THE LONG TERM ASSOCIATION OF EARLY CHILDHOOD DIARRHEA WITH SCHOOL SUCCESS: A CASE STUDY FROM PAKISTAN[1]

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Abstract
Diarrhea is a significant cause of morbidity and mortality among children in many places, yet its long-term effects on child development and school success are poorly understood. This paper uses multiple linear regression on a group of 107 children in Pakistan, to analyze the associations between diarrhea and infant malnutrition history, parental income and education with school test results in math, English and Urdu. Controlling for parental education and income, malnutrition, and diarrhea data from birth to age five, long-term diarrhea before age two is associated with lower Z-scores in math and diarrhea after age two is associated with lower Z-scores in English. Diarrhea was less significantly associated with Urdu Z-scores. This study does not establish diarrhea as a cause for poorer school performance but it indicates that long-term early childhood diarrhea is an important risk factor for poorer school performance.

Introduction

A child's school achievement is affected by many variables, including many that affect a child before he or she ever goes to school (Abadzi 200). The years during which brain cells are being formed and sensory environmental stimulation affects the structure and organization of neural pathways (Richardson 1994, Puchner 1995) are critical. A good number of these variables are influenced by parental income and education, and the association of these parental characteristics with educational achievement is well established (Hanson *et al*. 1997, Axinn *et a*l. 1997, Duncan *et al*. 1994). During these pre-school years, poor nutrition can also have long-term affects on development (Pollitt 1990, Pollitt 1997, Brown and Sherman 1995, Shrestha and West 1994, Wachs 1995, Grantham-McGregor 1995, Levinger 1992, Seshadri and Gopaldas 1989, Morley 1995, Levitsky and Strupp 1995). Micronutrient deficiencies of iron, iodine and vitamin A play a major role in children's development and their school performance (Pollitt 1990, Pollitt 1997, Haas and Fairchild 1989, Shurch 1995). Evidence is mounting regarding the importance of a wide range of other micronutrients as well.

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Deficiencies in magnesium, potassium, selenium, copper, calcium, vitamin D and zinc in child development, while poorly understood, seem to have a functional significance even when they do not reach clinical proportions (Wachs 1995, Tomkins *et al*. 1995, UNICEF 1993).

Early childhood diarrhea is a widespread public health problem in developing countries that is not usually associated with developmental impairment. Surveys conducted by the World Health Organization in the 1980s show that a young child in a developing country suffers, on average, 3.3 episodes of diarrhea per year and that more than one-third of the deaths among children younger than five are associated with diarrhea (Mata 1992). Oral rehydration therapy has greatly reduced fatality rates from acute watery diarrhea, but it has done little to prevent diarrhea or reduce its duration, frequency or stool volume (Bhutta 1996, Molbak 1997, Molla 2000). This is important in light of evidence linking diarrhea as a cause and effect of malnutrition (Mata 1992, Briend 1990, Sullivan 2000, Molla, SArkar, Khatoon and Rahman 1983) and micronutrient deficiencies (Scrimshaw, Ruenser, Keusch, Jolla, Ozalp and Torun 1983, Brewster 1997, Roy 2000) and suggests that frequent and prolonged diarrhea during infancy and pre-school years could significantly alter a child's development and reduce school performance. One recent study of 46 children in Brazil (Meihous, Moore, Patrick, Derr, Lorntz, Lima and Guerrant 2002) already makes this point.

This paper describes a study that examines the statistical associations between diarrhea in the first five years of a child's life and their subsequent primary school performance, controlling for parental education and income as well as malnutrition measures. Establishing the long-term impact of early childhood diarrhea on school performance would add urgency to efforts to reduce its incidence and duration.

Methodology

Diarrhea and Household Data

In 1989, the Aga Khan University (AKU) in Karachi, Pakistan and the Aga Khan Health Service Pakistan (AKHSP) began collecting diarrhea data on all children under the age of five in the village of Oshikhandas near Gilgit, the administrative capital of the Northern Areas of Pakistan. Community health workers trained in data collection visited households every week, under the supervision of AKHSP medical staff. Data collectors were careful to take diarrhea histories from the primary care giver (usually the mother) and followed up with those who were not available at the time of the scheduled visit. Detailed questionnaires were filled out about the beginning and end dates of periods of diarrhea data, total duration, consistency, severity and treatment. Children were weighed monthly in general although children with diarrhea were weighed weekly, and their height was recorded every three months. All children born after the beginning of the study were added while data collection stopped for children who reached age five. Periods of out-migration were carefully noted.

