Original article

The effect of early childhood stunting on children's cognitive achievements: Evidence from young lives Ethiopia

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Abstract

Background: There is little empirical evidence on the effect of childhood malnutrition on children's cognitive achievements in low income countries like Ethiopia. A longitudinal data is thus vital to understand the factors that influence cognitive development of children over time, particularly how early childhood stunting affects cognitive achievement of children up to the age of 8 years.

Objective: To examine the effect of early childhood stunting on cognitive achievements of children using longitudinal data that incorporate anthropometric measurements and results of cognitive achievement tests such as Peabody Picture Vocabulary Test and Cognitive Development Assessment quantitative tests.

Method: Defining stunted children as those having a standardized height for age z-score less than -2; we used a Propensity Score Matching (PSM) to examine the effect of early childhood stunting on measures of cognitive performance of children. The balance of the propensity score matching techniques was checked and found to be satisfied (P<0.01)

Results: Early childhood stunting is significantly negatively associated with cognitive performance of children. Controlled for confounding variables such as length of breastfeeding, relative size of the child at birth, health problems of early childhood such as acute respiratory illness and malaria, baseline household wealth, child gender, household size and parental education, estimates from PSM show that stunted children scored 16.1% less in the Peabody Picture Vocabulary Test and 48.8% less in the Quantitative Assessment test at the age of eight, both statistically significant at P<0.01.

Conclusions: It is important to realize the importance of early investment in terms of child health and nutrition until five years for the cognitive performance of children. As household wealth and parental education are particularly found to play an important role in children's nutritional achievements, policy measures that are directed in improving household's livelihood may have a spill-over impact in improving child nutritional status, and consequently cognitive development and schooling. [*Ethiop. J. Health Dev.* 2017;31(2):75-84]

Key word: Early childhood, stunting, cognitive achievements, Ethiopia

Introduction

For children to be successful at later stages in life, cognitive skills are deemed crucial (1). Evidence also suggests that such cognitive skills are highly dependent on the home environment and parents' nutritional investment throughout the life time of the children although early investments have a more positive impact than do later investments (1-3). This assertion stems from the fact that the years from conception through birth to eight years of age are critical for healthy physical and mental development of children (4).

However, notwithstanding the importance of early nutrition on children's health status as well as their ability to learn, think analytically and socialize with others and their capacity to adapt to changes, child malnutrition rates are very high in many parts of the developing world (1-10), where chronic malnutrition as measured by stunting affects 37% of all under-5 children in Sub-Saharan Africa and robs at least 2–3% of its GDP growth due to losses from increased health care costs in addition to losses from poor cognitive function and the deficits it causes in schooling and learning ability (5). Malnutrition in Ethiopia specifically contributes to an estimated 270, 000 deaths of under-five children each year (11).

A growing number of both experimental and non-experimental empirical studies have been done in developing countries. Many of those studies indicate that early nutritional supplements have positive effects on cognitive achievement among teenagers, and later on their adulthood development (12-18). As example, a randomized nutrition intervention in rural Guatemala that captures the effect of exposure to an intervention from birth to 36 months indicated significantly positive and fairly substantial effects a quarter century after it ended – increased attainment and speedier grade progression by women, higher scores on reading comprehension tests as well as on non-verbal cognitive tests for both women and men were observed (12). A recent experimental study in slum areas of Delhi also showed that iron supplements administered two to six year olds reduced pre-school absenteeism by one-fifth and had significant positive effects on child weight within the first six months of the program, particularly among poorer communities (18-19). A study from Vietnam that used cross-sectional data collected during a baseline survey of a randomized trial to examine the association between results of educational tests and the anthropometric status of school children also concluded that better nutrition during early childhood would significantly increase educational achievement in adulthood under the condition that the individuals

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completed the transition to complete primary education (20).

Similar to the randomized experimental studies, longitudinal studies also demonstrate that children who experience early malnutrition are more likely to have lower scores in tests assessing cognitive function, psychomotor development, fine motor skills, activity levels and attention span (1-2, 21-24). A study on more than 2000 Filipino children showed a negative consequence of malnutrition on cognition and schooling, where severe or moderate stunting resulted in lower scores in cognitive tests at the ages of 8 and 11, as compared to non-stunted children (25). A similarly crafted study also examined the effects of early childhood nutrition and subsequent academic achievement using a longitudinal data set that follows a large sample of children from birth until the end of their primary education (21). The findings demonstrate that malnourished children perform more poorly in school, even after correcting for the effects of unobserved heterogeneity both across and within households. The advantage (at least part of it) that well-nourished children enjoy arises from the fact that they enter school earlier and thus have more time to learn (26).

There are few studies on this issue in Africa and the existing results are somehow mixed for two main reasons (22, 27). One, it is very difficult to get data on all variables of interest, which might result in serious problems of omitted variable bias; and two, the variables that have data are frequently measured with error, which can lead to problems of attenuation bias (21). Yet, in spite of the difficulties, a longitudinal data from rural Zimbabwe showed that early childhood nutritional deficiencies in the form of low height-for-age can be linked to poorer cognitive attainment later in life (22). Another study from Nigeria also compared school academic performances of primary school pupils after a retrospective assessment of their health and nutritional history dating back to their prenatal gestation periods. However, there was no significant association between early nutritional status and later school performance (26-27). To sum up, it has long been known that good nutrition is essential to children's physical and cognitive development (1-3, 18, 20), but recent evidence sheds new light on the optimal timing of interventions to improve child nutrition and the long-term effects of such interventions. Authors like Dobbing particularly argue that the period from birth to six month is a critical period for brain development so that poor nutrition during this period has a long lasting effect on cognitive development of children (28-29), whereas some others like Glewwe and King, who assessed the impact of timing of malnutrition on cognitive development by employing longitudinal data, suggest that the period from 18-24 months since birth may be critical for cognitive development (30). Given such differences in the estimated impacts of the timing of malnutrition on cognitive development and learning outcomes, it is worthwhile to provide evidence on whether children's stunning up to the age of five years has an effect on cognitive development of children at the age of eight. Moreover, it is particularly useful to provide such evidence for Ethiopians where malnutrition of children is highly prevalent and has become a major contributor to child mortality as underlying cause for nearly 50% of under-five deaths (31), but there have been relatively few studies. By estimating the effect of the z-score of height-for-age on cognitive development of eight year old children using longitudinal data from Young Lives project, this study hence provides fresh evidence on the relation between early childhood stunting and cognitive development of children for a typical developing country, Ethiopia.

Method

Sample children: The data used in this study comes from Young Lives, a 15-year survey investigating the changing nature of childhood poverty in Ethiopia, India, Peru and Vietnam (*www.younglives.org.uk*). In Ethiopia, the project is overseen by the Ethiopian Development Research Institute (EDRI) and University of Oxford, funded by UK aid from the Department for International Development (DFID). In each country, the Project follows 2000 children aged 1 and other 1000 children aged 8 years in 2002. While the first group is referred as a Younger Cohort, the latter is termed as an Older Cohort. The children were selected from 20 sentinel sites of Ethiopia's five major regions (Tigray, Amhara, Oromia, SNNP and Addis Ababa) that represent for more than 90% of the total population.

The methodology in the first stage was purposive because the sentinel[1] sites in each region were chosen such that the cost of tracking children in the future was manageable, to reduce the probability of attrition in remote pastoralist areas (32). In each region three to five sentinel sites were selected, with a balanced representation of poor and less-poor households, and urban and rural areas. Finally, from each sentinel site 100 children who were born between April 2001 and June 2002 (the Younger Cohort) and 50 children born between April 1994 and June 1995 (the Older Cohort) were selected using simple random sampling.

As the aim of this study is to examine the impact of early childhood stunting on cognitive performance of children aged 5 and 8, we, however, made use of data only from the Younger cohort who were first appraised in 2002 when they were around age one. The children were then re-interviewed in 2006 and 2009. At the beginning, there was no refusal from parents of the kids to be part of the long-term study, but once started some children were untraceable (n=33) and some others (n=10) refused to give responses up to round three. Additionally, 72 children died up to the third round. Excluding deaths, the total attrition rate over

[1]The concept of a sentinel site comes from health surveillance studies and is a form of purposive sampling where the site is deemed to represent a certain type of population, and is expected to show typical trends affecting those particular people or areas (41).

eight years is 2.15%, reducing the sample of the children to 1884 by the third round (Table 1).

Table 1: **Sample size by Round and preschool experience of urban and rural sample**

Residence area	Round 1 (2002) Age 1	Round 2 (2006) Age 5	Round 3 (2009) Age 8	Preschool Attendance
Urban area	700	762(+)	745	56.91%
Rural Area	1299	1150	1139	3.33%
Total	1999	1912	1884	24.53 %

Source: Woldehanna (33), 2016

Note: (+) shows an increase in the urban sample in Round 2 as the result of mobility from rural to urban areas

The Young Lives longitudinal data is of high quality, where the validity and reliability of the tools used in each survey were approved by the Ethics Committee of University of Oxford and the data collection process was managed by the Ethiopian Development Research Institute (EDRI). Prior data collection in each survey an extensive training focusing on the child, household and community questionnaires, tracking schedule, preliminary interview, consent form, household roster and contact details was given for all field supervisors and enumerators

Immediately following the trainings, pilot surveys were conducted so that necessary amendments could be made to the questionnaires and organization of the field work.

The field enumerators were considered well trained if no error of administrating and scoring was reported by their field supervisors during the piloting. Many of the field supervisors were educated to university level and were with a good track of field work supervision, and more interestingly, working with the same field supervisors and enumerators since the baseline survey in 2002 has enabled us to build stable relations with the families of the children and to minimize errors of administering the interviews and cognitive tests (33-34).

The data collected in all the three rounds include a great deal of information on children's and their families' circumstances (including, but not limited to, prenatal health care, self-reported five point (Likert) birth weight ranging from -2 to 2, child illness in the last 24 hours as reported by parents, family background and wealth, household composition, family structure, per capita consumption expenditure, work patterns and social relationships).

Measures: The data from the Young Lives also contains information on children's nutritional, educational and cognitive outcomes. Therefore, childhood stunting in this study is measured by the z-scores of the child's height-for-age[2] at the ages of 1 and 5 years. The construction of height-for-age z-score is based on comparisons with a "healthy" reference population based on the WHO (2007) criteria. The WHO (2007) has developed a table to measure nutritional achievements based on cross-national data. We have used this WHO table to compute height-for-age z-scores (35). Based on the tables' cut-off, a child whose height-for-age z-score is less than -2 is termed as stunted, and if it is less than -3, the child is severely stunted. Those with less than -6 and above 6 height-for-ages are considered as biologically implausible scores and hence were removed from the analysis.

The validity of this reference standard stems from the empirical observation that well-nourished and healthy children have a very similar distribution of height and weight to the reference population, regardless of their ethnic background or where they live (36-37).

Regarding the outcome variables, child's cognitive achievements were measured by The Peabody Picture Vocabulary Test (PPVT), the Cognitive Developmental Assessment Quantitative (CDA-Q) and Mathematics Tests. The PPVT is a widely-used test of receptive vocabulary. Its main objective is to measure vocabulary acquisition in persons from 2.5 years old to adulthood (38). The test is individually-administered, untimed, norm-referenced and orally-administered. The maximum limit of the score is 204, but to avoid any bias the raw scores were standardized for poor statistical behaviors. As the same set of questions was given to the children at both five and eight years of ages, the PPVT results are straightforwardly comparable between the second and third rounds of the survey.

The quantitative assessment used to measure numerical abilities of the children was also derived from the International Evaluation Association (IEA). At the age of 5, the Cognitive Developmental Assessment quantitative (CDA-Q) had 15 items that were administered orally. But, at the age of eight the assessment test has two parts. While the first part was administered orally and had 9 items, scoring "1" for correct and "0" for blank or incorrect, the second part was a written test administered by the child and had 20 items, making the overall questions 29. This means that, unlike in the PPVT test, the results from Mathematics test between the two rounds are not straightforwardly comparable (39-40).

[2]Height-for-age reflects cumulative linear growth. Height-for-age deficits indicate past or chronic inadequacies in nutrition and/or chronic or frequent illness, but cannot measure short-term changes in malnutrition. Low height-for-age relative to a child of the same sex and age in the reference population is referred to as 'shortness'. Extreme cases of low height-for-age, where shortness is interpreted as pathological, are referred to as 'stunting'.

All cognitive achievement tests were also adapted to the Ethiopian context and translated into local languages during the test administration. To make the results straightforwardly interpretable in the analysis, we also transformed the PPVT and Mathematics scores into logarithm form. As additional evidence, we also looked at the school readiness and progress of the children at the ages of 7 and 8, respectively.

Analysis: In addition to a simple descriptive statistics, we used Propensity Score Matching (PSM) model to estimate the effect of childhood stunting on cognitive performance of children aged 5 and 8 years. The goal of such estimation strategy is to re-establish experimental conditions in a non-experimental setting (41). The process of estimation proceeds in two steps.

First, a propensity score for each child as a conditional probability of being stunted given a full set of covariates is estimated from a logit model. That is, the probability that a child to be stunted is given by

$$\Pr(d_i = 1) = F(\alpha x_i) + \varepsilon_i \qquad (1)$$

where d is dummy variable for a child being stunted, while *x* are a vector of variables that affect both the stunting and cognitive development outcomes, ε is an error term, α are vector of parameters to be estimated and F(.) is a logistic function.

Second, the propensity scores generated from relation 1 are used to create a matched control group of children who were not stunted. That is, the Average Treatment effect on the Treated (ATT) is provided by

$$\text{ATT} \equiv E(CD_{i1} - CD_{i0} \mid d_i = 1) \qquad (2)$$

where d_i is dummy variable if the child is stunted and 0 otherwise, CD_{i1} and CD_{i0} are cognitive outcomes, with CD_{i1} the score of outcome that would be observed if the child was stunted, CD_{i0} the outcome score that would be observed on the same age if the child was not stunted.

Selecting variables to be included in the logit model of propensity score needs a deeper knowledge of the reasons for stunting, if not omitting relevant variables can seriously increase bias in resulting estimates. There is no guideline on how to choose conditioning variables, *x*, but selection of *x* variables intuitively is very important such that the covariates must include variables that affect both the outcome and being stunted (42).

The advantage of our longitudinal data is that we can capture much of the differences among the children by including variables what happened to mothers and the households before and after the birth of the children and match the stunted with the non-stunted in a better way than many studies relying on cross-section data (20-23). If the matching process proceeds appropriately, the stunted and non-stunted will have similar measured characteristics and the effects of stunting can be estimated by comparing the mean scores of the matched children. To do this, we examined the level of matching scores using kernel density graphs and limit the sample children for whom there is sufficient overlap in propensity scores (in the area of common support). To check the robustness of the results we estimated the PSM using alternative techniques such as Kernel Matching Method, Radius Matching and One-to-One Matching techniques.

Results

Descriptive statistics: Table 2 reports the variables of interest of this study. It appears that 52% of the children are male and 60% of the sample households reside in rural areas. On average, at age 1 the children had a height-for-age z-score that is 1.53 standard deviations below the WHO standard. This makes more than one-third (42%) of them in the sample are to be stunted (height-for-age z-scores less than –2), while more than one-fourth (22%) of them are severely stunted (height-for-age z-scores less than –3). There seems, however, a sort of recovery from early stunting by the age of 5 years, where the height-for-age z-score was 1.45 standard deviations below the WHO standard and the percentages of early stunted and severely stunted children declined to about 31% and 8%, respectively.

Also, as reported by the primary caregivers of the children about one-half (47%) of the children have experienced some kind of health problem by the age of 1 year, with 13% of them severely ill or injured such as acute respiratory illness and malaria in the last 24 hours of the survey time. Self-reported five point (Likert) scale for the relative size of the children at birth (ranging from -2 to 2) also show that the sample children have an average birth size of 0 on the 5 point scale, indicating that the average birth weight of the children was extremely small that might be one of the factors for the high level of stunting (-1.53 of height-for-age z-score at age 1).

Regarding maternal health care services, many of the children's mothers were young adults with average age of 27 years during giving birth. Also, only about 62% of them reported that the pregnancy was wanted, while 38% of them were unaware of their pregnancy till the first few months. As the result, the average number of antenatal visits during pregnancy was very limited in number, only 2 times during the whole pregnancy period. It was also reported that about 6% of the mothers were disabled or had long-term health problems. Again, at the age of 1 year, about 6% of the children's parents were not living together as the result of divorce, separation or death.

Table 2: **Basic characteristics of the sample children and their families (1883)**

	Mean	Std. Dev.	Min	Max
	-			
Z-score of height-for-age at age one	1.53	1.86	-5.98	5.91
Dummy for stunted child at age 1 (zhfa<-2)	0.42	0.49	0	1
Dummy for severely stunted child at age 1 (zhfa<-3)	0.22	0.41	0	1
Z-score of height-for-age at age 5	-1.45	1.12	-	4.59
Dummy for stunted child at age 5 (zhfa<-2)	0.31	0.46	0	1
Dummy for severely stunted child at age 5 (zhfa<-3)	0.08	0.27	0	1
# of antenatal visits by mother during pregnancy	2.05	2.62	0	16
Mother's age at birth (years)	27.48	6.39	15	55
Dummy for wanted pregnancy	0.62	0.48	0	1
Dummy if child was born before expected	0.10	0.30	0	1
Mother has a permanent health problem	0.06	0.24	0	1
Dummy for child had health problems at age 1	0.47	0.50	0	1
Likert scale for the relative size of child at birth (from -2 to 2)	0.00	1.02	-2	2
# of months mother breastfeed the child	32.32	10.35	0	36
Dummy for severe illness or injury	0.13	0.34	0	1
Age of the child in months 2006	62.32	3.83	52.7	75.36
Household wealth index at age 1 (2002)	0.21	0.17	0.00	0.74
Household wealth index at age 5 (2006)	0.28	0.18	0.01	0.87
Household wealth index at age 8 (2009)	0.33	0.18	0.01	0.86
Household size at age 1	5.75	2.15	2	16
Per capita annual consumption expenditure (Birr in 100)	14.79	11.54	97.08	106.62
Highest grade completed by primary caregiver (in years)	2.76	3.66	0	14
Highest grade completed by father (in years)	4.40	4.19	0	14
Dummy for parental divorce or separation by age 1	0.05	0.21	0	1
Dummy for male	0.53	0.50	0	1
Dummy for urban site	0.40	0.49	0	1
Dummy if household received support from NGOs or	0.66	0.47	0	1
Dummy variable for child being enrolled in preschool	0.25	0.43	0	1

Source: Own computation

Table 3: **Cognitive achievement and school enrolment and progression**

	All children (N=1883)	stunted at age 5 (n=587)	non-stunted at age 5 (n=1296)	
	Mean	Mean	Mean	Mean Difference[(a)]
Standardized core of PPVT test at age 5 (out of 204)	67.54	63.25	69.44	-6.19***
Standardized core of PPVT test at age 8 (out of 204)	78.51	69.99	82.36	-12.37***
% Standardized core of PPVT test at age 5	33.11	31.00	34.04	-3.04***
% Standardized core of PPVT test at age 8	38.48	34.31	40.37	-6.06***
# of correctly answered Q-CDA test at age 5 (out of 15)	8.21	7.74	8.43	-0.69***

# of correctly answered Q-CDA test at age 8 (out of 29)	6.34	4.62	7.12	-2.49***
% of math questions correctly answered at age 5	54.76	51.60	56.18	-4.58***
% of math questions correctly answered at age 8	21.87	15.94	24.55	-8.60***
Dummy variable for a child begun formal school at 7	0.77	0.64	0.84	-0.20***
Grade completed at the age 8	0.79	0.59	0.88	-0.30***

*Note: *p < 0.1; **p < 0.05; ***p < 0.01*
(a): Test that all means are the same: Hotelling T2 = 35074.2; Prob > F = 0.0000

Although the wealth indices[3] of the sample households over the three rounds of the survey consistently improved–from 0.21 in 2002 to 0.23 in 2006 and further to 0.35 in 2009, many of the households where the children were drawn from were still poor as the wealth index criterion of Young Lives states that a household whose wealth index is below 0.45 is considered poor (32). The average household size during the baseline survey was 6, with per capita annual consumption expenditure 1480 Ethiopian Birr. Also, the average years of schooling for the mothers and fathers were found to be low at 2.8 and 4.4, respectively. A quarter (25%) of the children also attended preschool during their early childhoods.

Preliminary difference of outcomes: one of the most important issues in this study is to explore whether early childhood stunting does really limit cognitive performance of children. To examine those preliminary differences between the means of different children, we applied both one-sample-t test and multivariate statistics. If we begin with the multivariate statistics as seen at the bottom of Table 3, the T^2 value is highly significant (Hotelling T2=35074.27 & P<0.01) indicating that we don't capitalize on chance when computing multiple t-tests. This statistical test indicates that stunted children had significantly lower cognitive scores than their non-stunted counterparts both at the ages of 5 and 8, where the differences in standard PPVT scores between the two groups at the ages of 5 and 8 were respectively 6.19 and 12.37. The same is true with the percentage of correctly answered CDA-Q and Maths tests, where stunted children scored respectively 4.58 and 8.60 percentage points lower than the non-stunted children. Furthermore, stunted children were less likely to enroll in formal schooling at the age of 7, with slower early grade progression at the age of eight, than those none-stunted children.

