Soil-Transmitted Helminths in Southwestern China: Links to Cognitive Ability, Nutrition, and School Performance among Children

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Abstract

Empirical evidence suggests that the prevalence of soil-transmitted helminth (STH) infections in remote and poor rural areas is still high among children, the most vulnerable to infection. There is concern that STH infections may detrimentally affect children's healthy development, including their cognitive ability, nutritional status, and school performance. Medical studies have not yet identified the exact nature of the impact STH infections have on children. The objective of this study is to examine the relationship between STH infections and developmental outcomes in 2,180 school-aged children in seven nationally-designated poverty counties in rural China. We conducted a large-scale survey in Guizhou province in southwest China in May, 2013. Overall, 42 percent of elementary school-aged children were infected with one or more of the three types of STH—*Ascaris lumbricoides* (ascaris), *Trichuris trichuria* (whipworm) and the hookworms *Ancylostoma duodenale* or *Necator americanus*. After controlling for socioeconomic status, we observed that children infected with one or more STHs have worse cognitive ability, worse nutritional status, and worse school performance than their uninfected peers.

Keywords: soil-transmitted helminths (STHs), cognitive ability, anemia, school performance, school attendance, working memory, processing speed, children, poor, rural, ethnic, China

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1. Introduction

A recent Cochrane Report (Taylor-Robinson et al., 2012) has raised questions about the nature of the relationship between infection with soil-transmitted helminths (STHs) and children's healthy development. In a meta-analysis of 42 papers, the authors of the report found that there was no clear, consistent relationship between STH infection and children's cognitive ability, nutritional indicators, or school performance. The report ended with a call for more concerted research that would help clarify the nature of the relationship between STH infection and these outcomes in children. