Cognitive Deficit and Poverty in the First 5 Years of Childhood in Bangladesh

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KEY WORDS
poverty, growth, cognition, home stimulation, parental education, MINIMat

ABBREVIATIONS
CI—confidence interval
HOME—Home Observation for Measurement of Environment
icddr,b—International Centre for Diarrhoeal Disease Research, Bangladesh
LMIC—low- and middle-income countries
MD—mental development index
PI—ponderal index
WPPSI—Wechsler Preschool and Primary Scale of Intelligence

Dr Hamadani conceptualized and designed the study, trained the staff and ensured quality of the data collection, and drafted the initial manuscript; Dr Tofail trained the staff and ensured quality of the data collection, and reviewed and revised the manuscript; Dr Alam trained the staff and ensured quality of the anthropometric data collection, and reviewed and revised the manuscript; Dr Huda trained the staff collecting developmental data, ensured quality of the data, and reviewed and revised the manuscript; Drs Ridout and Attanasio analyzed the data, and reviewed and revised the manuscript; Dr Grantham-McGregor developed the initial concept and analytical plan of the study, reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

This trial has been registered with the ISRCTN Register (http://isrctn.org) (identifier ISRCTN16581394).

doi:10.1542/peds.2014-0694

Accepted for publication Jul 24, 2014

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WHAT’S KNOWN ON THIS SUBJECT: More than 200 million children <5 years old in low- and middle-income countries are not reaching their potential in cognitive development because of factors associated with poverty.

WHAT THIS STUDY ADDS: Poverty affects children’s cognition as early as 7 months and continues to increase until 5 years of age. It is mainly mediated by parental education, birth weight, home stimulation throughout the 5 years, and growth in the first 24 months.

abstract

OBJECTIVE: We aimed to determine the timing and size of the cognitive deficit associated with poverty in the first 5 years of life and to examine the role of parental characteristics, pre- and postnatal growth, and stimulation in the home in Bangladeshi children. We hypothesized that the effect of poverty on cognition begins in infancy and is mainly mediated by these factors.

METHODS: We enrolled 2853 singletons, a subsample from a pregnancy supplementation trial in a poor rural area. We assessed mental development at 7, 18, and 64 months; anthropometry at birth, 12, 24, and 64 months; home stimulation at 18 and 64 months; and family’s socio-economic background. In multiple regression analyses, we examined the effect of poverty at birth on IQ at 64 months and the extent that other factors mediated the effect.

RESULTS: A mean cognitive deficit of 0.2 (95% confidence interval −0.4 to −0.02) z scores between the first and fifth wealth quintiles was apparent at 7 months and increased to 1.2 (95% confidence interval −1.3 to −1.0) z scores of IQ by 64 months. Parental education, pre- and postnatal growth in length, and home stimulation mediated 86% of the effects of poverty on IQ and had independent effects. Growth in the first 2 years had larger effects than later growth. Home stimulation had effects throughout the period.

CONCLUSIONS: Effects of poverty on children’s cognition are mostly mediated through parental education, birth size, growth in the first 24 months, and home stimulation in the first 5 years. Pediatrics 2014;134:e1001–e1008
Early life experience affects brain development and later health, cognitive development, and school attainment. An estimated 219 million children <5 years old in low- and middle-income countries (LMIC) fail to reach their developmental potential because of factors associated with poverty. Cognitive function on school entry predicts educational attainment and later adult functioning, which has consequences for the next generation. Recent Lancet series identified poor nutrition and home stimulation as the main risk factors. Cross-sectional studies have shown children >36 months old have cognitive deficits associated with poverty, whereas in Madagascar, deficits were already present at 36 months. Language deficits were reported in 5-year-old children in Peru, India, Ethiopia, and Vietnam. More recently, 4 cross-sectional studies showed wealth at birth and maternal education were related to mothers’ reports of communication, gross motor, and personal/social development in children 3 to 23 months. Longitudinal studies are needed to determine when the effects of poverty first become apparent and what risks mediate the effect at different ages. Several longitudinal studies have shown growth failure in the first 2 years is related to later cognition and schooling. However, an important risk factor, stimulation in the home, was not taken into account. There are few longitudinal studies in LMICs tracing the development of cognitive deficits associated with poverty through the first 5 years that have examined the role of pre- and postnatal growth and home stimulation, as well as parental education.

