuscript received: October 4, 2004, Initial review completed: December 3, 2004, Revision accepted: March 21, 2005.

Objective: *To explore the contribution of biologic risk factors versus socio-demographic and environmental risk factors in cognitive development of children with birth weight less than 2000 g, at the age of 12 years.* ***Design:*** *Prospective cohort study.* ***Setting:*** *Infants discharged from a NICU of a referral hospital, with birth weight less than 2000 g between 1987-89 and followed up in the High Risk Clinic.* ***Methods:*** *The children were assessed at the age of 12 years, with the Weschler's Intelligence Scale for IQ and by Wide Range Achievement Test for mathematics skills. Mother's education, father's education, socio-economic status, family structure, spaciousness of the house, the locality in which the child lived and the type of school the child attended, were all recorded. A stimulation score was determined at 6 and 12 months and 3 years. Family environment score was used at 12 years.* ***Results:*** *The cohort consisted of 180 children, with 90 controls. The mean IQ of the study group was 89.5 $\pm$ 16.9, which was significantly lower than that of controls (97.2 $\pm$ 14.1) ($P<0.05$). The mathematical skills of the study group were significantly poorer ($P<0.05$) than that of controls. A multiple linear regression analysis was done using IQ as the dependent variable and all risk factors at birth, stimulation scores and socio-environmental factors as independent variables. Mother's education was the most important factor contributing to the total IQ, a variance of 25.2% of the total variance 44.2%. Father's education emerged as an important factor for mathematics skills. School was the next important factor for IQ as well as academics. Controlling for all other background factors, birth weight was the only biologic factor of significance, and this had a very small contribution.* ***Conclusion:*** *Parental education and the type of school attended by the child were the most important factors influencing cognitive development. The only biologic factor of importance was birth weight, but this too had a very small contribution.*

Key words: *Low birth weight, cognitive development, biology, environment*

SURVIVAL of low birth weight and very low birth weight infants has improved considerably in the last two decades in India, hence there is increased interest in the outcome of these babies. In the last century, the primary emphasis in outcome studies was on the incidence of major disabilities like cerebral palsy, mental retardation and blindness. But a time has come, when one has to think of the problems encountered in the "non handicapped" survivor. While biologic factors are more predictive of major handicap, social and environmental factors are more predictive of school age outcome(1). Low birth weight

babies are exposed to a "double jeopardy", of both biologic and environmental risk(2,3). Cognitive development is a process incorporating heredity and biological factors (nature), factors related to the quality of caretaking (nurture) and a complex interaction between them. The effect is more likely to be a combination of both nature and nurture(4). Neonatal medical risk factors become less critical over time, as environmental influences begin to play a more dominant role in cognitive outcome(5).

We have previously reported the cognitive outcome of children weighing less than 2000 g at 12 years(6). This communication tries to explore the relative contribution of biologic and socio-environmental factors in determining the cognitive outcome in these "non handicapped" children at 12 years.

Subjects and Methods

Infants weighing less than 2000 g discharged from a Neonatal Special Care Unit between October 1987 to April 1989 were enrolled in the study. Full term infants weighing ≥2500g with a normal antenatal, natal and postnatal course, were enrolled as controls. They were followed up prospectively till the age of 12 years.

A. Socio-demography

A detailed socio-demographic and environmental background of each child was obtained and confirmed by a social worker by carrying out a home visit.

Mother's and Father's Education

This was divided in four categories (*i*) illiterate or primary school, (*ii*) middle school, (*iii*) high school, (*iv*) college.

Socio-economic Status was determined by using the revised Kuppuswamy Scale(7). The socio-economic status was divided in four categories (*i*) lower class, (*ii*) lower middle class, (*iii*) upper middle class, and (*iv*) upper class.

Family

The family size was determined by the number of persons living in the same house. (*i*) >10 persons, (*ii*) 6-10 persons, (*iii*) <5 persons. A note was made whether the family was nuclear or non-nuclear. History regarding single parent bringing up the child was noted.

Spaciousness of the house was calculated by the number of persons sharing a room in the house. It was divided into three categories (*i*) more than 3 persons, (*ii*) 3 persons, (*iii*) 1 to 2 persons.

School

The school attended by the child was classified into 3 categories as per the state education department's classification: (*i*) municipal corporation schools, (*ii*) average schools, (*iii*) good schools.

Locality

The locality in which the child lived was divided into four categories. (*i*) slums, (*ii*) lower middle, (*iii*) upper middle, (*iv*) high class.

