Association of basic vaccination with cognitive and learning ability among children: insights from the India Human Development Survey, 2004–05 and 2011–12

Article *in* Journal of Biosocial Science · January 2021

DOI: 10.1017/S0021932020000760

CITATIONS
9

READS
127

2 authors:

William Joe
University of Delhi
109 PUBLICATIONS **1,538** CITATIONS
SEE PROFILE

Ajay Kumar Verma
Banaras Hindu University
6 PUBLICATIONS **9** CITATIONS
SEE PROFILE

Journal of Biosocial Science (2021), page 1 of 14
doi:10.1017/S0021932020000760

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Association of basic vaccination with cognitive and learning ability among children: insights from the India Human Development Survey, 2004–05 and 2011–12

William Joe and Ajay Kumar Verma*

Population Research Centre, Institute of Economic Growth, Delhi University (North Campus), Delhi, India
*Corresponding author. Email: ajaykum.verma@gmail.com

(Received 11 February 2020; revised 13 November 2020; accepted 16 November 2020)

Abstract

Basic vaccination is important to protect children from infectious diseases and illnesses. Adequate levels of vaccination coverage reduce the morbidity and mortality burden among children and promote their physical and mental development. This study aimed to assess the association between basic childhood vaccination and the cognitive and learning ability of school children in India. Nationally representative follow-up data on 6183 children from the Indian Human Development Surveys conducted in 2004–05 and 2011–12 (IHDS I & II) were analysed. Children aged 8–10 years who had received all basic vaccines by the age 12 months performed better in a maths test than partially vaccinated or unvaccinated children (OR: 1.87, 95% CI: 1.48, 2.35). Similarly, fully vaccinated children performed better in writing tasks than partially vaccinated or unvaccinated children (OR: 1.77, 95% CI: 1.44, 2.18). Likewise, fully vaccinated children had better reading skills than fully unvaccinated children (OR: 1.60, 95% CI: 1.23, 2.09). The results suggest that enhancing child vaccination coverage can have significant benefits beyond health and can potentially improve the long-term educational outcomes of children.

Keywords: Childhood vaccination; Cognitive development; Maths; reading and writing

Introduction

Childhood vaccination is important to protect children from various diseases and illnesses. Adequate levels of vaccination coverage mitigate the mortality and morbidity burden among children in both developed and developing countries (Andre *et al.*, 2008). Vaccines stimulate the body's immune system and protect individuals from subsequent infection and disease (Pasquale *et al.*, 2015). Vaccination not only has a significant life-saving potential, but also contributes to economic growth and well-being. For instance Ozawa *et al.* (2017) estimated the benefits of vaccination for 72 low-income countries and concluded that a vaccination programme would save 6.4 million lives and avert 426 million cases of illness, US$6.2 billion in treatment costs and US$145 billion in productivity losses during 2011 to 2020. Similarly, Largeron *et al.* (2015) concluded that vaccination against infectious disease in children, adults and elderly people decreases health care costs by reducing the need for medical care, diagnostic tests, treatment and hospitalization. Quilici *et al.* (2015) also found that childhood vaccination could protect individuals from fifteen crucial infectious diseases and also increase school attendance in European countries.

While most studies of childhood vaccination have assessed its association with morbidity, mortality and the cost-benefits of child health, in recent years attempts have been made to examine its association with school attainment and cognitive development. Anekwe *et al.* (2015),

in their study in South Africa, found that timely receipt of measles vaccination was associated with better school grades at ages 6–11 years. Similarly, Bloom and colleagues (2011) concluded that vaccination against measles, polio, tuberculosis, diphtheria, pertussis and tetanus was associated with increased cognitive test scores in childhood. Children who were vaccinated in childhood against hepatitis B and diphtheria-tetanus-pertussis (DTP) using a formulation with or without thimerosal showed better scores on the Wechsler intelligence scale for children (WISC-R) (Mrozek-Budzyn *et al.*, 2015). What's more, the effects were long-lasting. In the context of China, Oskorouchi *et al.* (2020) found that adults aged 45 years and above who were fully vaccinated before the age of 15 scored more highly on numeracy and episodic memory tests. Nandi *et al.* (2020), in their study in India, showed that adults who were born during or after the implementation of the 1978 Universal Immunization Programme (UIP) had better school grades than those born prior to the UIP. A longitudinal study in India (Nandi *et al.*, 2019a) revealed that Haemophilus Influenza type b (Hib) vaccinated children under the 6 years scored higher in English and maths at age 11–12 years. At age 14–15 years they had higher scores in reading and maths than unvaccinated children. A longitudinal cohort study from Ethiopia, India and Vietnam concluded that children who were vaccinated for measles at age 6–18 months had better cognition and school performance at age 7–12 years than measles-unvaccinated children (Nandi *et al.*, 2019b). Clearly, experimental and observational studies have demonstrated the many benefits of childhood vaccination, including improved physical development, better educational outcomes and equity in the distribution of health gains (Jit *et al.*, 2015).

Previous studies have revealed an association between certain vaccines and cognitive development in particular regions of India. However, few studies have evaluated the association between childhood vaccination and cognitive development using nationally representative surveys in the country. The present study analysed panel data from the 2004–05 and 2011–12 Indian Human Development Surveys to examine the association between child vaccination status and cognitive and learning ability among children at age 8–10 years. The IHDS 2004–05 provides information on childhood vaccination for under-5 children and this was matched with performance scores in reading, writing and maths for children aged 8–11 years, available in IHDS 2011–12.