Propensity Score Matching (PSM): to infer causality, it may be appropriate to see if stunting has an effect on PPVT and Mathematics test scores. Accordingly, we employed propensity score matching techniques where we run first stage logit model estimation of stunting at age 5 so as to predict propensity scores of stunting that are used for matching to estimate average treatment effects of the treatment (stunting) on the treated (stunted). Variables potentially associated with the probability of a child being stunted (treatment) and cognitive developments (outcomes) are included in the first stage logit regression model. Those mainly include dummy for a child being stunted at the age of one, which is expected to capture the carry-over effect that might exist starting from birth, length of breastfeeding, relative size of the child at birth, dummy for child had health problems such as acute respiratory illness and malaria by the age of one year, baseline family wealth index, child gender, household size, and parental education levels in years. The coefficients from logit model indicated that being stunted at age 5 is highly associated with being stunted at age 1. The inclusion of being stunted at age one year in the first logit model is particularly very important to capture the carry-over effect that might arise from time lag at the ages of five and eight. As expected, early household circumstances such as baseline household wealth index, education and residential areas (in favour of urban area) were found to be negatively associated with being stunted at the age of 5.

Having identified the contributing factors for early childhood stunning in this way and driving predicted values from the logit model, we computed the distribution of the propensity score for each child in the treated and control groups to identify the existence of a common support and the level of matching in terms of covariates.

Figurer 4 exhibits the distribution of the children with respect to the estimated propensity scores. Most of the stunted children are found in the right side of the distribution, while those stunted children are found in the left side of the distribution graph. As seen in the second panel of the figure, the match between the stunted and non-stunted appears to be satisfactory. In other words, the matching result indicates that the differences between the two group of children can be captured by the observables and the only remaining relevant difference between the two groups of children is being stunted or not at early years of time and there is no individual effect in relation to the cognitive outcomes. To ensure that the stunted and non-stunted children look identical in terms of their covariates, we further ran a balancing test, which helps to check

[3] Wealth index variable captures indicators that are broader than production assets, such as home ownership and the durability of that home, plus access to infrastructure such as water and sanitation. It is constructed by summing three components: measures of housing quality, consumer durables and services. The components are calculated as scaled values (0 to 1). The measure of housing quality is based on the type of material the floor, roof and walls were made of, and the number of rooms relative to household size. The service component is the average of the dummy variables on the availability of electricity, piped water, fuel for cooking and toilet facilities. The consumer durables measure is the sum of the dummy variables related to households' ownership of radio, TV, refrigerator, bicycle, motorcycle, car, mobile phone, landline phone and fan.

whether the propensity score model is adequately specified. Results of this test also indicated that the balancing condition is satisfied. The conditional probabilities estimated from the propensity score model are then used to compute the matching analysis, where as the result we find 1813 of children in the region of common support, with 569 stunted and 1244 non-stunted. Only 70 children (18 stunted and 52 non-stunted) were found to be off the common support, which as the result we excluded them from the propensity score matching analysis.