The study was limited to school children for whom fewer than 90 days of data were missing over their first five years of life, leaving a total of 107 children (39 girls and 68 boys) spread between class 1A (52 children), class one (38) and class two (17). The mean age of children at the time of the study was 89 months (SD 8.7). School tests were administered in early December 1997.

At the beginning of the study, household information including parental income and education was also collected. The income variable was divided into six categories ranging from no income up to greater than Rs. 4000 per month (in 1987 rupees). The education variable was broken into eight steps, covering illiteracy, basic literacy, primary schooling and completion of each subsequent school stage up to a professional degree. Data were entered into a computerized database in Gilgit by trained AKHSP staff and carefully examined by the Department of Community Health Sciences at the Aga Khan University in Karachi. Data collection continued through mid 1996.

A variety of categorical diarrhea variables was derived from the data that included the total number of episodes, total duration in days and episodes broken down into three duration categories representing 0-7 days, 8-14 days and more than 14 days. These categories were then further subdivided into categories before and after the age of two years.

Each child's height and weight at approximately age two were extracted from the data and a second set of measurements was made concurrent with the subject tests. From these measures Z-scores for weight-for-age, height-for-age and weight-for-height were calculated using epidemiological software developed by the Center for Disease Control and Prevention in Atlanta (CDC).[3] In the absence of local references, these Z-scores were referenced against US norms using 1995 data from the United States National Center for Health Statistics. Thus the Z-score means are not zero.

School Performance Data

Three private schools in Oshikhandas had developed rather rigorous end-of-year tests in math, English and Urdu (the national language of Pakistan but not the mother tongue of the children). These tests were given on three consecutive days and lasted no longer than 90 minutes. Because each school used very different syllabi and had teachers of varying quality, it was difficult to standardize an achievement test. Consequently, teachers developed school-specific tests based on what children had been exposed to and drilled on during the academic year as a fair measure of student performance. Students, teachers and parents all accepted these measures of performance because they are familiar with them and believe, rightly or wrongly, that the immediate goal of schooling is for a child to do well on these tests.

Tests were remarkably similar across schools. Math tests for Class 1-A (reception or kindergarten) in which a child identifies larger and smaller items in drawings, larger and smaller numbers in pairs, counting items in boxes, and filling in numbers in increasing and decreasing sequences. For Class 1, the subject moved on to multiples of 2, 5 and 10; two digit addition and subtraction; more complex sequences; use of coins and notes in money; and multiplication of single digits. English and Urdu tests included spelling (adding missing letters), using words in sentences, joining letters (for Urdu), plural forms, naming parts of the body, completing sentences by selecting the correct word from a list, answering simple written questions about village life, and reading out loud.

To compare results across schools, raw subject scores for each child were converted into Z-scores based on the distribution of results within each class. This provided a normalized measure of each child's performance relative to others in the same class. This approach had two advantages: i) rigorous school-specific tests could be used that are more likely to measure differences between better and poorer performers, and ii) differences between schools due to widely varying styles and quality of teaching and classroom environment were eliminated. Within the same class, better and poorer performers are equally exposed to the same advantages and disadvantages of their environment.

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Table 1: Early Childhood Diarrhea Burdens and Anthropometry for 107 children ages 5.5 and 8.5 years, in Oshikhandas, Northern Areas Pakistan

	N	Mean	St. Dev
Diarrhea Episodes Before Age 2	107	2.44	2.08
Diarrhea Episodes After Age 2	107	0.49	0.81
Total Diarrhea Episodes Before Age 5	107	2.93	2.43
Total Diarrhea Duration Before Age 2 (Days)	107	17.89	20.98
Total Diarrhea Duration After Age 2 (Days)	107	2.72	4.92
Total Diarrhea Duration Before Age 5 (Days)	107	20.60	22.10
Weight For Age Z @ Age 2	86	-0.82	0.89
Weight for Age Z During Study	104	-0.65	0.77
Weight for Height Z @ Age 2	84	0.54	1.57
Weight for Height Z During Study	104	0.51	0.88
Height for Age Z @ Age 2	83	-0.22	1.39
Height for Age Z During Study	104	-0.40	0.89

Statistical Methods

For the main analysis multiple regression was used to identify factors that account for a portion of the variance in student's class Z-score in math, English and Urdu. The sets of explanatory variables were entered in an ordered stepwise regression: non-diarrhea variables (parental income and education and child malnutrition measures) were entered into the analysis first and those with an F-value above a predetermined level of significance (in this case 5%) were retained. The effects of various diarrhea variables were then analyzed to identify those that explain significantly more of the performance variance, controlling for the environmental and nutritional variables selected in the first step. This differs greatly from a less structured selection process in which all variables are considered together and those with the most significant F value are entered first.