Methods

Data

Data were taken from the India Human Development Surveys (IHDS). This is a nationally representative household survey jointly carried out by the National Council of Applied Economic Research (NCAER) and the University of Maryland, USA. The first round of IHDS interviews were completed in 2004–05, and covered 41,554 households in 1503 villages and 971 urban neighbourhoods across India. The IHDS survey is a multi-topic panel survey, and the IHDS 2011–12 survey included 42,152 households in 384 districts, 1420 villages, and 1042 urban neighbourhoods across the country. However, the IHDS 2011–12 re-interviewed 83% of these households, as well as split households (those located within the same village or town and an additional sample of 2134 households), to trace changes in people's lives.

The IHDS 2011–12 gathered information on school knowledge among children who were 8–11 years old. Reading, writing and arithmetic knowledge tests were administered to all available children in these age groups in surveyed household. The tests were developed in collaboration with Pratham NGO New Delhi, India, and were pre-tested to ensure comparability across languages. The IHDS 2004–05 round provides childhood vaccination information on 11,781 eligible households. Childhood vaccination information was canvased in the household data file of IHDS 2004–05 and information about children's maths, writing and reading tests was recorded in an

individual data file in IHDS 2011–12. Furthermore, the matched household data set was merged with the IHDS 2011–12 individual data file through the link file of the survey. Of the total eligible cases, 9781 children aged 8–11 from IHDS–II were matched, and the rest of the cases were deleted because of data unavailability on account of household migration, death etc. between 2004–05 and 2011–12. The Stata software program *zanthro* was used to measure the anthropometric status of children, which provides anthropometric indicators based on the WHO reference for child growth standards 2007 (Vidmar *et al.*, 2013). As per the referred norms, *zanthro* calculates weight-for-age information for children aged 0–10 years, so children above the age of 10 years were excluded. Accordingly, the study was based on a final analytical sample of 6183 cases.

Bivariate analysis was used to examine the association between the acquisition of basic skills by children and their immunization status. A multivariate logistic regression model was used to examine the effect of childhood vaccination on cognitive development among school-age children, which was measured by different skill tests.

Outcome variable

The outcome variable was the 'cognitive and learning ability of 8- to 10-year-old children measured by their level of skill in maths, reading and writing'. For maths, children were grouped into four categories, 1) cannot identify any numbers between 10 and 99, 2) can identify numbers only, 3) can subtract two-digit numbers with borrowing but cannot divide numbers and 4) can divide as well as subtract. For the reading task, children were classified into five categories: 1) cannot recognize any letters, 2) can recognize letters but cannot read words, 3) can read words but not connect them into sentences, 4) can read simple two-to-three sentence paragraphs but not a one-page story and 5) can read a one-page story. For the writing task children were divided into three categories: 1) cannot write a simple sentence, 2) can write a simple sentence with two or fewer mistakes and 3) can write a simple sentence without making a mistake.

For the multivariate analysis, the maths task was coded into two categories: 0=can't recognize any numbers; 1=can read numbers and/or subtract a two-digit number from another two-digit number and/or divide a three-digit number with a one-digit number. The reading task was coded into two categories: 0=cannot read at all; 1=can read letters and/or words and/or a short paragraph and/or a short story. The writing task was coded into two levels: 0=can't write at all; 1=can write with two or fewer mistakes and/or no mistakes.

Key explanatory variable

The vaccination status of children was the key explanatory variable. Information on vaccination was collected for the last two children of eligible women in the IHDS 2004–05, and was categorized into three: full vaccination, partial vaccination and no vaccination. 'Full vaccination' meant having three doses of the polio vaccine, three doses of DPT (diphtheria-pertussis-tetanus), one dose of BCG (Bacillus Calmette-Guérin) against tuberculosis and one dose of the measles vaccine before the age of 12 months. Partial vaccination meant that the child missed one or more vaccine whereas no vaccination meant the child did not receive any vaccine.

Other variables

Socioeconomic and other background variables included in the analysis were child's age, sex, size at birth, type of school, religion, caste, anthropometric indicators (stunting, underweight); and maternal education, wealth index tertiles, place of residence, source of drinking water and whether there was a toilet facility in the household.

Results

Results of bivariate analyses

Tables 1, 2 and 3 show the results of the bivariate analysis of the sample children's mathematical, writing and reading abilities, respectively, by their vaccination status and other explanatory variables. Overall, vaccinated children had better mathematical ability than unvaccinated children (Table 1). Of those with full vaccination, 11.4% could not identify numbers at all between 10 and 99, but 35.2% could; 33.0% could do two-digit subtraction; and 20.6% could divide a three-digit number by a single-digit number and also perform two-digit subtraction. On the other hand, only 9.0% of unvaccinated children could perform numerical division and only 18.3% could subtract.

As for writing ability, of the fully vaccinated children, 42.8% were able to write a simple sentence without making a mistake, whereas only 24.1% of the unvaccinated ones could do so (Table 2). While 19.6% of fully vaccinated children could not write a simple sentence, more than twice as many (43.6%) were unable to do so among the unvaccinated children. Significant differences were also found in the reading ability of fully vaccinated and unvaccinated children (Table 3). Of the fully vaccinated children, 7.6% were unable to identify words, but three times as many among unvaccinated children (22.2%) were unable to do so. Rates of paragraph and story-reading ability among the fully vaccinated children were 21.4% and 39.0%, respectively, while among those that were unvaccinated the respective rates were 12.0% and 22.7%.