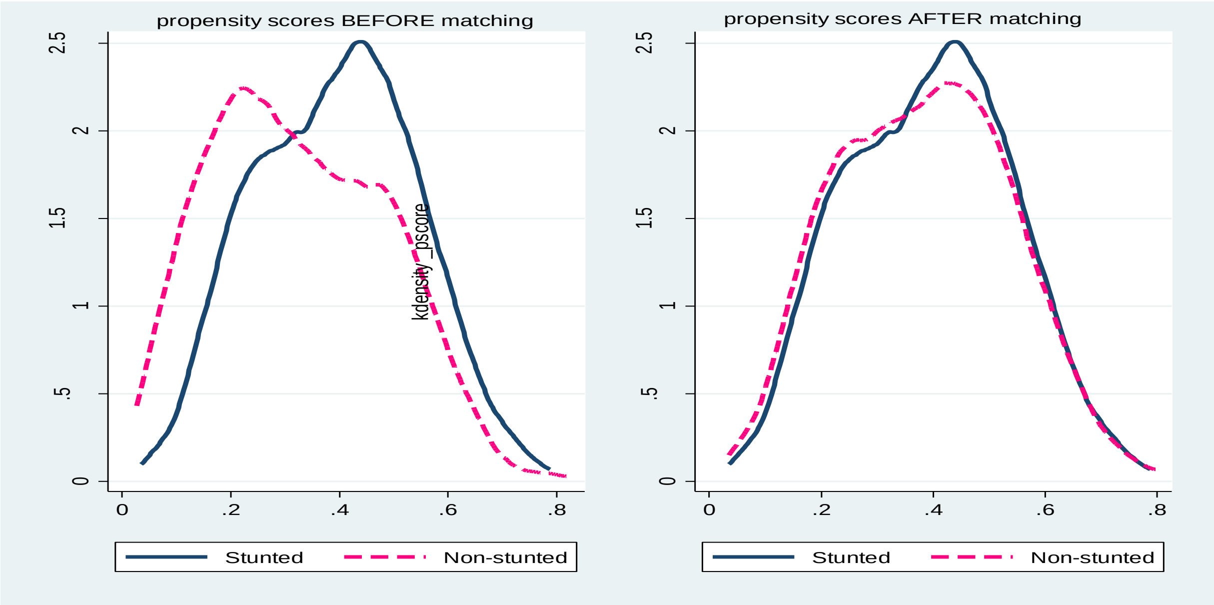

Figure 1: **Kernel density distribution of propensity score before and after matching of the stunted and non-stunted children**

Average Treatment effect of the Treatment (ATT) estimates: As discussed earlier in the methodology part, we used various matching techniques including kernel, radius and one-to-one matching techniques with the application of stata "psmatch2" command (42) to estimate the Average Treatment effect of the Treatment (ATT) on cognitive development of stunted children. The results indicate that effect of estimates from the three matching techniques are generally in the same direction, but for economic of space we only reported estimation results from the kernel and radius matching analysis in Table 4.

The results of the ATT confirm that there are cognitive achievement advantages from being non-stunted in early years of time. The differential effects are consistently significant and higher in magnitude in both matching models. From the kernel analysis it is apparent to observe that stunted five-year-old children scored 16.1% lower in the standard PPVT test and 7% lower in the Cognitive Developmental Assessment quantitative test (CDA-Q) than their none-stunted counterparts. The differences in scores also are visible at the age of eight, where the difference in standard PPVT score remained flat at 16.1% and the difference in Mathematics score was much higher (44.8%) at age 8 than at the age of 5 (7.2%). This may signify that the negative effect of childhood stunting magnifies as the children get older.

Furthermore, although it might not be an indicator of cognitive development, we also tried to look at whether there is an association between childhood stunting and schooling at the ages of 7 and 8. The results show similar effects to those of cognitive outcomes, where stunted children were found with 17.8% less likely to be enrolled in school at the age of 7 than none-stunted children. Among those who got enrolled at the seven years of age, stunted children also showed a slow grade progression at the age of 8, implying that none-stunted children showed higher primary school enrolment and grade progression rates than stunted children of the same age.

All in all, the result from the PSM analysis sheds light on the causal effect of malnutrition on cognitive achievement of children at the ages of 5 and 8 years, which is in support of our initial hypothesis that early childhood nutrition is one of the key intervention points for the development of children's brain and cognitive performance.

Table 4: **ATT estimates of Propensity Score Matching (PSM)**

	Kernel matching			**Radius matching**		
Variables [a]	ATTk	S.E.	T-stat	ATT	S.E.	T-stat
Logarithm of standardized PPVT score at age 5	-0.161	0.027	-5.9***	-0.165	0.026	-6.38***
Logarithm of standardized PPVT score at age 8	-0.161	0.021	-7.51***	-0.166	0.019	-8.78***
Logarithm of % of CDA-A score at age 5	-0.072	0.023	-3.16***	-0.077	0.022	-3.42***
Logarithm of % of math score at age 8	-0.448	0.046	-9.71***	-0.452	0.041	-10.93***
Probability of being enrolled in school at 7	-0.178	0.023	-7.7***	-0.177	0.023	-7.62***

Level of grade achieved by a child at 8	-0.281	0.035	-8.12***	-0.280	0.035	-7.96***

note: *** p<0.01, ** p<0.05, * p<0.1 (T>=1.65=*; T>1.96=***; T>2.6=***); N=1,833; ATT=Average treatment effect on the treated.
first stage logit model used to predict propensity scores of stunting at age 5 that are used for matching the children and to estimate Average Treatment effects of the Treatment (stunting) on the treated (stunted) was controlled for being stunted at age one year (that might capture any carry-over effect), number of months breastfeeding, relative size at birth, health problems at early years such as respiratory problems and malaria incident, sex of the child, baseline household wealth index, household size and composition and parental/primary caregivers' educational level in years (readers interested in this issue can contact the authors at the corresponding email address).

Discussion

This study was conducted to find empirical evidence in support of the claim that nutrition in the early years of life can have a profound effect on children's health status as well as their ability to learn, think analytically and socialize with others and their capacity to adapt to changes (2-10). To do this, we used a very rich dataset, gathered over three time periods (infancy, early childhood and elementary age) with very low attrition rates from the Young Lives project in Ethiopia that is a 15-year Longitudinal survey investigating the changing nature of childhood poverty in the country. We specifically looked at whether stunting at age five (and at age one) really limits children's cognitive development at later ages. The data obtained from the surveys revealed that about one-third of sample children were stunted by the age of 5 and to look at the potential effect of this childhood stunting on cognitive performance of the children, we used both simple statistics (multivariate mean test) and Propensity Score Matching (PSM) model.

The multivariate mean test revealed a marked difference in scores between the stunted and non-stunted children at both the ages of five and eight years. For example, at the age of 8 the average PPVT score was 72.88 for stunted children and 81.29 for their non-stunted counterparts, which is more than 12 points of difference. As in the PPVT test scores, the quantitative assessment score was also much higher for non-stunted children with 8.60 percentage points of difference (in favor of non-stunted children) at the age of 8, all differences statistically significant at P<0.01. These preliminary results show that stunting has noticeable negative effect on cognitive development of children at the age of five and eight years old in Ethiopia.

However, to infer causality we employed different propensity score matching techniques: kernel analysis, radius and one to one matching controlling for confounders. We found consistent results across all these estimating techniques (with some difference in magnitude of parameter estimates) that reinforced our hypothesis that childhood nutrition has significantly and positively impact on children's cognitive development as measured by two separate achievement test scores, namely Picture Peabody Vocabulary test (PPVT) score and cognitive development assessment-quantitative test (CDA-Q) or Mathematics test. Our propensity score matching results from the Kernel analysis particularly shows that stunted children scored 16.1% less in PPVT test and 48.8% less in Mathematics test at the age of eight, confirming these preliminary results from the simple statistics test. The estimation results also are robust to alternative estimates of matching techniques, providing further evidence, consistent with the literature (2-10), that well-nourished children are found to perform better while malnourished children are in cognitive disadvantage.

Strength and Limitation: There is one caveat on the representativeness of the sample children, however. As the aim of the Young Lives longitudinal survey has been mainly to follow the lives of children and to track the impact of poverty on their overall development over the 15 years of time and accordingly to inform policy makers better about the reality of childhood poverty, there was some selection bias towards poor households from the beginning of the survey in 2002. If this assumption of oversampling of poor households holds true, the data does not need to be representative for the whole Ethiopia and our interpretation of the results is under this caution. Nevertheless, in spite of this selection bias towards poor family of the children, the longitudinal survey design is an appropriate and valuable instrument in analyzing causal relations and modeling child welfare in the country, where it is hard to find any kind of such longitudinal dataset (40).

In conclusion, the result of the study show those children that were nutritionally disadvantaged at age five (and at age one) are found to perform relatively poorly on cognitive performance and schooling at a later age. The policy implications that we can draw from our empirical exercise are the importance of early investment in terms of child health and nutrition at around the age of one and five years on cognitive performance of children. Since providing balanced diet and health services are the key for children's nutritional achievements, efforts (and perhaps increased resources) should be devoted to improving prenatal and postnatal care, mothers' (parental) education, and other related environmental factors. As baseline household wealth and parental education also are found to play an important role in children's nutritional achievements, policy measures that are directed in improving household's livelihood may have a spill-over impact in improving child health, and consequently cognitive development and reducing school drop-out.

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