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ABSTRACT

Impacts of Double-Fortified Salt on Anemia and Cognition: Four-Year Follow-up Evidence from a School-Based Nutrition Intervention in India*

Long-term follow-up of early childhood health interventions is important for human capital accumulation. We provide experimental evidence on child health and human capital outcomes from the longer-term follow-up of a school-based nutrition intervention in India. Using panel data, we examine the effectiveness of the use of iron and iodine fortified salt in school lunches to reduce anemia among school children. After four years of treatment, treated children, on average, have higher hemoglobin levels and a lower likelihood of anemia relative to the control group. Interestingly, the intervention did not have any impact on cognitive and educational outcomes.

JEL Classification: C93, I15, I18, O12

Keywords: anemia, children, double-fortified salt, cognition, mid-day meal, India

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1. Introduction

Anemia is an important global public challenge, especially in developing countries. Worldwide, about 43% of children aged 6-59 months were anemic in 2011, translating to approximately 273 million anemic children (WHO 2015). According to WHO (2015) data, the burden of anemia is more pronounced in Africa (62.3%) and Southeast Asia regions (53.8%). In rural India, 60% of 6-59 months-old children were anemic in 2015-16 (IIPS and ICF 2017). Inadequate nutrition and poor health undermine the development of human capital (Dasgupta and Ray 1986; Strauss and Thomas 1998). Growth failure due to malnutrition below primary-school age is associated with lower schooling, lower test performance, lower household per capita expenditure, and higher probability of living in poverty as an adult (Alderman 2006; Currie and Vogl 2013; Hoddinott et al. 2013). Childhood anemia is of interest to policymakers and development economists because of its high prevalence in developing countries and its strong association with grades, attendance, and educational attainment (Chong et al., 2016; Halterman et al. 2001; Li et al. 2018). Among other factors, inadequate nutrient intake and infectious disease burden are the leading causes of anemia among children in low-income countries (WHO 2015).

The efficacy studies conducted in a controlled environment show significant impacts of salt fortified with iron and iodine called double-fortified salt (DFS) on hemoglobin (Hb) and iron-deficiency anemia (IDA) (Larson, Wong-McLoughlin, and Ferng 2009). Yet, large-scale DFS programs yield limited impacts on anemia in developing countries (Banerjee, Barnhardt, and Duflo 2018). The limited impacts in these studies are primarily due to the low take-up of the DFS. One potential channel to deliver micronutrients to children is to utilize either education or health infrastructures. According to a recent study, if DFS is distributed through a school lunch program, the take-up rate is higher and students are less likely to be anemic in a short span of a one-year treatment (Krämer, Kumar, and Vollmer 2020).

Our study builds on the evidence reported in Krämer, Kumar, and Vollmer (2020) and aims at estimating a longer-term impact of a school-based DFS intervention on children's anemic status and cognition after a four-year follow-up. It is of particular interest for policymakers to understand if the early one-year treatment estimates of DFS effectiveness studies persist for a longer period. Bouguen et al. (2018) note that measuring long-term program impacts is important for a better understanding of the underlying mechanisms. Short-term benefits of health interventions are likely to underestimate the true program effects if benefits persist in the long run. Thus, the long-term program impacts could be valuable for the cost-effectiveness analysis of the programs.

Surprisingly, the evidence base is limited on the long-term impacts of DFS programs. To the best of our knowledge, our study is the first effectiveness study to estimate DFS impacts after four years of continued treatment among school-age anemic children. This paper fills this gap by estimating the four-year impacts of the DFS intervention implemented in Krämer, Kumar, and Vollmer (2020). Specifically, we aim at exploring whether a two-and-a-half-year longer school-based delivery of the DFS increases the effectiveness of the treatment in reducing anemia among children. We provide evidence on child health, cognition, and education outcomes after a four-year follow-up of a school-based DFS intervention in India in which the treatment exposure varies for the treatment and the control group.

To estimate the long-term impacts of DFS on anemia, cognition, and school attainment, we exploited the staggered roll-out of the intervention across treated and control schools. We conducted the DFS experiment in two administrative blocks of Jehanabad district in Bihar, one of the poorest states of India with a high prevalence of anemia among school children (World Bank 2016; IIPS and ICF 2017). The original intervention provided the DFS to 54 public primary and middle schools since 2015 while the 53 control schools continued to use the conventional iodized salt (see Krämer, Kumar, and Vollmer (2020) for details). As the study by Krämer, Kumar, and Vollmer (2020) demonstrated positive health effects of DFS on anemia, ethical concerns made it mandatory to no longer deprive the control schools of the treatment. Thus, control schools started receiving the DFS in December 2017. The baseline and endline surveys were conducted in 2014 and 2019, respectively. Thus, our experimental design provided four years of treatment exposure in the treatment schools while children in the control schools would have eventually been exposed to the DFS for one and a half years. The assessed outcomes are Hb levels, cognitive outcomes, and educational achievements of 2,000 children in grade II at baseline. We used the double differences (DD) method with child fixed effects to estimate the causal impacts of the DFS intervention on children's health, cognition, and education outcomes.