Results of multivariate logistic regression analyses

The multivariate regression analyses indicated significant associations between childhood vaccination and the mathematical, writing and reading abilities of the 8- to 10-year-old children (Table 4). Children who were fully vaccinated by the age of 12 months were more likely to be able to do simple mathematical tasks (OR: 1.87, 95% CI: 1.48, 2.35), write sentences (OR: 1.77, 95% CI: 1.44, 2.18) and read words, paragraphs and stories (OR: 1.60, 95% CI: 1.23, 2.09) than unvaccinated children.

Among the other explanatory factors, maternal education, social or caste background and household socioeconomic status all had significant effects on the mathematical, writing and reading abilities of the children. Those with mothers with more than 10 years of schooling were more likely to be able to do simple maths (OR: 3.63, 95% CI: 1.91, 6.91), write (OR: 3.18, 95% CI: 2.08, 4.87) and read (OR: 7.3, 95% CI: 2.62, 20.31) than those with illiterate mothers. Compared with poor children, those from economically advantaged households had better odds of doing simple maths (OR: 1.63, 95% CI: 1.23, 2.15), writing sentences (OR: 1.49, 95% CI: 1.18, 1.87) and reading (OR: 1.94, 95% CI: 1.38, 2.72). Children from scheduled caste and scheduled tribe (SC/ST) households were less likely to be able to perform well in maths (OR: 1.94, 95% CI: 1.38, 2.72), writing (OR: 1.94, 95% CI: 1.38, 2.72) and reading (OR: 1.94, 95% CI: 1.38, 2.72) than other social groups.

Age of the child, nutritional status and type of school were all found to be associated with mathematical, writing and reading abilities. Children at the age 10 years had a higher chance being able to do simple maths (OR: 2.2, 95% CI: 1.83, 2.64), write a sentence (OR: 2.24, 95% CI: 1.91, 2.63) and read (OR: 2.12, 95% CI: 1.71, 2.61) than younger children (8 years). Children of 10 years of age had relatively higher odds ratio for writing compared with reading and mathematical solving abilities. As expected, older children were better as mathematics, writing and reading than younger children. Girls were less likely to be able to do simple maths than boys (OR: 0.78, 95% CI: 0.67, 0.92). However, there was no significant gender difference in writing and reading skills. Children with normal height-for-age (not stunted) had better odds of being able to do maths (OR: 1.61, 95% CI: 1.33, 1.57), write (OR: 1.57 95% CI: 1.34, 1.84) and read (OR: 1.45, 95% CI: 1.17, 1.80) compared with stunted children. Children with normal weight-for-age (not underweight) were more likely to be able to do maths (OR: 1.31, 95% CI: 1.07, 1.6), write (OR: 1.37, 95% CI: 1.16, 1.62) or

Table 1. Bivariate analysis of association of children's mathematical ability with explanatory variables

Characteristic	*N*	No maths (%)	Number (%)	Subtraction (%)	Division & subtraction (%)	χ^2
Vaccination status						
No vaccination	740	31.49	41.22	18.24	9.05	291.65 ($p<0.001$)
Partial vaccination	2198	22.34	39.17	26.02	12.47	
Full vaccination	2656	11.41	35.13	32.91	20.56	
Age of child						
8 years	1760	24.55	42.05	24.20	9.20	172.53 ($p<0.001$)
9 years	1738	16.46	37.11	30.49	15.94	
10 years	2156	14.98	34.04	29.82	21.15	
Sex						
Male	2965	16.49	37.47	28.84	17.20	20.55 ($p<0.001$)
Female	2689	20.53	37.49	27.67	14.32	
Height-for-age						
Stunted	3110	23.22	40.61	25.21	10.96	231.13 ($p<0.001$)
Normal	2544	12.54	33.65	32.04	21.78	
Weight-for-age						
Underweight	3599	22.37	40.18	25.34	12.11	220.02 ($p<0.001$)
Normal	2055	11.48	32.75	33.43	22.34	
Type of school						
Government	3489	22.56	40.24	25.25	11.95	255.82 ($p<0.001$)
Private	2106	10.40	32.95	34.00	22.65	
Maternal education						
No schooling	2732	28.95	41.54	20.35	9.15	760.08 ($p<0.001$)
<5 years	349	15.47	43.84	33.52	7.16	
5–10 years	2067	8.95	34.74	34.69	21.63	
>10 years	506	2.17	22.33	41.30	34.19	
Wealth index						
Poor	1810	31.82	42.54	18.18	7.46	689.09 ($p<0.001$)
Middle	1744	18. 0	40.31	27.69	13.99	
Rich	1683	6.48	28.76	36.96	27.81	
Religion						
Hindu	4487	17.94	37.24	28.21	16.60	82.24 ($p<0.001$)
Muslim	825	24.85	40.61	25.45	9.09	
Other	342	9.06	33.04	35.96	21.93	
Caste						
Other	1381	11.51	34.03	32.15	22.3	131.06 ($p<0.001$)
OBC	2421	18.84	38.21	29.16	13.8	
SC/ST	1849	23.04	39.16	24.12	13.68	

(*Continued*)

Table 1. (*Continued*)