A large randomized trial (Maternal and Infant Nutrition Intervention in Matlab) of the effect of nutritional supplementation of >3000 pregnant women on birth outcomes was conducted in Bangladesh. We followed a subsample of children for 5 years and measured their development and a range of risk factors. Supplementation benefits on children’s cognition were apparent at 7 months of age but not at 18 or 64 months. We therefore combine the groups and treat them as a cohort study for this article. We hypothesized that poverty is associated with cognitive deficits, and parental education, pre- and postnatal growth, and home stimulation would mediate the effects of poverty on cognition.

The aims were to (1) examine the timing of the development of cognitive deficits associated with poverty and its size, and (2) determine the extent that birth characteristics, pre- and postnatal growth, parental characteristics, and stimulation in the home mediate the effects.

**METHODS**

The study was conducted in a poor rural area southeast of Dhaka, comprising 67 villages, and divided into 4 blocks, each with a health center. The International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) collects vital information in the area through a Health and Demographic Surveillance System.

**Study Population**

All pregnant women identified through monthly surveys were enrolled and followed until delivery. A subsample of 2853 singleton children comprising all those born between May 2002 and December 2003 were selected for a study of child development.

**Measurements**

On enrollment, information was collected on socioeconomic background. The quality of the home environment was measured with the Home Observation for Measurement of Environment (HOME) for Infants and Toddlers at 18 months of age and the Early Childhood HOME inventory at 64 months. Both the instruments were modified for use in Bangladeshi children. The intent of each question was kept, but changes were made to increase the variability of the responses in this population.

Birth weight, length, and head circumference were measured and ponderal index (PI) calculated (weight [kg]/height [m]³). Gestational age was recorded from the mother’s report.

On enrollment, mothers’ weight and height were measured and BMI (weight [kg]/height [m]²) calculated. Children’s weight and length were measured at 12, 24, and 64 months of age. Heights and weights were converted to standard scores using the World Health Organization growth standards.

**Developmental Assessments**

Children were assessed on 3 occasions at the nearest health center by psychologists who rotated around the centers.

At 7 months, children’s problem-solving ability was measured by using two 1-step means-end tests “Support” and “Cover” in which infants manipulate an intermediary object (cloth) to retrieve a goal (a toy). The tests were videoed and scored later. Both tests have similar scoring methods and we used the sum of the scores in the analyses.

At 18 months, the Bayley Scales of Infant Development Revised version was used to measure children’s mental development index (MDI), which has been used frequently in Bangladesh. At 64 months, the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) was used to measure children’s IQ. It was extensively piloted and modified to be culturally appropriate, but the basic constructs were not changed. Test-retest reliability after 7 to 10 days was good (r = 0.93, P = .01, n = 60) and scores were related to earlier Bayley scores (r = 0.36, P < .001, n = 1881), which concurs with the size of correlations reported elsewhere. Correlations between problem solving and later MDI
and IQ were \( r = 0.19 \) (\( P < .001 \)) and \( r = 0.18 \) (\( P < .001 \)), respectively. Supervisors observed \( \sim 5\% \) of all tests and intraclass correlations were \( >0.87 \) for every tester at each test.

**Analysis**

Using externally standardized scores may not be appropriate when the cognitive tests were not standardized for Bangladesh, so to avoid comparisons with international test norms we converted all scores to standard scores using the mean and SD of the total sample. Standardized scores also facilitate comparison across different tests. Children’s age at testing correlated with IQ (\( r = -0.07, P = .002 \)); we therefore controlled for age in all analyses.

To assess economic resources, we calculated a wealth index, which was the first principal component of variables including household possessions, land ownership, and ratings of housing materials. The resulting factor had an eigenvalue of 5.1 and accounted for 18% of the variance. The index has been described previously\(^ {23} \) and was divided into quintiles, with the first being the poorest.