Our results show that improvement in Hb and anemia found after one year of treatment in Krämer, Kumar, and Vollmer (2020) are still present after four years of treatment. A two and a half-year longer treatment benefits child health even when the comparison group has also received the treatment at least in the past one and a half years. Children in the treatment group have on average a 0.245 g/dL higher Hb level than the control group and also a lower likelihood of anemia, less than 13.4 percentage points (pp). Further, the school-based DFS intervention decreases the incidence of mild anemia by 10.6 pp. The treatment effects on health outcomes are non-uniform and vary by school attendance rate. However, despite significant health gains, the treatment has no impact on the children's human capital outcomes. The results have high policy relevance as they show the potential of an early start of using fortified foods in school feeding programs to increase the health of adolescents without crowding out other interventions because salt is anyways used for preparing the lunch.

This paper contributes to the limited evidence base on the effectiveness of DFS on children's health in low-income countries. We explore this by examining whether a longer use of DFS in the Midday-Meal-Scheme (MDM) increases its effectiveness and whether the effects of a DFS intervention in early childhood (in grade III) persist in early adolescents (in grade VI). Our study also contributes to the policy debate on the delivery channel to provide micronutrients to children that can ensure higher take-up and compliance. Our study tests the effectiveness of school-based mechanisms in contrast to other public channels. Other rigorous studies using the same DFS formula in India focus on another public channel: the Public Distribution System (PDS) (Banerjee, Barnhardt, and Duflo, 2018). They found that despite the free delivery of DFS only 61 to 75% of households used DFS and impacts on general health or cognition for the pre-defined groups were statistically insignificant.

Further, some studies with school-level treatment used multiple fortified salts for meals and found increases in Hb levels and even in memory and attention for children aged 5-18 (Sivakumar et al. 2001; Kumar and Rajagopalan 2007; Vinodkumar and Rajagopalan 2009). However, these studies had smaller sample sizes and short treatment durations, often less than one year. The MDM is also used to provide additional micronutrients via other fortification vehicles in India like the study by Berry et al. (2020) who assessed the impact of the usage of a micronutrient mix to fortify the MDM in Odisha, India. The authors did not find any effects on Hb levels, child health, and subsequently human capital measures of cognitive or learning outcomes. Other studies using DFS found effects on Hb levels, too (Osei et al. 2010; Radhika et al. 2011; Pinkaew et al. 2013). However, the sample sizes and exposure periods do neither surpass the earlier introduced studies in this section nor do they consider different treatment starts. Thus, we provide novel insights into the increased effectiveness of the DFS in the MDM given an earlier treatment start.

Our study findings are also linked to the long treatment duration that starts in one life stage but ends in another. The exposure to the DFS started in childhood when children were on average eight years old in grade III while we collected health and other human development outcomes after the treatment period of a maximum of four years. At this time the children were on average eleven years old and in grade VI (early adolescence). The outcomes in early adolescence or mid-childhood years are important for long-term outcomes and, thus, are more amenable to policy interventions (Almond, Currie, and Duque 2018).

Despite the evidence that longer-term iron supplementation has positive effects on the cognitive performance of children older than two years of age and adolescents, iron nutrient interventions targeting early adolescents in India are rare (Bryan et al. 2004). Exceptions are the evaluations of India's Adolescent Girls' Anemia Control Programme or a study conducted by Deshmukh, Garg, and Bharambe (2008) that failed due to lack of compliance in taking iron supplements. More recently Berry et al. (2020) examined the usage of the MDM to provide iron-folic acid (IFA) supplementation for adolescents. They provided evidence on the supplementation of IFA in Odisha, India, for primary school children who attended the grades I-V, but not grade VI like in our study. They found that the IFA program had significant large effects for moderately anemic students in schools that were distributing tablets more recently compared to schools that ran out of tablets. Thus, our study provides evidence of how exposure to DFS in one life stage, childhood, can affect another life phase, adolescence.

2. Intervention and Experimental Design

2.1. Study Design and Sample Selection

The intervention was implemented in two administrative blocks (Kako and Modanganj) in the Jehanabad district of Bihar, India. The prevalence of anemia in the study setting was 62% among 6-59 months-old children (IIPS and ICF 2017). Out of all 228 government-funded schools in the two blocks, 107 schools were randomly selected to participate in the intervention. 54 schools were randomly chosen to receive the DFS intervention since 2015 while the remaining 53 schools were in the control group. The target group was school children aged 7-9 years because this age group had the large potential to be affected in their cognitive abilities because of a developmental phase of the frontal lobes in the brain during this time (Thatcher 1991; Anderson 2002). The baseline survey sampled on average 20 children from grade II in each school, leading to a baseline sample of 2,000 children. The endline survey was done from January to July 2019.

2.2. Intervention

We provided the DFS at a subsidized price to the treatment schools for the preparation of the school lunch. The subsidy amount was such that no additional financial burden was imposed on the treated schools. Our study team provided the DFS to treated schools each month. Only the headmaster and the cook were informed of the treatment and cooks were advised to use the DFS in the MDM preparation instead of the conventionally used iodized salt. The control schools continued to use iodized salt until December 2017 (see Krämer, Kumar, and Vollmer (2020) for details).

The rollout of the intervention followed a staggered design. The treatment schools received the intervention from August 2015 to July 2019. As Krämer, Kumar, and Vollmer (2020) showed positive health effects of the DFS intervention on Hb levels and anemia, we did not want to exclude the control schools from the health benefits of DFS due to ethical concerns. Therefore, we started providing the DFS to the control schools in December 2017. Appendix Table A1 displays the timeline of the intervention.