Breastfeeding

The age upto which exclusive breast feeding was carried on was noted.

B. Stimulation and "Parenting"

The stimulation received by the child at home or the "care giving environment" was assessed at different ages using different tests.

The initial assessment was done in infancy at 6 and 12 months to determine early stimulation. An interaction score and stimula-

tion score devised in our Development Clinic and validated on 100 normal infants from the Well Baby Clinic, was used.

Interaction Score was calculated by the number of persons interacting with the child, multiplied by the number of hours of interaction by each person. The type of interaction or stimulation was divided into 7 headings. These consisted of (*i*) physical contact, (*ii*) sensory stimulation, (*iii*) motor stimulation, (*iv*) Speech. Each of the preceding headings were divided into active (score 2), or passive interaction (score 1), (*v*) outings (score 2), (*vi*) fun and frolic (score 2), (*vii*) age appropriate toys (> 3 toys – score 3).

The next assessment was done at 3 years. This stimulation score was also validated on 100 normal children. This was done under 5 major headings – (*i*) Language stimulation, (*ii*) Physical environment of the house, (*iii*) Encouragement of social maturity, (*iv*) Quality of stimulation and (*v*) Maternal attitude and disciplining. There were a total of 25 items under these 5 headings and each item was given one mark.

C. Family environment scale (FES)(8)

The family environment scale was used at 12 years. This consisted of three main divisions. (1) Relationship dimensions consisting of cohesion, expressiveness and conflict, (2) Personal growth dimensions consisting of independence, achievement orientation, intellectual cultural orientation, active recreational orientation and moral religious orientation, (3) System maintenance dimensions consisting of organization and control.

D. Cognitive assessment

All the children were assessed for their cognitive development at 12 years. These tests were administered by a trained psychologist.

Weschler's Intelligence Scale Revised (*WISC-R*)(9)

The main advantage of this test is that it gives a separate verbal and performance IQ. An IQ $\geq$ 85 was considered as normal.

Wide Range Achievement Test (*WRAT*)(10)

This test was done to assess the mathematics skills of these children. A score $\geq$ 85 was considered as normal.

Statistical analysis

Analysis was done using the statistical package for social sciences (SPSS) for windows (version 10). The mean IQ in various groups was compared using the student '*t*' test. To explore the difference between groups, simple Chi square test was used. To check the linearity in mean IQ for various independent variables, the test for linearity (ANOVA) was used.

A multiple linear regression analysis was done to find out the predictors of IQ in the cases with IQ as the dependent variable and the biologic and socio-environmental factors as the independent variables. Pearson's correlation coefficient was used to check the relationship between IQ and the variables with a numerical value only. The variables having significant correlation were then included as independent variables along with the other categorical variables in the multiple linear regression analysis using the forward elimination method.

Results

The cohort has been described in details in our previous publication alongwith an assessment of their cognitive development(6).

Baseline Data

The birth weight of the study group ranged from 860-1999 g with a mean of 1549 $\pm$

242.3. The study group had 73 females and 107 males and the control group had 35 females and 55 males. Out of the 180 children with birth weight less than 2000g, 147 (81.29%) were preterm, and almost half of those (n = 74) were small for gestational age (SGA). The group had 33 (18.8%) full term SGA children.

Cognitive Development

The mean total IQ of the study group determined by WISC (R) was 89.5 ± 16.9, whereas the mean IQ of the control group was 97.2 ± 14.1. This difference was significant (P< 0.05). The mean performance IQ was 95.4 ± 16.3 as compared to 102 ± 13.5 in controls (P < 0.05). The mean verbal IQ was 86.5 ± 18 compared to 94.2 ± 16.2 in controls (P < 0.05). The mathematics score on the WRAT was 82.7 ± 16.9, which was significantly less than that of the control group (87.8 ± 15.8). There was no difference between the IQ of males and females.

Table I provides a comparison of socio-demographic variables of the study group and controls. As seen in this table, the two groups were well matched.

The children of mothers with college education had a mean IQ of 101.25 ± 16.01 whereas children of mothers with 10-12 standard education had a mean IQ of 93.2 ± 13.01. Children of mothers with middle school education had a mean IQ of 86.11 ± 16.33 and those with only primary school education had the lowest IQ of 76.52 ± 14.16. The p value for trend was significant (P < 0.001). A similar trend was seen (P< 0.001) when the mean IQs of children with different education categories of the fathers were compared. Children attending good schools had a mean IQ of 100.73 ± 15.04, whereas those attending average schools had a mean IQ of 88.84 ± 14.11. The lowest mean IQ of 73.8 ± 17.11 was seen in children attending municipal corporation schools, P value for trend was significant (P <0.001).