We used the method described previously\(^ {10} \) to calculate growth in length and weight from birth to 12, 12 to 24, and 24 to 64 months independent of previous measures. We regressed the measure at the older for each interval on the previous measure, then used the standardized residuals. We included a quadratic term in the regressions to account for nonlinear relationships.\(^ {10} \) Birth length and weight were expressed in SD scores for this sample. The HOME scores at 18 and 64 months were highly correlated (\( r = 0.624, P < .001 \)). To obtain a measure of later stimulation independent of the early HOME, we regressed the 64-month on the 18-month HOME and used the standardized residual.

First we examined differences in cognitive scores at each test session by wealth quintiles at birth with analyses of covariance controlling for age, using all available subjects. We did not combine the sessions because the different tests may measure different components of cognition. We then examined which variables were associated with IQ at 64 months in all children tested then (\( n = 2280 \)) with multiple regression analyses. We used only the 64-month test to minimize sample loss. We first documented the cognitive deficit related to wealth at birth, controlling for tester; treatment group in the initial randomized trial, residential block, and child’s gender and age.

We then considered potential mediating factors by adding blocks of variables in a series of steps. In the second step, we entered father’s education, maternal age, BMI, education, and first born. In the third step, we entered biomedical variables: gestational age, birth length, PI, and growth in length and weight from birth to 12, 12 to 24, and 24 to 64 months. Birth length and weight were highly correlated, so we used length because it was more highly correlated with IQ scores. In the fourth step, we entered HOME scores at 18 months and HOME residual at 64 months. The total HOME and the subscales at 18 and 62 months all had significant low to moderate correlations with IQ. We used the total HOME, which had the highest correlations. We examined interaction terms between gender and HOME and gender and the 3 growth variables. In computing the SEs, confidence intervals (CIs), and \( P \) values, we allow for correlation within clusters defined by the residential blocks following standard methods.\(^ {24} \)

Although the regression was significant, gestational age, PI, growth in weight, mother’s age and BMI, and first born were not significant in any step, so we omitted these variables to have a more parsimonious model.

### Missing Data

When the value for one of the regressors was missing, we substituted an arbitrary value and added as an additional regressor an indicator that took the value 1 for observations with a missing value and 0 otherwise (see Table 1).\(^ {25,26} \)

To correct for the effects of loss to follow-up, we weighted all regressions with the inverse of the probability of the individual being assessed at 64 months.\(^ {27} \) The probability was estimated using a logistic regression with enrollment characteristics (mother’s age, BMI, and parity; parental education; birth weight, length, and head circumference; gestational age at birth; wealth index).

### Mediation

To test whether the IQ deficit associated with economic resources at birth was mediated by variables in the regression, we used the method of MacKinnon et al\(^ {28} \) and tested whether the coefficients on the wealth variable were significantly smaller when potential mediating variables were added to the regression. These tests were constructed by bootstrapping methods, to take into account the fact that different regressions are estimated on the same sample.\(^ {29} \)

We also examined whether the effects of parents’ education on child’s IQ were mediated by growth and home stimulation in similar analyses.

### Ethics

Written consent was obtained from mothers. The institutional review board of icddr,b approved the project.

### RESULTS

Of the initial 2853 children, 2116 (74%) were tested at 7 months, 2112 (74%) at 18 months, and 2260 (79%) at 64 months. By 64 months, 96 (3.4%) had died, 44 (1.5%) refused, 63 (2.2%) had moved to other areas, 358 (12.6%) were not available after several visits due to
Mothers’ education (2255) (593) .005
Mothers’ age, y 26.3 ± 5.9 (2252) 25.9 ± 5.8 (583) 2
Parity, 1st child 32.1 (2253) 40.5 (583) <.001
SES index, quintiles (2260) (593) .005
1. Lowest 21 18
2. 22 19
3. Middle class 20 17
4. 22 19
5. Highest 18 25
Income expenditure quintiles 20 (2254) 18 (587) 2

SES, socioeconomic status.

being away from the home, 28 (1.0%) were ill at the time of testing, and 4 (0.1%) were disabled and it was not possible to test them. Characteristics of the tested and not tested samples at 64 months are given in Tables 1 and 2. Lost children had lower gestational age (P = .05), and higher father’s (P < .001) and mother’s (P = .005) education, mother’s BMI (P = .006), and wealth index (P = .005) than tested children. There were no other differences. The tested children’s mean age was 64.5 (SD 1.9) months; 95% were tested within 4 months of 64 months.