In Bihar generally, primary schools (PS) provide education from grade I-V and middle schools (MS) from I-VIII. However, there are also MS that only teach grade VI-VIII. After completing grade V, students are mandated to transition to MS. The sampled children in the baseline year attended grade II. Starting in April 2018, children who were enrolled in PS had to transition to MS to attend the next highest grade, grade VI. Some of the children joined MS with grades I-VIII that had been selected as a school in our sample. To continue with their education, other children went to schools (MS with grades I-VIII or only VI-VIII) that were not included in our sample. We were able to survey children who had attended at baseline either one of 43 treatment schools or one of 42 control schools. As the parents and children were not informed about the intervention, we are confident that the selection of the school after grade V is independent of the treatment status of the schools and so does not introduce selection bias. However, child and household characteristics might in general drive the selection of attending a certain type of school in any grade.

The treatment exposure varies from 32 months to 48 months for children who attended a treatment school at baseline. The children who moved to MS that are not in our sample after grade V would have been exposed to 32 months of the fortified meal (from August 2015 to March 2018), while children who continued their education in one of our sampled schools consumed fortified meals for 48 months. The children in the control group who attended one of our sampled schools at least until grade V received the DFS in their lunch only briefly (four months from December 2017 to March 2018). Other children in the control group who continued going to a school in our sample had school lunch with the DFS for about 20 months (from December 2017 to July 2019). This design gives us a panel sample of 1,051 children for health outcomes and 843 children for cognition and education outcomes.

As our study is interested in the intention-to-treat (ITT) effects to measure the increased effectiveness of a four-year-long duration of a school-based food fortification program to reduce anemia among children, we focus on the original treatment and control group. Though this means that the measured effects are downward biased because a part of the children in the control group received the treatment and a part of the children in the treatment group did not receive the treatment for the whole four years. Thus, the ITT estimates would be a conservative estimate of the DFS intervention.

2.3. Variables and Data Collection

The main health outcomes of interest are Hb levels in g/dL, any anemia status, mild anemia status, and moderate or severe anemia status. Depending on the Hb level we classify the children's anemia status following the WHO (2011) adjusting for age. We group moderate and severe anemia status because there were very few cases of severely anemic children in our baseline sample.

The cognitive outcomes were assessed based on the following five tests: block design, forward digit-span, backward digit-span, Raven's Colored Progressive Matrices, and a Stroop test. Based on these five tests we constructed a cognitive index using a principal component analysis. The tests were adapted to capture the temporal and secular increase in cognitive ability. Math and reading test scores were based on the survey tool developed by the Indian Governmental Organization Pratham (ASER Centre 2014). All human capital outcomes were normalized by subtracting the baseline mean and dividing it by the baseline standard deviation. The unit of the outcome is then standard deviations from the mean in the pre-intervention data collection. The control variables include time-variant characteristics such as household size, mother's and father's years of schooling, and asset index. The asset index was generated using the first component of a principal component analysis consisting of several household assets.

2.4. Empirical Method

Taking advantage of the balanced panel data, we used the DD method to estimate the causal impact of the DFS intervention on children's outcomes. The following model would estimate the ITT effects of the intervention:

$$Y_{ist} = \alpha_i + \beta_1 Post_t + \beta_2 \, Post_t \times Treat_s + \delta_1 X_{it} + \varepsilon_{ist} \qquad (1)$$

where Y_{ist} represents outcome variables for child i attending school s at time t. α_i constitutes the intercept and captures child fixed effects. $Post_t$ is a dummy variable that takes the value of one for the post-treatment period and zero for the pre-treatment period. $Treat_s$ is a dummy indicator of assignment to the intervention arm of longer exposure to the DFS; otherwise, it is zero. The variable $Treat_s$ is not included separately because the main effect of treatment is constant within the child and is absorbed by the child fixed effects. X_{it} denotes time-variant controls at the child level. ε_{ist} is the independent and identically distributed error term across clusters and children within clusters. Standard errors are clustered at the level of randomization, the school level.

Our panel data suffers from considerable attrition. To address the possibility of non-random attrition, we adjusted the DD regression with weights to correct for attrition.

When estimating the treatment effects using the inverse probability of attrition weighting (IPW) method, we assigned weights to observations based on the inverse probability of their attrition status. The parameter β_2 shows the ITT estimates of the effect of the DFS intervention on children's outcomes. The ITT estimates provide a lower bound of the program effects as it does not depend on program compliance and reduces the bias caused due to differential attrition. The coefficient β_2 is further likely to be underestimated because the children in the control group also received the treatment for a few months and some of the treated children could not receive treatment if they moved to a different school after grade V.

3. Results

3.1. Randomization Balance and Attrition

Tables 1 and A2 show the baseline characteristics and outcome variables across the treated and control groups for the health and education samples, respectively. The baseline characteristics are widely balanced across the treatment arms apart from a few exceptions in Table 1. All the control variables in Panel B and C are balanced across treatment and control at baseline except for gender and caste in columns 4 and 8, respectively. The Hb levels and thus anemia outcomes are not balanced in baseline and estimation sample. However, we attribute these imbalances to chance since randomization was carried out carefully and correctly. Further, the child fixed effects in equation (1) are also likely to account for these baseline imbalances in the health outcomes as well as the gender and the caste. Since anemia prevalence is higher in the treated groups relative to the control group, the parameter β_2 will potentially be biased in the downward direction. Except for health outcomes, covariates are balanced in Table A2, indicating successful randomization of children across intervention arms.