Characteristic	*N*	No maths (%)	Number (%)	Subtraction (%)	Division & subtraction (%)	χ^2
Place of residence						
Rural	4251	21.52	38.74	25.48	14.26	270.58 ($p<0.001$)
Urban	1403	8.98	33.64	36.78	20.6	
Source of drinking water						
Unimproved	2996	25.2	39.12	22.10	13.58	233.3 ($p<0.001$)
Improved	2643	10.76	35.63	35.25	18.36	
Child size at birth						
Large	741	21.46	38.46	25.51	14.57	33.17 ($p<0.001$)
Average	3814	16.70	37.26	28.92	17.12	
Small	1045	22.01	37.51	28.23	12.25	
Household has own latrine						
No	3860	23.50	40.13	24.38	11.99	377.16 ($p<0.001$)
Yes	1766	7.36	31.54	36.75	24.35	

read (OR: 1.46, 95% CI: 1.15, 1.85) compared with underweight children. Children who were of average size at birth were more likely to be able to do maths (OR: 1.25, 95% CI: 1.1, 1.56), whereas those who were of small birth size had poor odds of scoring better in reading tests (OR: 0.76, 95% CI: 0.55, 1.04).

Children attending private schools had better mathematical (OR: 1.44, 95% CI: 1.19, 1.75), writing (OR: 1.57, 95% CI: 1.34, 1.85) and reading skills (OR: 1.32, 95% CI: 1.05, 1.66) than those attending government schools. Finally, household environmental factors, including source of drinking water and household having a toilet facility, were also found to be associated with cognitive and learning ability. However, urban–rural place of residence had no significant association with test performances in maths, writing or reading. Children from households with an improved source of drinking water had higher odds of scoring well in maths (OR: 1.56, 95% CI: 1.3, 1.86), writing (OR: 1.5, 95% CI: 1.29, 1.74) and reading (OR: 1.52, 95% CI: 1.22, 1.88) compared with those with unimproved drinking water facilities. Similarly, children from households with their own toilet facility had higher scores in maths (OR: 1.81, 95% CI: 1.4, 2.34), writing (OR: 1.26, 95% CI: 1.03, 1.56) and reading (OR: 1.48, 95% CI: 1.09, 2.02) than households with shared sanitation or those resorting to open defecation.

Discussion

This study examined the association between childhood vaccination and cognitive and learning ability among school children aged 8–10 years in India. The four salient findings of the study were as follows. First, children who received all basic vaccinations by the age 12 months were more likely to perform mathematical tasks, write a sentence and read than those with none or only partial vaccination. In particular, fully vaccinated children performed better in mathematics. Second, maternal education is an important covariate, and was found to be significantly associated with children's mathematical, writing and reading abilities. Third, the mathematical skills of girls were poorer than those of boys, but there were no significant gender differences in writing and

Table 2. Bivariate analysis of association of children's writing ability with explanatory variables

Characteristic	*N*	No writing (%)	2 or fewer mistakes (%)	No mistakes (%)	χ^2
Vaccination status					
No vaccination	743	43.61	32.3	24.09	244.88 ($p<0.001$)
Partial vaccination	2189	34.17	35.36	30.47	
Full vaccination	2641	19.61	37.56	42.82	
Age of child					
8 years	1754	36.89	33.87	29.25	97.42 ($p<0.001$)
9 years	1729	25.45	38.11	36.44	
10 years	2150	24.19	36.19	39.63	
Sex					
Male	2957	27.49	36.66	35.85	3.29 ($p=0.19$)
Female	2676	29.67	35.39	34.94	
Height-for-age					
Stunted	3096	35.01	35.34	29.65	166.82 ($p<0.001$)
Normal	2537	20.61	36.93	42.45	
Weight-for-age					
Underweight	3588	34.00	35.28	30.71	167.15 ($p<0.001$)
Normal	2045	18.92	37.41	43.67	
Type of school					
Government	3475	34.47	36.17	29.35	239.81 ($p<0.001$)
Private	2099	17.48	36.21	46.31	
Maternal education					
No schooling	2728	42.27	33.25	24.49	667.78 ($p<0.001$)
<5 years	345	26.38	47.83	25.80	
5–10 years	2059	15.98	39.24	44.78	
>10 years	501	6.79	30.14	63.07	
Wealth index					
Poor	1806	44.46	33.33	22.20	505.01 ($p<0.001$)
Middle	1743	29.03	39.70	31.27	
Rich	1667	13.62	35.51	50.87	
Religion					
Hindu	4467	27.74	36.31	35.95	50.53 ($p<0.001$)
Muslim	826	36.68	34.62	28.69	
Other	340	19.12	36.18	44.71	
Caste					
Other	1368	18.49	36.26	45.25	128.94 ($p<0.001$)
OBC	2418	29.4.0	36.97	33.62	
SC/ST	1844	34.87	34.71	30.42	

(Continued)

Table 2. (*Continued*)

Characteristic	*N*	No writing (%)	2 or fewer mistakes (%)	No mistakes (%)	χ^2
Place of residence					
Rural	4235	32.14	35.87	32.00	134.45 ($p<0.001$)
Urban	1398	17.6.0	36.62	45.78	
Source of drinking water					
Unimproved	2990	37.02	33.24	29.73	233.3 ($p<0.001$)
Improved	2643	18.92	39.24	41.85	
Child size at birth					
Large	734	30.38	37.19	32.43	17.47 ($p<0.001$)
Average	3805	27.31	35.51	37.19	
Small	1041	31.22	37.66	31.12	
Household has own latrine					
No	3849	34.50	35.39	30.11	252.27 ($p<0.001$)
Yes	1757	15.48	37.45	47.07	

reading skills. Fourth, the nutritional status of children was found to be significantly associated with children's mathematical, writing and reading skills.