Cognitive Deficit

Figure 1 shows the relation between wealth quintiles at birth and cognitive scores in SD scores (z scores) in all available tests. The gap between the highest and lowest quintile in cognitive scores was 0.2 (95% CI –0.4 to –0.02) z scores (P = .02) at 7 months, 0.7 (95% CI –0.9 to –0.5) z scores (P < .001) by 18 months, and reached 1.2 (95% CI –1.3 to –1.0) z scores (P < .001) by 64 months. All differences between adjacent quintiles were significant by 64 months (all P ≤ .01).

Multiple Regression Analyses of WPPSI

Table 3 shows results of multiple regressions on WPPSI IQ in z scores. There was a small decline with age at test, and girls had slightly higher scores than boys. In the first step, for every quintile of wealth, there was an increase of 0.3 z scores of IQ (95% CI 0.27 to 0.32, P < .001). In the second step, fathers’ and mothers’ education had similar effects on IQ of 0.05 (95% CI 0.04 to 0.06, P < .001) z scores per year of schooling.

In the third step, birth length and growth in length for the 3 intervals all had significant effects (all P < .05). The effect of growth from birth to 12 and 12 to 24 months was 0.13 (95% CI 0.09 to 0.17) and 0.11 (95% CI 0.07 to 0.14) z scores, respectively, which combined was larger than the effect of growth from 24 to 64 months (0.06, 95% CI 0.02 to 0.1) z scores (P < .015). In the fourth step, in the home at 18 months and the HOME residual at 64 months both had significant effects on IQ (both P < .001), while all other covariates remained significant. None of the tested interactions with gender were significant.

Mediators

By the final step, the initial IQ gap associated with wealth had been reduced by 86%. The reduction in the coefficients of wealth in steps 2 to 4 are shown in Table 4. In step 2, fathers’ and mothers’ education reduced the coefficient of wealth by 0.17 (SE 0.014) z scores, and in step 3, the coefficient on wealth was significantly reduced by pre- and postnatal growth by 0.02 (SE 0.004) z scores. Similarly, in step 4, home stimulation variables reduced the coefficient by 0.06 (SE 0.01) z scores (all reductions P < .001).

We also examined whether the effect of mothers’ and fathers’ education on IQ was mediated by growth and stimulation. Pre- and postnatal growth reduced the coefficients of fathers’ education by 0.004 (SE 0.001) z scores and mothers’ education by 0.006 (SE 0.001) (both reductions P < .001). Stimulation in the HOME reduced the coefficients of mothers’ education by 0.025 (SE 0.003) z scores (P < .001) and of fathers’ education by 0.015 (SE 0.003) (P < .001). Combined growth and home stimulation explained 66% of the effect of maternal education and 40% of fathers’ education.

The regressions were repeated without the weighting for loss of subjects and there was minimal difference in the results.

DISCUSSION

In a large population-based rural sample, we showed that a cognitive deficit associated with poverty at birth was apparent as early as 7 months of age, becoming substantial by 18 months and increasing to >1 standard score by 64 months. Moreover, the average level of cognitive development of children in each quintile tracked from 7 months through to 5 years, when each
quintile was significantly different from the adjacent ones. These children are likely to maintain their developmental trajectories throughout childhood. This cognitive deficit has serious implications for school attainment and subsequent adult earnings and the intergenerational continuance of inequity. The size of the effect at 5 years (1.2 SD) compares with 0.57 to 1.5 SD in 18-month Bayley MDI and was larger (0.4–0.5 SD) in children 16 to 23 months than younger children in India and Indonesia, but there was no age difference in Peru and Senegal. It is likely that the cross-sectional design accounts for this inconsistency.