(Table 1 about here)

The attrition in the panel data is likely to bias our findings. Systematic differences between children who left the study and those who continued to be in the study would bias the causal impacts. For example, severely anemic kids may have stopped coming to school, or students with better cognition may have transferred to private schools. The attrition rate in our analytical sample is higher than the attrition rate after a one-year follow-up in Krämer, Kumar, and Vollmer (2020) who recorded an attrition rate of about 20%. After four years of treatment, we estimated an attrition rate of about 40%.[1] The main reason for attrition is the relocation of households and children who moved to boarding schools or away for work. We were unable to track them.

Table 2 examines the determinants of attrition in our sample. It shows the results from the regression of an attrition dummy on treatment, observed baseline characteristics, and the interaction of both. For the health outcomes sample presented in column 1, we find that the observable characteristics like gender, mother's primary schooling, total enrollment in school, and student-teacher ratio predict attrition. There is not only evidence for selective attrition but also differential attrition because the interaction term of treatment and anemia is statistically significant. In column 2, we find evidence for differential attrition for being Hindu and for selective attrition. Female, Hindu, total school enrollment, and the student-teacher ratio are statistically significant predictors of attrition. As mentioned before, we addressed this concern of attrition by estimating the IPW-DD model.

(Table 2 about here)

3.2. Health and Cognitive Impacts

After adjusting for attrition using the IPW method, we find statistically significant effects of the DFS intervention on Hb levels (Panel A, Table 3). Compared to the control group that only received the DFS in the MDM at least for the past one and a half years, children in the treatment group (four years of treatment exposure) have on average a higher Hb level of 0.245 g/dL. We also find statistically significant differences between groups for any and mild anemia. On average, children in the treatment group are 13.4 pp and 10.6 pp less likely to be anemic or mild anemic compared to children in the control group. Considering the baseline mean prevalence of any and mild anemia of 40.2% and 16.1%, the estimated treatment effects translate to a 33.3% or 65.8% reduction, respectively.[2] Moderate or severe anemia shows a reduction in the likelihood: children exposed to four years of treatment were 2.7 pp less likely to be moderate or severe anemic. We do not find statistically significant

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[1]The baseline sample available for analysis is 1,789 students for the health sample. Of these 1,051 students have been successfully re-interviewed in 2016 and 2019 with all available covariates for our estimation sample for health outcomes. The attrition rates are 41.3 % ((1789-1051)/1789) and 53.7% ((1770-820)/1770) in the health outcome and education outcome sample, respectively.

[2]This is the ratio of the coefficient divided by the baseline mean of the estimation sample: 0.134/0.402 or 0.106/0.161.

differences between the treatment and control groups for moderate or severe anemia although the sign of the coefficient is in the expected direction.

(Table 3 about here)

Panel B shows the effects on cognitive outcomes and Panel C on educational outcomes. We do not find statistically significant effects of the DFS on cognitive outcomes. The estimates are imprecisely estimated and, unexpectedly, change the sign across outcomes. The estimates for math and reading test scores are positive but are again imprecisely estimated. These results show that the improvements in the Hb levels were not large enough to improve cognitive outcomes of children, a finding similar to Krämer, Kumar, and Vollmer (2020).

3.3. Heterogeneity

One can imagine that the intensity of treatment increases with school attendance as students would consume MDM more frequently, thus leading to greater impacts. Table 4 explores heterogeneity by endline school attendance. We calculated school attendance as the ratio of the total number of days a child was present in school and the total number of days the school was open in the twelve months before the endline survey. We conducted the heterogeneity analyses for the sub-groups of 70, 80, and 90% attendance in Panel A and attendance terciles in Panel B. There is evidence of heterogeneous impacts on health outcomes by attendance rate. The effect sizes are larger for high-attendance sub-groups considering Hb levels. The Hb level increases by 0.577 g/dL at 90% attendance while the Hb level improves by 0.245 g/dL at the 70% attendance rate. However, only the effects for 80 and 90% attendance are statistically significant. The effects of DFS intervention on any anemia or mild anemia are larger at the top attendance tercile compared to the bottom attendance tercile. Yet, the findings for the middle tercile are much smaller in magnitude.

Turning to the cognitive and education outcomes, the heterogeneous pattern is even less consistent as none of the estimates are precisely estimated, and they even alternate signs without becoming statistically significant (Table A3).[3]

[3]There could be a concern that attendance could be endogenous. However, Krämer, Kumar, and Vollmer (2020) provided evidence that attendance after one year of treatment had not been affected by the DFS intervention. Thus, it was likely to be exogenous and heterogeneity analyses could be conducted without any bias.

(Table 4 about here)

One reason for the absence of significant effects on the human capital outcomes and unexpected signs could be the low variation of these outcomes due to ceiling effects (Wang et al. 2008). For example, in the reading test, it was relatively easy for children in grade VI to score high so that the true extent of very well-performing students could not be determined. The highest measured level of assessment was whether children could read a story fluently. Another plausible explanation could be that for the test scores to increase supplementary inputs apart from nutritional supplementation are needed. For example, psychosocial stimuli which are important for cognitive development can only be provided by high-quality schools. Nutrition is a necessary condition but not sufficient to improve the cognitive and educational outcomes of children.

3.4. Robustness and Sensitivity Analysis

To test the validity and stability of our main findings, we conducted several robustness checks in Table 5. We estimated equation (1) either without the time-variant control variables, with the inclusion of IFA supplementation, or with the inclusion of school-level controls to ward off the confounding effects of school quality. The model without controls leads to a larger sample size but results are qualitatively similar (Panel A).