In this linear regression analysis, the non-diarrhea variables were not correlated with the diarrhea variables, the errors were independent and followed a normal distribution. The standardized residuals were also randomly distributed. The effects of outliers were checked using Cook's distance and DFBETA. The maximum Cook's distance was 0.05987 and the maximum DFBETA was 0.10534, indicating that outliers did not unduly influence the size of the regression coefficients.

Results

Mathematics

In selecting independent non-diarrhea variables for the regression equation on mathematics Z-scores, the F-values of father's and mother's education, father's and mother's income, and combined parental income were compared. Of these father's income proved to be the most significant, and controlling for this the remaining variables were not statistically significant at the 5% level or even at the 10% level. Father's income was therefore the only variable from among the household environment variables included in the analysis. It accounted for 5.1% of the variance in mathematics Z-scores with a p-value of 0.020. The positive coefficient for father's income indicates that children of higher income fathers performed better in mathematics as expected. The regression was also run using all six of the anthropometric Z-scores (weight-for-age, height-for-age, and weight-for-height at age 2 and approximately age 7) in turn but all were insignificant with height-for-age in 1997 (between the ages of 5 and 8) having the lowest p-value of 0.341. None of these malnutrition measures was therefore included in subsequent analyses.

Controlling for father's income, diarrhea lasting more than 14 days before age two proved to be the most significant diarrhea variable, accounting for an additional 6.5% of the variance with a p-value of 0.007 making it significant at less than the 1% level. The negative coefficient indicates that diarrhea lasting more than 14 days before age two is negatively associated with mathematics performance. Adding further diarrhea variables in addition did not account for further variance in math performance. Together father's income and this diarrhea variable explain 11.6% of the variance in mathematics Z-scores as demonstrated in Table 2:

Table 2. Stepwise regression analysis of Math Z-scores vs episodes of diarrhea lasting more than 14 days before age 2 controlling for father's income (n = 107)

Variable	Standardized Coefficient	Change in R Squared	P value
FI -Father's income	0.229	0.051	0.015
14PB2 - Episodes lasting more than 14 days before 2	-0.255	0.065	0.007
	Total R Squared	0.116	

Regression coefficients and P values for each diarrhea variable alone, controlling for Father's income (n = 107, dependent variable Math Z-scores) in descending Standardized Coefficient (ascending P Value) order.

Variable	Standardized Coefficient	P Value
14PB2 – Episodes lasting more than 14 days before 2*		
14P – Episodes before age 5 lasting more than 14 days*	-0.255	0.007
8P – Episodes lasting 8 or more days before age 5*	-0.230	0.015
TDURB2 – Total diarrhea days before 2*	-0.223	0.019
TDUR – Total diarrhea days before age 5*	-0.214	0.025
8PB2 – Episodes lasting 8 or more days before 2*	-0.208	0.029
EP – Total episodes before 5*	-0.206	0.031
B2EP – Before 2 episodes	-0.191	0.046
TDURA2 – Total diarrhea days after 2	-0.172	0.073
A2EP – After 2 episodes	-0.147	0.124
DR8T14A2 – Episodes lasting 8 to 14 days after 2	-0.134	0.161
8PA2 – Episodes lasting 8 or more days after 2	-0.135	0.161
DUR07 – Episodes before age 5 lasting 0 to 7 days	-0.117	0.221
B2EPWL – Before 2 episodes with weight loss	-0.115	0.231
DUR07A2 – Episodes lasting 0 to 7 days after 2	-0.113	0.240
DUR8T14 – Episodes before age 5 lasting 8 to 14 days	-0.100	0.298
EPWL – Episodes before age 5 with weight loss	-0.095	0.321
DUR07B2 – Episodes lasting 0 to 7 days before 2	-0.090	0.350
DR8T14B2 – Episodes lasting 8 to 14 days before 2	-0.089	0.353
14PA2 – Episodes lasting more than 14 days after 2	-0.067	0.484
A2EPWL – After 2 episodes with weight loss	0.045	0.640
	0.020	0.833