To reinforce these results, we divided the cohort into two groups, those with below average IQ and those with average or above average IQ (≥85). Amongst 36 college educated mothers, there were only 6 children with below average IQ, whereas there were 30 children with average IQ (P <0.001). Similar findings were seen when father's education was compared.

Stimulation and Parenting

The stimulation scores did not show any difference between cases and controls at 6 and 12 months. Only the interaction score at 6 months showed a significant difference between the two groups (p <0.05). The stimulation score did not show any difference between cases and controls at 3 years. There were only 30 mothers who had exclusively breast fed their infants upto 6 months, and there were only 3 single parent families. Therefore no further analysis of these two variables was done.

Multivariate Analysis

A multiple linear regression analysis was done using IQ as the dependent variable. The independent predictor variables were: (*i*) All biologic risk factors – birthweight, gestation, weight for gestation (AGA/SGA), septicemia/ meningitis, seizures, hyperbilirubinemia, intraventricular hemorrhage, respiratory distress, birth asphyxia. (*ii*) All socio environmental and parental factors shown in *Table I*. (*iii*) Stimulation score, interaction score and 10 items of family environmental scale – only those factors having a significant correlation with IQ were included as the independent variables. *Table II* shows the final model with all the significant factors influencing IQ.

TABLE I –*Comparison of Background Factors of Cases and Controls*

Variables		Cases N (%)	Controls N (%)	P values
Mother's Education				
	College	36 (20.0)	17 (18.8)	0.133
	High school	71 (39.4)	40 (44.5)	
	Mid school	27 (15.0)	20 (22.2)	
	Primary	46 (25.6)	13 (14.5)	
Father's education				
	College	43 (24.0)	33 (37.1)	0.066
	High school	90 (50.3)	41 (46.1)	
	Mid school	22 (12.3)	10 (11.2)	
	Primary	24 (13.4)	5 (5.6)	
Socio Economic Status				
	Upper	33 (18.4)	12 (13.3)	0.694
	Upper middle	47 (26.1)	25 (27.8)	
	Lower middle	65 (36.1)	37 (41.1)	
	Lower	35 (19.4)	16 (17.8)	
Family Size (Number of persons)				
	≥ 10	11 (6.1)	9 (10.0)	0.5134
	6-10	70 (38.9)	33 (36.7)	
	≤ 5	99 (55.0)	48 (53.3)	
Spaciousness (Persons per room)				
	1 to 2	85 (47.2)	30 (33.3)	0.089
	3	37 (20.6)	22 (24.5)	
	≥ 4	58 (32.22)	38 (42.2)	
School				
	Good	44 (24.6)	26 (29.6)	0.169
	Average	109 (60.9)	56 (63.6)	
	Corporation	26 (14.5)	6 (6.8)	
Locality				
	Upper class	12 (6.7)	12 (13.3)	
	Middle class	152 (84.4)	73 (81.1)	
	Lower class	16 (8.9)	5 (5.6)	0.1396

Total IQ

Among the correlates of IQ at 12 years, mother's education explained 25.2%, type of school 8.6%, birth weight 4.1%, a small contribution by two items of the family environment scale, (expressiveness and control) and spaciousness of the house. These factors together explained 44.2% of the variance in total IQ.

Performance IQ

Mother's education, birth weight, school and FES – control contributed to a total variance of 32.4% in performance IQ.

Verbal IQ

Type of school, father's education, stimulation score at 3 years and FES – expressiveness, explained 34.6% variance in verbal IQ.

TABLE II–*Determinants of IQ - Multiple Linear Regression Analysis*

Dependent variable	Independent variable	Beta	Adjusted R^2	Total variance %	Contribution to total variance %
Total IQ				44.2	
	Mother's education	0.290	0.252		25.2
	School	0.284	0.338		8.6
	Birth weight	0.213	0.379		4.1
	Spaciousness	0.167	0.405		2.6
	FES - expressiveness	0.145	0.426		2.1
	FES- control	-0.141	0.442		1.6
Performance IQ				32.4	
	Mother's education	0.294	0.176		17.6
	Birth weight	0.231	0.239		6.3
	School	0.245	0.275		3.6
	FES – control	–0.183	0.304		2.9
Verbal IQ				34.6	
	School	0.321	0.220		22
	Father's education	0.190	0.297		7.7
	3yr stimulation score	0.196	0.325		2.8
	FES – expressiveness	0.167	0.346		2.1
Mathematics Score				36.4	
	Father's education	0.360	0.256		25.6
	School	0.320	0.342		8.6
	FES – control	0.166	0.364		2.2

FES – Family Environmental Scale.

Mathematics score

Father's education, school and FES – control, explained 36.4% of the variance in mathematics score.

Discussion

When a low birth weight child has difficulties in school, it is blamed on the biologic risk factors associated with low birth weight and the NICU stay, by both parents and pediatricians. But research has shown that the interaction between risk and protective factors, may be a dynamic aspect of the environment, that mediates or moderates outcome(11). Parents are said to be the key figures for caregiving, and responsive parenting in early childhood has been reported to be associated with better cognitive development(12). In our study, stimulation in infancy did not emerge as a significant factor influencing IQ. Stimulation score at 3 years had a small contribution to verbal IQ.

Duration of exclusive breast feeding upto 24 weeks has been reported to have significant impact on IQ(13). Out of our 180 mothers, only 30 were exclusively breast feeding till 24 weeks, and this number was too small to draw any conclusions. The Western literature cites many studies on family stability and cognitive development. They talk about single parent families(14,15) and families making frequent geographical moves, affecting the cognitive development of children. Our cohort had only 3 single parent families and this family structure does not appear to be of any importance in India.

Key Messages

- The cognitive development of "non handicapped" children with birth weight < 2000 g is greatly influenced by socio-envirionmental factors at the age of 12 years.
- Mother's education, father's education and the type of school attended by the child are important factors.
- Birth weight is the only biologic factor that has a small contribution to later IQ.

We found mother's education to be the most important factor contributing to the total IQ. The school attended by the child was the next important factor. Spaciousness of the house, which had a small contribution, may be a proxy for socio-economic status. Performance IQ is supposed to depend on the innate intelligence and the hereditary make up of the child (nature), whereas the verbal IQ is determined more by the environment(1). Hence we analysed the factors affecting these two arms of intelligence separately.

For the performance IQ, it was the mother's education that contributed 17.6% of the variance to a total variance of 32.4%. For the verbal IQ, school was the most important factor, followed by the father's education. Father's education has been reported by several authors(14,16) as a very important factor influencing the IQ of children. In our study, father's education was the most important factor for mathematics score. It was the second most important factor for the verbal IQ. This appears strange, considering how much time the Indian mother spends with the child.

Bradley *et al.* examined 3 models of home environment – Model I (primacy of experience), Model II (predominance of contemporary environment) and Model III (cumulative environment). Strongest relation at the age of 10 years was found with the contemporary environment(17). We found that two aspects of family environment scale assessed at 12 years, contributed to cognitive development. Expressiveness, the freedom to express their feelings, had a small contribution to the verbal IQ. The other factor was control, the extent to which set rules and procedures are used to run family life, which had a small contribution to the performance IQ and mathematics score.

Many studies have reported the importance of socio-economic status(14,18) in influencing the cognitive development. We found that spaciousness of the house, which may be a proxy for socio-economic status to have a small contribution to total IQ. Many of these studies have not considered parental education. It is possible that parental education is related to socio-economic status in India.

The type of school attended by the child was seen to influence the total IQ, performance IQ, verbal IQ and mathematics skills. To the best of our knowledge, the importance of school for better cognitive outcome has not been reported in any other study.

Controlling for the socio-demographic and environmental factors, birthweight was the only significant biological factor and even this had a much smaller contribution to IQ compared to mother's and father's education and the type of school. Hack(14) has reported only 2% variance attributable to very low

birthweight in her 8 year study.

In non-disabled low birth weight children, socio-demographic and environmental factors greatly overshadow biologic risks as determinants of cognitive development at 12 years. It is therefore important to realize the huge power that the environment will have on these children, and in particular, the parents who feature in that environment, because they will quite literally be leaving a mark on the brain.

Contributors: SC conceived the project, supervised it and is the guarantor of the paper. MO collected and analysed the data. AC did all the psychological tests. MH made home visits and confirmed all information. AP supervised the project. AM did statistical analysis.

Funding: Indian Council of Medical Research, Ansari Nagar, New Delhi.

Competing interests: None.

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