We conducted another robustness check to account for the implementation of the weekly iron-folic acid supplementation (WIFS) program in Panel B. The WIFS program provides once a week one IFA tablet containing 100 mg elemental iron and 500 ug folic acid for each child attending grade VI-XII of government, government-aided, or municipal schools (Ministry of Health & Family Welfare, 2016). The WIFS program is administered by the schools. The WIFS program started in late 2017 in Bihar and only four schools that the children in our sample attended started distributing the tablets in 2018. In 2019, all but one school in our sample was actively participating in the WIFS program. As the provision of IFA supplements could potentially bias our estimates, we added it as an additional control to the covariates in this robustness check. The effects do not change in statistical significance or sign. They are similar to the main findings in Table 3. Finally, the inclusion of time-variant school-level controls (enrollment, class size, and student-teacher ratio) in Panel C also does not affect the main results.

(Table 5 about here)

4. Discussion and Conclusions

Previous research has demonstrated that a year-long school-based distribution of DFS through a school feeding program can be effective in improving Hb levels and anemia among school children in a resource-constraint setting like Bihar, India (Krämer, Kumar, and Vollmer 2020). However, whether the early effects of DFS persist or dissipate in the long run remains an open question. We fill this gap by conducting a four-year follow-up study of the DFS experiment in Krämer, Kumar, and Vollmer (2020). We find that after four years of continued treatment, treated children, on average, have higher Hb levels and a lower likelihood of being anemic. The size of the point estimates in our study is larger for the health outcomes compared to the magnitude of the one-year treatment effects in Krämer, Kumar, and Vollmer (2020). According to our findings, higher treatment intensity measured as school attendance increases the effectiveness of the DFS intervention. However, the improved health status did not realize an improvement in cognitive and educational outcomes of children. We contribute to the literature by examining whether a longer treatment of the DFS in the MDM increases its effectiveness. We also provide novel insights into how a childhood intervention (in grade III) affects outcomes for young adolescents (in grade VI) which are critical for long-term adult outcomes.

Krämer, Kumar, and Vollmer (2020) found evidence of heterogeneous effects on test scores. Contrarily, we do not find evidence of such heterogeneous effects after four years of continued treatment. Ceiling effects, adapted tests, and the increasing influence of school quality could offer potential explanations for the insignificant results in our study (Wang et al. 2008). As we do not have a pure control group, our results should be interpreted as effects of longer treatment duration relative to a control group that also received the DFS one and a half years before the follow-up survey.

Our results have high policy relevance as they show the potential of early use of fortified foods in school feeding programs to increase the health of adolescents without crowding out other interventions. Salt is used while cooking lunch every day and so does not require additional staff capacity or resources. The results highlight that anemia reduction induced by a two-and-a half-year longer treatment delivery can be retained even when all children received the DFS in the MDM for at least the past one and a half years. An important policy implication is that even a continuous use of the DFS in one meal provided at school for four years is not sufficient to affect the cognitive outcomes of anemic children. Therefore, iron pills supplementation, food fortification, or the use of DFS in all meals should be explored in future studies. We further speculate that the effects of nutritional intervention on educational outcomes are mediated by complementary school resources and infrastructures. Thus, we recommend a more holistic approach for future nutrition interventions at the school level. Apart from a treatment arm with only DFS supply, future studies should complement the DFS intervention with measures improving the quality of education at schools.

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Table 1: Balance in baseline and estimation samples using baseline data for the health sample

	Estimation sample (with attrition)				Baseline sample (without attrition)			
	N	Control means	Treatment means	p-values	N	Control means	Treatment means	p-values
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Child level outcome variables								
Health outcomes								
Hemoglobin (g/dL)	1,051	11.631 (1.055)	11.477 (1.044)	0.027**	1,789	11.587 (1.095)	11.445 (1.097)	0.024**
Any anemia	1,051	0.402	0.496	0.002***	1,789	0.421	0.485	0.022**
Mild anemia	1,051	0.161	0.233	0.006***	1,789	0.175	0.207	0.082*
Moderate/ severe anemia	1,051	0.241	0.264	0.430	1,789	0.246	0.278	0.197
Panel B. Child and household level covariates								
Hindu	1,051	0.964	0.975	0.678	1,789	0.970	0.971	0.963
Caste (SC/ST)	1,051	0.235	0.316	0.146	1,789	0.219	0.311	0.068*
Rural	1,051	0.974	0.980	0.740	1,789	0.974	0.986	0.410
Family size	1,051	7.821 (3.325)	7.681 (3.398)	0.565	1,789	7.845 (3.530)	7.662 (3.352)	0.390
Father's years of schooling	1,051	5.268 (4.756)	5.532 (4.855)	0.561	1,789	5.429 (4.848)	5.555 (4.891)	0.731
Mother's years of schooling	1,051	1.592 (3.061)	1.597 (2.982)	0.980	1,789	1.810 (3.275)	1.798 (3.218)	0.956
Asset index	1,051	-0.104 (0.797)	-0.032 (0.990)	0.396	1,789	-0.030 (0.950)	-0.021 (0.999)	0.903
Female	1,051	0.602	0.536	0.040**	1,789	0.542	0.521	0.446
Panel C: School level covariates								
Total enrollment	106	224.231 (169.239)	222.278 (149.302)	0.950	108	220.537 (167.112)	222.278 (149.302)	0.995
Class size	106	29.288 (20.375)	27.519 (12.626)	0.594	108	28.648 (20.280)	27.519 (12.626)	0.729
Student-teacher ratio	106	37.695 (12.608)	33.866 (10.457)	0.092	108	37.139 (12.744)	33.866 (10.457)	0.147