***** *Significant at the 5% level or better*

The list of all diarrhea variables in Table 2 (each entered in the regression equation alone, controlling for father's income) ordered by standardized coefficient is very useful for comparing the association of before and after age 2 diarrhea variables and their combinations with mathematics Z-scores. Three important observations derive from these results:

- Comparing the before-age-two and the after-age-two variables, none of the after-age-two variables is significant at the 5% level, while three of the before-age-two variables are significant at this level. These are 14PB2, 8PB2 and TDURB2.
- There is evidence that after-age-two diarrhea is significant since three of the variables covering the entire first five years of life are more significant than their before-age-two subset. These are TDUR, EP and 8P. The significance of these variables is increased by the inclusion of after-age-two data. Therefore, after-age-two diarrhea plays a role, albeit a less pronounced one.
- Episodes with weight loss (B2EPWL and A2EPWL) are not significant which would suggest that diarrhea related malnutrition is not an important factor in mathematics Z-scores. This is consistent with the lack of significance for the malnutrition measures.

English

As with math, father's income proved to be the most significant of the parental education and income variables. Controlling for father's income the remaining income and education variables did not explain significantly greater variance in English Z-scores. Father's income alone accounted for 8.1% of the variance in English Z-scores with a p-value of 0.002. None of the malnutrition measures proved to be statistically significant. In this case weight-for-age at age two had the lowest p-value of 0.333.

Controlling for FI, the number of after-age-two episodes (A2EP) explained the greatest variance in English Z-scores, accounting for 6.7% of the variance with a P-value of 0.005. As with the math analysis, adding additional diarrhea variables did not increase the explanatory of power of the model and the associated coefficients were not significant. Of those reporting diarrhea, the after age two average duration in this data set was 5.6 days. Together FI and A2EP accounted for 14.8% of the variance in English Z-scores as indicated in Table 3, below.

Table 3: Stepwise regression analysis of English Z-scores vs. episodes of diarrhea after age 2 controlling for Father's income (n = 107)

Variable	Standardized Coefficient	Change in R Squared	P value
FI -Father's income	0.285	0.081	0.002
A2EP - After 2 episodes	-0.260	0.067	0.005
	Total R Squared	0.148	

Regression coefficients and P values for each diarrhea variable alone, controlling for Father's income (n = 107, dependent variable English Z-scores) in descending Standardized Coefficient (ascending P Value) order.

Variable	Standardized Coefficient	P Value
A2EP - After 2 episodes *	-0.260	0.005
TDURA2 - Total diarrhea days after 2 *	-0.258	0.005
DUR07A2 - Episodes lasting 0 to 7 days after 2 *	-0.200	0.033
8PA2 - Episodes lasting 8 or more days after 2 *	-0.192	0.041
EP - Total episodes before 5 *	-0.185	0.049
DR8T14A2 - Episodes lasting 8 to 14 days after 2	-0.180	0.056
TDUR - Total diarrhea days before age 5	-0.177	0.059
14P - Episodes before age 5 lasting more than 14 days	-0.167	0.076
A2EPWL - After 2 episodes with weight loss	-0.154	0.101
14PB2 - Episodes lasting more than 14 days before 2	-0.147	0.117
8P - Episodes lasting 8 or more days before age 5	-0.145	0.124
TDURB2 - Total diarrhea days before 2	-0.140	0.138
EPWL - Episodes before age 5 with weight loss	-0.132	0.161
DUR07 - Episodes before age 5 lasting 0 to 7 days	-0.130	0.167
DUR8T14 - Episodes before age 5 lasting 8 to 14 days	-0.121	0.199
B2EP - Before 2 episodes	-0.117	0.217
8PB2 - Episodes lasting 8 or more days before 2	-0.102	0.280
DR8T14B2 - Episodes lasting 8 to 14 days before 2	-0.083	0.379
B2EPWL - Before 2 episodes with weight loss	-0.077	0.414
14PA2 - Episodes lasting more than 14 days after 2	-0.075	0.430
DUR07B2 - Episodes lasting 0 to 7 days before 2	-0.056	0.553

***Significant at the 5% level or better*

The Table 3 results allow several observations:

- In contrast with the mathematics analysis, a comparison of before-age-two variables with after age two reveals that none of the before-age-two variables is significant at the 5% level whereas four of the five variables significant at the 5% level are after age 2. This is strong evidence that the greatest negative association of diarrhea with performance in English is for diarrhea after the age of two.
- Unlike the mathematics analysis, combining variables across the age-two divide does not increase their significance. For instance, combining A2EP with B2EP to form EP increases the p-value of the variable from 0.005 to 0.049, a significant rise. This rise is encountered with all

such combinations, which suggests that diarrhea before age two does not have a measurable association with English Z-score.