Before discussing these findings, it is worth mentioning the key limitations of the study. Vaccination information was collected with a reference period of the last two births since January 2000 in survey households and was for children under the age of 5 years in IHDS-I (2004–05); and around 75% of the vaccination data were self-reported by survey respondents (mothers). The mathematical, reading and writing tasks were the same for all children at age 8–10 years, irrespective of their age/grade or schooling status. Apart from quality of school, teachers' levels of education and parental efforts in child's education can also influence the performance of children. The IHDS did not cover all children in the follow-up survey. Hence, it was not possible to claim causal associations, but the study offers important insights for the further analysis of associations.

The multivariate regression analysis showed a positive and statistically significant association between children receiving all basic vaccinations by 12 months of age and their mathematical, writing and reading abilities at age 8–10 years. Previous studies have revealed that infectious disease can affect the cognitive ability of children. Berger and colleagues (2018) found that infants with critical pertussis scored poorly in visual reception, receptive language and expressive language. Goetghebuer *et al.* (2000) found that Pneumonia, Haemophilus and Influenza type b (Hib) were associated with hearing loss, mental retardation, motor abnormalities and seizures. Moreover, studies have demonstrated a long-term effect of tuberculous meningitis (TBM) on neurocognition, resulting in cognitive impairment in adults and children (Chen *et al.*, 2015; Davis *et al.*, 2019). Hamborsky *et al.* (2015) suggested measles could lead to intellectual disability and increase neurologic complications. Childhood vaccination protects them from infectious disease such as polio, measles, diphtheria, pertussis (whooping cough), rubella (German measles), mumps, tetanus, rotavirus and Haemophilus Influenza type b (Hib) (CDC, 2014). Mina *et al.* (2015) suggested that measles vaccines may also offer protection from non-measles infections and in the long-term increase immunologic memory.

Table 3. Bivariate analysis of association of children's reading ability with explanatory variables

Characteristic	*N*	No reading (%)	Letter (%)	Word (%)	Paragraph (%)	One page story (%)	χ^2
Vaccination status							
No vaccination	745	22.15	21.74	21.48	11.95	22.68	263.78 ($p<0.001$)
Partial vaccination	2204	15.65	17.29	22.28	16.02	28.77	
Full vaccination	2668	7.57	12.97	19.15	21.36	38.94	
Age of child							
8 years	1766	17.10	19.82	24.01	15.46	23.61	177.86 ($p<0.001$)
9 years	1749	10.92	15.67	20.58	19.55	33.28	
10 years	2162	10.45	12.63	18.13	18.69	40.1	
Sex							
Male	2979	12.42	14.97	20.51	18.36	33.74	5.18 (0.27)
Female	2698	12.94	16.72	20.94	17.49	31.91	
Height-for-age							
Stunted	3125	16.13	18.72	22.78	16.9	25.47	237.71 ($p<0.001$)
Normal	2552	8.42	12.23	18.18	19.24	41.93	
Weight-for-age							
Underweight	3617	15.70	17.86	21.81	16.23	28.39	182.42 ($p<0.001$)
Normal	2060	7.33	12.18	18.79	20.97	40.73	
Type of school							
Government	3504	15.24	18.81	22.29	17.52	26.14	274.32 ($p<0.001$)
Private	2114	7.10	10.93	18.16	19.02	44.80	
Maternal education							
No schooling	2741	21.63	20.5	21.38	13.43	23.06	712.79 ($p<0.001$)
<5 years	351	9.97	15.10	24.22	23.08	27.64	
5–10 years	2077	4.19	12.08	20.70	21.67	41.36	
>10 years	508	0.79	6.10	14.76	23.62	54.72	
Wealth index							
Poor	1816	24.17	20.65	21.42	12.83	20.93	625.74 ($p<0.001$)
Middle	1753	10.78	17.80	22.30	17.74	31.37	
Rich	1691	3.84	9.34	16.68	20.58	49.56	
Religion							
Hindu	4506	11.83	16.18	20.17	17.64	34.18	65.06 ($p<0.001$)
Muslim	830	18.80	15.54	23.49	17.71	24.46	
Other	341	8.80	11.44	21.11	22.58	36.07	

(*Continued*)

Table 3. (*Continued*)

Characteristic	*N*	No reading (%)	Letter (%)	Word (%)	Paragraph (%)	One page story (%)	χ^2
Caste							
Other	1386	7.86	11.40	20.27	19.77	40.69	121.98 ($p<0.001$)
OBC	2431	12.38	16.66	20.16	18.26	32.54	
SC/ST	1857	16.64	17.99	21.76	16.10	27.52	
Place of residence							
Rural	4266	14.84	17.30	21.17	16.48	30.22	147.55 ($p<0.001$)
Urban	1411	6.09	11.27	19.35	22.40	40.89	
Source of drinking water							
Unimproved	3008	17.92	18.28	19.32	14.63	29.85	227.5 ($p<0.001$)
Improved	2669	6.74	13.00	22.29	21.69	36.27	
Child size at birth							
Large	741	11.61	17.54	19.84	19.03	31.98	28.31 ($p<0.001$)
Average	3832	11.87	15.40	20.20	18.03	34.50	
Small	1050	16.00	16.38	22.57	17.14	27.90	
Household has own latrine							
No	3870	16.33	18.55	21.37	16.05	27.7	317.07 ($p<0.001$)
Yes	1779	4.83	9.61	19.22	22.20	44.13	