Notes: Columns 2, 3, 6, and 7 report baseline means by intervention arm for outcomes (Panel A), child and household level covariates (Panel B), and school level covariates (Panel C) in the study analysis. N stands for the number of observations and standard deviations are reported in parentheses. Columns 5 and 8 report p-values from tests on the equality of means for each variable. SC/ST denote Scheduled Caste/Scheduled Tribe. *, ** and *** denote statistical significance at the 10%, 5%, 1% levels.

Table 2: Correlation between attrition and pre-treatment characteristics

	Health sample	Cognition & education sample
	(1)	(2)
Treatment	0.118	-0.247
	(0.415)	(0.434)
Hemoglobin (Hb)	-0.003	0.006
	(0.025)	(0.023)
Anemic (Hb < 11.5)	0.059	0.072
	(0.054)	(0.054)
Female	-0.091**	-0.055*
	(0.030)	(0.032)
Mother is primary schooled	0.094**	0.073
	(0.040)	(0.047)
Hindu	-0.061	-0.189**
	(0.097)	(0.092)
Above median family size	0.008	0.001
	(0.026)	(0.028)
Total enrollment in school	-0.001***	-0.001***
	(0.000)	(0.000)
Student-teacher ratio	0.005**	0.007***
	(0.002)	(0.002)
Treat * Anemic (Hb < 11.5)	-0.129*	-0.085
	(0.069)	(0.070)
Treat * Hb	-0.031	-0.015
	(0.034)	(0.033)
Treat * Female	0.049	0.055
	(0.049)	(0.050)
Treat * Mother is primary schooled	-0.027	-0.038
	(0.059)	(0.058)
Treat * Hindu	0.106	0.261*
	(0.138)	(0.148)
Treat * Above median family size	0.016	-0.002
	(0.042)	(0.043)
Treat * Total enrollment in school	-0.000	0.000
	(0.000)	(0.000)
Treat * Student-teacher ratio	0.004	0.004
	(0.004)	(0.003)
Observations	1,789	1,727
p-value from joint F-statistics on the interaction	0.690	0.567

Notes: Coefficients are from the Linear Probability Model for a dummy indicating attrition. Robust standard errors clustered at school levels are in parentheses. *, ** and *** denote statistical significance at the 10%, 5%, 1% levels. Baseline anemic is a dummy variable and coded as one for children with less than 11.5 Hb levels. All models control for asset tercile, class size, and block fixed effects. Coefficients for these control variables are not shown in the table but none of them are significant and are available upon request.

Table 3: Effects of the DFS on anemia and cognitive outcomes (IPW-DD estimates)

Outcomes	Treat*post	Mean of the dependent variable, baseline	Observations
	(1)	(2)	(3)
Panel A: Health outcomes			
Hemoglobin (g/dL)	0.245**	11.631	2,102
	(0.094)		
Any anemia	-0.134***	0.402	2,102
	(0.039)		
Mild Anemia	-0.106**	0.161	2,102
	(0.033)		
Moderate or severe anemia	-0.027	0.241	2,102
	(0.029)		
Panel B: Cognitive outcomes			
Block design	-0.070	3.722	1,640
	(0.111)		
Forward digit-span	0.001	4.073	1,640
	(0.078)		
Backward digit-span	-0.072	1.073	1,640
	(0.101)		
Raven's Colored Progressive Matrices	0.008	4.765	1,640
	(0.115)		
Stroop test	-0.073	5.104	1,640
	(0.117)		
Cognitive index	-0.035	-0.039	1,640
	(0.096)		
Panel C: Education outcomes			
Math test score	0.075	4.786	1,640
	(0.109)		
Reading test score	0.118	0.914	1,640
	(0.109)		

Notes: Estimated coefficients are based on an inverse probability of attrition weighted double differences (IPW-DD) model estimated separately in each row. All rows include child fixed effects and time-variant household controls (household size, mother's and father's years of schooling, and asset index). The asset index was generated using the first component of a principal component analysis consisting of several household assets. Any anemia is defined as a hemoglobin value < 11.5 g/dL for children aged 5-11 years, < 12g/dL for children aged 12-14 years and girls aged 15 and above, and < 12.9 g/dL for boys aged 15 and above. Mild anemia is defined as a hemoglobin value ≥ 11 & < 11.5 g/dL for children aged 5-11 years, value ≥ 11 & < 12g/dL for children aged 12-14 years and girls aged 15 and above, and ≥ 11 & < 12.9 g/dL for boys aged 15 and above. Moderate or severe anemia is defined as a hemoglobin value < 11 g/dL. Outcomes in Panel B and C are normalized with reference to the baseline mean, however, the mean at baseline is reported without normalization. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively. Standard errors, clustered at the school level, are reported in parentheses.