- As with math, episodes with weight loss do not add value to the analysis. The weight loss variable (A2EPWL) is the least significant of the after-age-two variables ($p = 0.101$).

Urdu

As with English and math, father's income (FI) was the most important variable from the parental education and income category for Urdu Z-scores. In contrast with the other two, however, father's education (FE) also proved to be significant, and the two variables together account for 14.1% of the variance in Urdu Z-scores. In further contrast with English and math, one malnutrition measure, height-for-age at age 2 (HAZ2) approached accepted levels of significance with a p-value of 0.070. HAZ2 accounted for an additional 3.1% of the variance in Urdu Z-scores such that FI, FE and HAZ2 together accounted for 17.2% of the variance.

Controlling for FI, FE and HAZ2, the number of diarrhea episodes lasting more than 14 days before age two is the most significant of all diarrhea variables with a P-value of 0.150. Adding 14P to the analysis increases the R^2 by 0.009, indicating that this variable accounts for only 0.9% of the variance on Urdu Z-scores. None of the other diarrhea variables approached recognized levels of significance in the analysis. The negative association is supported by the negative coefficients of all diarrhea but the regression analysis is not sufficiently sensitive to quantify this.

Discussion

The analysis confirms the negative association of diarrhea with school performance for mathematics and English, whereas the strength of the association is much weaker for Urdu. A common factor in all three subject areas is the close association with father's income (FI). Wealthier households may create environments that are more conducive to developing a child's ability to perform in school whether by diet-related micronutrient or trace element deficiency or stimulation using toys or television. Fathers with higher incomes may also have other characteristics that give their children an advantage in school.

Mathematics and English

Diarrhea is negatively associated with mathematics and English performance in distinct ways. For math, diarrhea before age two has the strongest negative association, although later it continues to have a slight negative association. For English, by contrast, multiple linear regressions could not identify any before-age-two diarrhea association, whereas after-age-two diarrhea proved significant. This could be evidence for differences in the timing of development of mathematics vs. second language ability, although the findings could be associated with other factors.

The apparent independence of mathematics and English performance from malnutrition variables would suggest that for this group of children, malnutrition as measured by height-for-age, weight-for-age and weight-for-height is not an important determinant of future or current school performance. The lack of performance association with diarrhea episodes involving weight loss supports this assertion. If diarrhea does in fact reduce a child's future ability to perform in these subject areas, it is possible that this occurs through trace element deficiencies that affect cognitive development rather through links with protein-energy malnutrition.

Urdu

The association of diarrhea with Urdu performance was not as strong as for mathematics and English. Urdu is also unique among the three subject areas in having a significant positive association with father's education as well as with a malnutrition measure at age two after controlling for father's income. Children with wealthier, more educated fathers and with greater height-for-age at age two performed better in Urdu.

One possible explanation for these differences between Urdu and mathematics and English could be that children come to school having had considerable exposure to Urdu in their first five years. Although Urdu is not the mother tongue of children in Oshikhandas, they hear Urdu on the radio and television and in many everyday conversations. They also see Urdu written and read, even more so if their fathers are more highly educated. For many children mathematics and English, by contrast, are encountered for the first time in the classroom. It is possible that the height-for-age-at-age-two association with Urdu performance is a result of malnutrition influencing their ability to absorb Urdu early in life before the children enter school, particularly if the malnutrition is long term. Those whose nutritional status is below the norm in early life are possibly less able to process and absorb the Urdu around them, and they thus enter school at a disadvantage due to the previous concurrent effects of malnutrition.

Conclusions

The findings of this paper are consistent with the possibility that diarrhea negatively influences school performance by affecting the bioavailability of trace elements and micronutrients that play complex roles in child development. At a minimum, this study has identified longer duration diarrhea in early childhood as an important risk factor for reduced school performance. However, these findings do not prove causation, and it is possible that other factors govern the diarrhea/school performance association

Given the success of oral rehydration therapy in reducing mortality from diarrhea, the continued high incidence of diarrhea in many parts of the world suggests that the number of survivors of severe early childhood diarrhea is increasing. If these findings are more generally applicable to a broader set of populations, the school potential of these diarrhea survivors could be significantly impaired, and it thus becomes a matter of urgency to reduce the incidence and duration of diarrhea in early childhood if only to increase the returns to investment in education.

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