The findings of this study suggest that basic childhood vaccination influences children's cognitive and learning ability at school-going age. A study from Philippines (Bloom *et al.*, 2011) had similar results, finding that receiving six childhood vaccines was associated with children's better cognitive development. The percentage of children in India aged 12–23 months receiving all basic vaccinations during 2015–16 was only 62%, and this varied considerably across states (from 35% to 91%) and districts (from 7% to 100%) (IIPS, 2017). India launched the initiative Transformation of Aspirational Districts in 2018, with a focus on improving health, nutrition and educational outcomes in order to achieve the Sustainable Development Goals (SDGs), and also to improve rankings and performance in the Human Development Index (HDI). Clearly, achieving universal coverage of all childhood vaccinations could be a cost-effective strategy to improve health and educational outcomes in India.

Higher maternal education had a positive association with the children's mathematical, reading skills and writing skills at age 8–10 years. Vikram *et al.* (2012) also found a positive relationship between maternal education and health knowledge and complete childhood immunization in India. Thus, maternal education seems to have a dual impact – on both child immunization and education. Fernald *et al.* (2012) also found a significant association between maternal education and children's maths, reading and writing test scores. In addition, the present study found a gender difference in mathematical ability, but not writing and reading. This is a critical theme in education as there is no specific reason why the sex of children should play a role in educational performance across disciplines. The observed gender difference in maths and reading ability may be due to excessive engagement of girls in activities beyond schooling and learning, with parents having a son preference in matters of learning and education. White *et al.* (2016) found that the

Table 4. Multivariate regression of the mathematical, writing and reading abilities of 8- to 10-year-old children

Characteristic	Maths OR [95% CI]	Writing OR [95% CI]	Reading OR [95% CI]
Vaccination status			
No vaccination (Ref.)			
Partial vaccination	1.20* [0.97, 1.48]	1.16 [0.95, 1.40]	1.11 [0.88, 1.41]
Full vaccination	1.87*** [1.48, 2.35]	1.77*** [1.44, 2.18]	1.60*** [1.23, 2.09]
Height-for-age			
Stunted (Ref.)			
Normal	1.61*** [1.33, 1.94]	1.57*** [1.34, 1.84]	1.45*** [1.17, 1.80]
Weight-for-age			
Underweight (Ref.)			
Normal	1.31*** [1.07, 1.60]	1.37*** [1.16, 1.62]	1.46*** [1.15, 1.85]
Child size at birth			
Large (Ref.)			
Average	1.25* [1.00, 1.56]	0.98 [0.80, 1.20]	0.83 [0.63, 1.09]
Small	1.14 [0.87, 1.48]	1.00 [0.79, 1.27]	0.76* [0.55, 1.04]
Age of child			
8 years (Ref.)			
9 years	1.69*** [1.40, 2.05]	1.76*** [1.49, 2.08]	1.71*** [1.37, 2.13]
10 years	2.20*** [1.83, 2.64]	2.24*** [1.91, 2.63]	2.12*** [1.71, 2.61]
Sex			
Male (Ref.)			
Female	0.78*** [0.67, 0.92]	0.96 [0.84, 1.10]	1.02 [0.86, 1.23]
Type of school			
Government (Ref.)			
Private	1.44*** [1.19, 1.75]	1.57*** [1.34, 1.85]	1.32** [1.05, 1.66]
Maternal education			
No schooling (Ref.)			
<5 years	1.80*** [1.29, 2.52]	1.71*** [1.30, 2.26]	1.88*** [1.28, 2.77]
5–10 years	2.11*** [1.72, 2.60]	2.21*** [1.86, 2.61]	3.21*** [2.45, 4.21]
>10 years	3.63*** [1.91, 6.91]	3.18*** [2.08, 4.87]	7.30*** [2.62, 20.31]
Wealth index			
Poor (Ref.)			
Middle	1.25** [1.05, 1.50]	1.23** [1.05, 1.44]	1.61*** [1.30, 1.99]
Rich	1.63*** [1.23, 2.15]	1.49*** [1.18, 1.87]	1.94*** [1.38, 2.72]

(*Continued*)

Table 4. (*Continued*)

Characteristic	Maths OR [95% CI]	Writing OR [95% CI]	Reading OR [95% CI]
Religion			
Hindu (Ref.)			
Muslim	0.58*** [0.45, 0.73]	0.63*** [0.51, 0.77]	0.52*** [0.39, 0.67]
Other	1.58** [1.01, 2.48]	1.20 [0.85, 1.68]	1.04 [0.65, 1.68]
Caste			
Other (Ref.)			
OBC	0.84 [0.66, 1.06]	0.76*** [0.62, 0.93]	0.88 [0.66, 1.16]
SC/ST	0.73** [0.56, 0.94]	0.65*** [0.53, 0.81]	0.70** [0.51, 0.95]
Place of residence			
Rural (Ref.)			
Urban	1.15 [0.90, 1.48]	1.02 [0.83, 1.24]	1.07 [0.79, 1.44]
Source of water			
Unimproved (Ref.)			
Improved	1.56*** [1.30, 1.86]	1.50*** [1.29, 1.74]	1.52*** [1.22, 1.88]
Household has own latrine			
No (Ref.)			
Yes	1.81*** [1.40, 2.34]	1.26** [1.03, 1.54]	1.48** [1.09, 2.02]
N	5072	5052	5095

Ref.=reference category
*$p<0.10$; **$p<0.05$; ***$p<0.01$.

impact of adverse time allocation on girls can increase in the presence of siblings as they may have to devote time to household chores.