Table 4: Heterogeneous treatment effects on health outcomes, by endline attendance rate

	Hemoglobin (g/dL)	Any anemia	Mild anemia	Moderate or severe anemia
	(1)	(2)	(3)	(4)
Panel A: High attendance levels				
<u>70% attendance</u>				
Treat*post	0.245	-0.144**	-0.125**	-0.019
	(0.162)	(0.056)	(0.055)	(0.047)
Observations	610	610	610	610
<u>80% attendance</u>				
Treat*post	0.507**	-0.266***	-0.260***	-0.007
	(0.197)	(0.084)	(0.071)	(0.062)
Observations	324	324	324	324
<u>90% attendance</u>				
Treat*post	0.577***	-0.146	-0.195*	0.049
	(0.187)	(0.071)	(0.098)	(0.081)
Observations	112	112	112	112
Panel B: Attendance terciles				
<u>Bottom tercile</u>				
Treat*post	0.267	-0.164*	-0.150*	-0.013
	(0.191)	(0.092)	(0.082)	(0.074)
Observations	368	368	368	368
<u>Middle tercile</u>				
Treat*post	0.137	-0.091	-0.015	-0.076
	(0.160)	(0.070)	(0.064)	(0.072)
Observations	434	434	434	434
<u>Top tercile</u>				
Treat*post	0.341*	-0.239***	-0.243***	0.004
	(0.183)	(0.073)	(0.065)	(0.055)
Observations	416	416	416	416

Notes: Each cell reports the DD coefficients from a separate regression. Standard errors, clustered at the school level, are reported in parentheses. Any anemia is defined as a hemoglobin value < 11.5 g/dL for children aged 5-11 years, < 12g/dL for children aged 12-14 years and girls aged 15 and above, and < 12.9 g/dL for boys aged 15 and above. Mild anemia is defined as a hemoglobin value ≥ 11 & < 11.5 g/dL for children aged 5-11 years, value ≥ 11 & < 12g/dL for children aged 12-14 years and girls aged 15 and above, and ≥ 11 & < 12.9 g/dL for boys aged 15 and above. Moderate or severe anemia is defined as a hemoglobin value < 11 g/dL. All regressions include child fixed effects and time-variant household controls reported in Table 3. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively.

Table 5: Robustness to exclusion or inclusion of control variables

	Hemoglobin (g/dL)	Any anemia	Mild anemia	Moderate or severe anemia
	(1)	(2)	(3)	(4)
Panel A: Without control variables				
Treat*post	0.273**	-0.123**	-0.087**	-0.036
	(0.101)	(0.037)	(0.030)	(0.030)
Mean of dependent variable, baseline	11.637	0.405	0.168	0.237
Observations	2,450	2,450	2,450	2,450
Panel B: With IFA control				
Treat*post	0.230**	-0.165***	-0.145***	-0.020
	(0.113)	(0.043)	(0.040)	(0.032)
Mean of dependent variable, baseline	11.660	0.379	0.145	0.233
Observations	1,404	1,404	1,404	1,404
Panel C: With time-variant school-level controls				
Treat*post	0.191*	-0.137**	-0.119**	-0.017
	(0.110)	(0.044)	(0.040)	(0.032)
Mean of dependent variable, baseline	11.641	0.384	0.147	0.237
Observations	1,492	1,492	1,492	1,492

Notes: Each cell reports the DD coefficients from a separate regression. Any anemia is defined as a hemoglobin value < 11.5 g/dL for children aged 5-11 years, < 12g/dL for children aged 12-14 years and girls aged 15 and above, and < 12.9 g/dL for boys aged 15 and above. Mild anemia is defined as a hemoglobin value ≥ 11 & < 11.5 g/dL for children aged 5-11 years, value ≥ 11 & < 12g/dL for children aged 12-14 years and girls aged 15 and above, and ≥ 11 & < 12.9 g/dL for boys aged 15 and above. Moderate or severe anemia is defined as a hemoglobin value < 11 g/dL. All panels include child fixed effects. Panel B and C include time-variant household controls reported in Table 3. Panel C additionally includes time-variant school level controls: number of children enrolled in school, class size, and student-teacher ratio. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively. Standard errors, clustered at the school level, are reported in parentheses.

Appendix

Table A1: Project Timeline

Year	2014	2015	2016	2017	2018	2019
Children in grade	1st /2nd	2nd/3rd	3rd/4th	4th/5th	5th/6th	6th/7th
Intervention						
Delivery to treatment schools		■	■	■	■	■
Delivery to control schools				■	■	■
Data collection						
Survey I	■	■				
Survey II			■			
Survey III						■

Table A2: Balance in baseline and estimation samples using baseline data for cognition and education sample