Most of the effect of poverty (86%) was mediated through parental education, pre- and postnatal growth, and stimulation in the home.

Parental Education

Although only 1% of mothers and 5% of fathers had >12 years of schooling, both fathers’ and mothers’ education had similar large effects on children’s IQ. In preliminary analyses (data not shown), primary education alone in both parents also had independent effects on IQ. Mothers’ education has been shown to be important for child development in other LMICs and developed countries; however, fathers’ education is usually less important than maternal education. Fathers’ education also has a strong effect on child growth in Bangladesh and may represent economic input not captured by the wealth index. We showed that much (60%) of the effect of maternal education on child’s IQ and somewhat less (40%) of paternal education was mediated by the quality of home stimulation and growth. Diarrhea often contributes to poor growth, so the link with parental education would probably be through poor nutrition and hygiene.

Growth

The children’s nutritional status was poor: 31% were born low birth weight and 52% were stunted by 24 months of age. Birth size and growth in the first 24 months had sustained effects on IQ at 64 months. Most (78%) low birth weight children were born at term and were small for gestational age, probably because of poor prenatal nutrition. Small for gestational age is related to completing secondary school. In Bangladesh, linear growth in the first 2 years was more important than later growth, concurring with other cohort studies and with nutritional supplementation studies that showed that supplementation in the first 2 years had more adult benefits than later supplementation.
later growth had a small effect, suggesting that effects are not entirely restricted to the first 24 months. Growth in length was more important for later IQ than growth in weight, contrasting with other studies.11

**Home Stimulation**

In contrast, home stimulation was important over the age range. The quality of home stimulation consistently varies by socioeconomic status in many LMICs37 and is related to children’s cognitive development.20,31,32 Programs aimed at improving home stimulation in young children have benefited children’s development concurrently and in later life.1,37

Limitations of the study include that it was observational and associations may not be causal and there may be other unmeasured variables that affect development. We also used a cognitive test not standardized for the country; however, the WPPSI test had good interobserver reliabilities and was related to earlier Bayley scores and with nutritional, socioeconomic, and home stimulation variables in theoretically expected ways, suggesting that it is valid in this population. We had no direct measure of income. We used the wealth measure, which included housing conditions, assets, and land ownership. Similar measures are frequently used in Bangladesh because it is difficult to assess income.38

The study strengths were the longitudinal design, large sample, extensive measures of home environment, and early measures of child development. These findings are likely to be relevant to rural areas in Bangladesh and least-developed countries in South Asia.

**TABLE 4** Coefficients Showing Change of the Effects of Family Resources Mediated by Nutrition and Home Stimulation

<table>
<thead>
<tr>
<th>Step 2 Father and Mother Education</th>
<th>Step 3 Nutritional Variables Entered</th>
<th>Step 4 Home Stimulation Entered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Coefficient (B)</td>
<td>SE of Change (B)</td>
<td>P</td>
</tr>
<tr>
<td>Socioeconomic status index</td>
<td>-0.171</td>
<td>0.014</td>
</tr>
<tr>
<td>Father’s education</td>
<td>-0.004</td>
<td>0.002</td>
</tr>
<tr>
<td>Mother’s education</td>
<td>-0.068</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Relatively few resources are spent on interventions for children <5 years old, although investment in early childhood brings greater economic returns than investments later56 and may have lifetime implications.

CONCLUSIONS

Cognitive deficits associated with poverty are present at 7 months of age and increase to 64 months when they are substantial. Most (86%) of the effect was mediated by parental education, pre- and postnatal growth, and home stimulation. Whereas nutrition is important in the first 2 years, stimulation was important throughout the 5 years, suggesting that interventions should cover the full age range beginning in early infancy or pregnancy.

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ACKNOWLEDGMENTS

We thank all the mothers and children who participated in the study. We are also grateful to all the field staff, the interviewers, and testers, and their supervisors. icddr,b is thankful to the governments of Australia, Bangladesh, Canada, Sweden, and the United Kingdom for providing core/unrestricted support.

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Pediatrics 2014;134;e1001; originally published online September 29, 2014; DOI: 10.1542/peds.2014-0694
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