The study found a strong association between child nutritional status and their cognition and learning ability. Children of normal nutritional status (normal height-for-age and weight-for-age) did better in mathematical, writing and reading tests than stunted or underweight children. Similar findings have been made in previous studies (Spears, 2012; Acharya *et al.*, 2019). Another study found that childhood immunization was associated with better nutritional status (Kim *et al.*, 2019). Anekwe and Kumar (2012) found that childhood vaccination was a predictor of infant growth and development, as the universal immunization programme in India was found to have a favourable impact on child anthropometric outcomes. Childhood vaccination against DTP, polio and measles also improves the nutritional status of children (Bhargava *et al.*, 2011), and has direct and indirect benefits for schooling and child educational outcomes.

Finally, access to an improved source of drinking water was also found to be associated with improved maths, reading and writing skills among children. Clean and safe (free from fecal contamination) drinking water improves the nutritional status of children (Johri *et al.*, 2019). The benefits even appear to be felt during gestation, as mothers who have access to safe drinking water during pregnancy are likely to give birth to children with better Word List Memory scores (Wulan *et al.*, 2015). Similarly, the present study found a significant association between having a toilet facility and children's mathematical, reading and writing skills. A systematic review by Sclar (2017) suggested that household access to sanitation was associated with improved cognitive

ability of children. Orgill and Pattanayak (2020) also revealed a significant association of village latrine coverage in early childhood with better cognitive scores 10 years later. Unimproved sanitation spreads diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid and polio and exacerbates stunting (WHO, 2019). Hence, improved sanitation protects children from infectious disease and improves their educational performance. Nevertheless, there is limited research on the association of drinking water and sanitation with cognitive and learning ability among children. There is a need for more research on the association of water, sanitation and hygiene (WASH) indicators with child cognitive development.

In conclusion, this study suggests that full childhood vaccination might be a potential factor affecting the educational attainment of children in India. There is therefore an urgent need to scale-up public spending on health care in the country.

Funding. This research received no specific grant from any funding agency, commercial entity or not-for-profit organization.

Conflicts of Interest. The authors have no conflicts of interest to declare.

Ethical Approval. This study was based on a secondary data set with no identifiable information on the survey participants. This dataset is available in the public domain for research use so no approval was required from any institutional review board.

References

Acharya Y, Luke N, Haro M, Rose W, Russell P, Oommen A and Minz S (2019) Nutritional status, cognitive achievement, and educational attainment of children aged 8–11 in rural South India. *PloS One* **14**(10), e0223001.

Andre FE, Booy R, Bock H, Clemens J, Datta S, John T and Santosham M (2008) Vaccination greatly reduces disease, disability, death and inequity worldwide. *Bulletin of the World Health Organization 86*, 140–146.

Anekwe TD and Kumar S (2012) The effect of a vaccination program on child anthropometry: evidence from India's Universal Immunization Program. *Journal of Public Health* **34**(4), 489–497.

Anekwe TD, Newell M, Tanser F, Pillay D and Bärnighausen T (2015) The causal effect of childhood measles vaccination on educational attainment: a mother fixed-effects study in rural South Africa. *Vaccine* **33**(38), 5020–5026.

Berger JT, Villalobos M, Clark A, Holubkov R, Pollack M, Berg R A and Newth CJ (2018) Cognitive development one year after infantile critical pertussis. *Pediatric Critical Care Medicine* **19**(2), 89.

Bhargava A, Guntupalli AM and Lokshin M (2011) Health care utilization, socioeconomic factors and child health in India. *Journal of Biosocial Science* **43**(6), 701.

Bloom DE, Canning D and Shenoy E (2011) The effect of vaccination on children's physical and cognitive development in the Philippines. *Applied Economics* **44**(21), 2777–2783.

CDC (2014) Why are childhood vaccines so important? In *Vaccines and Immunizations*. Centers for Disease Control and Prevention. URL: https://www.cdc.gov/vaccines/vac-gen/howvpd.htm (accessed 16th May 2018).

Chen HL, Lu C, Chang C, Chen P, Chen M, Hsu N and Lin W (2015) Structural deficits and cognitive impairment in tuberculous meningitis. *BMC Infectious Diseases* **15**(1), 279.

Davis AG, Nightingale S, Springer P, Solomons R, Arenivas A, Wilkinson R and **Tuberculous Meningitis International Research Consortium** (2019) Neurocognitive and functional impairment in adult and paediatric tuberculous meningitis. *Wellcome Open Research* **4**(178), 178.

Fernald LC, Kariger P, Hidrobo M and Gertler P (2012) Socioeconomic gradients in child development in very young children: evidence from India, Indonesia, Peru, and Senegal. *Proceedings of the National Academy of Sciences of the USA* **109** (Supplement 2), 17273–17280.

Goetghebuer T, West T, Wermenbol V, Cadbury A, Milligan P, Lloyd-Evans N and Weber M (2000) Outcome of meningitis caused by Streptococcus pneumoniae and Haemophilus influenza type b in children in The Gambia. *Tropical Medicine & International Health* **5**(3), 207–213.

Hamborsky J, Kroger A and Wolfe C (eds) (2015) *Epidemiology and Prevention of Vaccine-Preventable Diseases. The Pink Book*, 13th Edition US Department of Health and Human Services, Centers for Disease Control and Prevention.

IIPS (2017) *National Family Health Survey (NFHS-4) 2015–16*. International Institute for Population Sciences (IIPS), Mumbai, India.

Jit M, Hutubessy R, Png M, Sundaram N, Audimulam J, Salim S and Yoong J (2015) The broader economic impact of vaccination: reviewing and appraising the strength of evidence. *BMC Medicine* **13**(1), 209.

Johri M, Sylvestre MP, Koné GK, Chandra D and Subramanian SV (2019) Effects of improved drinking water quality on early childhood growth in rural Uttar Pradesh, India: a propensity-score analysis. *PloS One* **14**(1), e0209054.

Kim R, Rajpal S, Joe W, Corsi DJ, Sankar R, Kumar A and Subramanian SV (2019) Assessing associational strength of 23 correlates of child anthropometric failure: an econometric analysis of the 2015–2016 National Family Health Survey, India. *Social Science & Medicine* **238**, 112374.

Largeron N, Lévy P, Wasem J and Bresse X (2015) Role of vaccination in the sustainability of healthcare systems. *Journal of Market Access & Health Policy* **3**(1), 27043.

Mina MJ, Metcalf C, De Swart R, Osterhaus ADME and Grenfell BT (2015) Long-term measles-induced immunomodulation increases overall childhood infectious disease mortality. *Science* **348**(6235), 694–699.

Mrozek-Budzyn D, Majewska R and Kiełtyka A (2015) Early exposure to thimerosal-containing vaccines and children's cognitive development. A 9-year prospective birth cohort study in Poland. *European Journal of Pediatrics* **174**(3), 383–391.

Nandi A, Deolalikar AB, Bloom DE and Laxminarayan R (2019a) Haemophilus influenzae type b vaccination and anthropometric, cognitive, and schooling outcomes among Indian children. *Annals of the New York Academy of Sciences* **1449**(1), 70.

Nandi A, Kumar S, Shet A, Bloom DE and Laxminarayan R (2020) Childhood vaccinations and adult schooling attainment: long-term evidence from India's Universal Immunisation Programme. *Social Science & Medicine*, doi.org/10.1016/j.socscimed.2020.112885.

Nandi A, Shet A, Behrman JR, Black MM, Bloom DE and Laxminarayan R (2019b) Anthropometric, cognitive, and schooling benefits of measles vaccination: longitudinal cohort analysis in Ethiopia, India, and Vietnam. *Vaccine* **37**(31), 4336–4343.

Orgill-Meyer J and Pattanayak SK (2020) Improved sanitation increases long-term cognitive test scores. *World Development* **132**, 104975.

Oskorouchi HR, Sousa-Poza A and Bloom DE (2020) The long-term cognitive and schooling effects of childhood vaccinations in China. *National Bureau of Economic Research Working Paper* No. w27217.

Ozawa S, Clark S, Portnoy A, Grewal S, Stack ML, Sinha A *et al.* (2017) Estimated economic impact of vaccinations in 73 low-and middle-income countries, 2001–2020. *Bulletin of the World Health Organization* **95**(9), 629.

Pasquale AD, Preiss S, Silva FTD and Garçon N (2015) Vaccine adjuvants: from 1920 to 2015 and beyond. *Vaccines* **3**(2), 320–343.

Quilici S, Smith R and Signorelli C (2015) Role of vaccination in economic growth. *Journal of Market Access & Health Policy* **3**(1), 27044.

Sclar GD, Garn JV, Penakalapati G, Alexander KT, Krauss J, Freeman MC *et al.* (2017) Effects of sanitation on cognitive development and school absence: a systematic review. *International Journal of Hygiene and Environmental Health* **220**(6), 917–927.

Spears D (2012) Height and cognitive achievement among Indian children. *Economics & Human Biology* **10**(2), 210–219.

Vidmar SI, Cole TJ and Pan H (2013) Standardizing anthropometric measures in children and adolescents with functions for egen: update. *Stata Journal* **13**(2), 366–378.

Vikram K, Vanneman R and Desai S (2012) Linkages between maternal education and childhood immunization in India. *Social Science & Medicine* **75**(2), 331–339.

White G, Ruther M and Kahn J (2016) Educational Inequality in India: an analysis of gender differences in reading and mathematics. *IHDS Working Paper No. 2016-2*. University of Maryland, College Park, USA.

World Health Organization (2019) *Sanitation*. URL: https://www.who.int/news-room/fact-sheets/detail/sanitation (accessed 14th June 2019).

Wulan N, Smith E, Prado E, Apriatni M, Muadz H and Shankar A (2015) The long-term impact of water and sanitation on childhood cognition. *FASEB Journal* **29** (Supplement 1), 899–892.

Cite this article: Joe W and Kumar Verma A. Association of basic vaccination with cognitive and learning ability among children: insights from the India Human Development Survey, 2004–05 and 2011–12. *Journal of Biosocial Science*. https://doi.org/10.1017/S0021932020000760