	Estimation sample				Baseline sample			
	N	Control means	Treatment means	p-values	N	Control means	Treatment means	p-values
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Child level outcome variables								
<u>*Health outcomes*</u>								
Hemoglobin (g/dL)	808	11.613	11.455	0.072*	1,727	11.597	11.439	0.012**
		(1.046)	(1.117)			(1.096)	(1.104)	
Any anemia	808	0.398	0.485	0.021**	1,727	0.421	0.486	0.019**
Mild anemia	808	0.147	0.204	0.044**	1,727	0.178	0.206	0.122
Moderate/severe anemia	808	0.251	0.281	0.368	1,727	0.243	0.280	0.138
<u>*Cognition outcomes*</u>								
Block design	820	3.722	3.909	0.416	1,770	3.690	3.801	0.566
		(2.173)	(2.150)			(2.254)	(2.188)	
Digit-span forward	820	4.073	4.116	0.597	1.770	4.068	4.096	0.719
		(0.909)	(0.965)			(1.016)	(0.995)	
Digit-span backward	820	1.073	1.247	0.179	1,770	1.105	1.142	0.720
		(1.328)	(1.297)			(1.294)	(1.304)	
Progressive matrices	820	4.765	4.838	0.669	1,770	4.815	4.687	0.371
		(1.576)	(1.683)			(1.655)	(1.711)	
Stroop test	820	5.104	5.350	0.449	1,770	5.462	5.271	0.475
		(3.515)	(3.366)			(3.488)	(3.370)	
Cognitive index	820	-0.039	0.073	0.273	1,77ß	0.002	-0.003	0.954
		(0.981)	(0.952)			(1.022)	(0.979)	
<u>*Education outcomes*</u>								
Math score	820	4.786	5.011	0.697	1,770	4.910	4.749	0.687
		(3.760)	(3.749)			(3.860)	(3.798)	
Reading score	820	0.914	0.936	0.856	1,770	0.947	0.871	0.446
		(1.158)	(1.134)			(1.157)	(1.102)	

Panel B. Child and household level covariates								
Hindu	820	0.965	0.969	0.901	1,770	0.968	0.971	0.913
Scheduled Caste/Scheduled Tribe	820	0.265	0.318	0.413	1,770	0.250	0.315	0.221
Rural	820	0.970	0.978	0.706	1,770	0.974	0.983	0.538
Family size	820	7.781	7.647	0.609	1,770	7.787	7.678	0.595
		(3.182)	(3.257)			(3.405)	(3.307)	
Father's years of schooling	820	5.289	5.596	0.564	1,770	5.377	5.521	0.701
		(4.754)	(4.794)			(4.816)	(4.870)	
Mother's years of schooling	820	1.592	1.693	0.714	1,770	1.800	1.779	0.920
		(3.073)	(3.106)			(3.264)	(3.222)	
Asset index	820	-0.038	-0.037	0.989	1,770	-0.008	-0.037	0.710
		(0.857)	(0.967)			(0.962)	(0.987)	
Female	820	0.578	0.536	0.249	1,770	0.550	0.540	0.726
Panel C: School level covariates								
Number of children enrolled in school	92	243.341	234.292	0.794	108	220.537	222.278	0.955
		(176.597)	(152.709)			(167.112)	(149.302)	
Class size	92	29.432	28.208	0.744	108	28.648	27.519	0.729
		(21.641)	(12.647)			(20.280)	(12.626)	
Student-teacher ratio	92	36.960	33.655	0.144	108	37.139	33.866	0.147
		(11.589)	(9.716)			(12.744)	(10.457)	

Notes: Columns 2,3,6, and 7 report baseline means by intervention arm for outcomes (Panel A), child and household level covariates (Panel B), and school level covariates (Panel C) in the study analysis. N stands for the number of observations and standard deviations are reported in parentheses. Columns 5 and 8 report p-values from tests on the equality of means for each variable. SC/ST denote Scheduled Caste/Scheduled Tribe. *, ** and *** denote statistical significance at the 10%, 5%, 1% levels.

Table A3: Heterogeneous treatment effects on cognition and education outcomes, by endline attendance rate

	Block design	Digit-span forward	Digit-span backward	Progressive matrices	Stroop tests	Cognitive index	Math test score	Reading test score
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: High attendance levels								
Treat*post (70% attendance)	-0.076	-0.040	-0.029	0.037	-0.189	-0.025	0.128	0.189
	(0.139)	(0.140)	(0.127)	(0.170)	(0.165)	(0.142)	(0.148)	(0.151)
Observations	582	582	582	582	582	582	582	582
Treat*post (80% attendance)	-0.121	-0.186	-0.240	0.022	-0.287	-0.185	0.273	0.066
	(0.141)	(0.160)	(0.168)	(0.248)	(0.230)	(0.183)	(0.188)	(0.195)
Observations	326	326	326	326	326	326	326	326
Treat*post (90% attendance)	0.110	-0.130	-0.227	0.200	-0.553	0.179	0.625**	0.149
	(0.265)	(0.233)	(0.274)	(0.403)	(0.410)	(0.259)	(0.252)	(0.383)
Observations	116	116	116	116	116	116	116	116
Panel B: Attendance terciles								
Treat*post (Bottom tercile)	-0.096	-0.117	0.164	0.122	0.064	0.045	-0.002	-0.019
	(0.180)	(0.163)	(0.209)	(0.250)	(0.208)	(0.168)	(0.180)	(0.190)
Observations	352	352	352	352	352	352	352	352
Treat*post (Middle tercile)	0.060	0.094	0.120	0.000	-0.128	0.011	0.025	0.132
	(0.180)	(0.148)	(0.162)	(0.181)	(0.232)	(0.159)	(0.181)	(0.211)
Observations	408	408	408	530	408	408	408	408
Treat*post (Top tercile)	-0.143	-0.134	-0.089	0.117	-0.203	-0.081	0.217	0.171
	(0.132)	(0.147)	(0.146)	(0.211)	(0.199)	(0.149)	(0.145)	(0.164)
Observations	406	406	406	406	406	406	406	406

Notes: Each cell DD coefficients from a separate regression report based on an inverse probability of attrition weighted double differences (IPW-DD) model. Standard errors, clustered at the school level, are reported in parentheses. All outcomes are normalized with reference to the baseline mean. All regressions include child fixed effects and time-variant household controls reported in Table 3. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively.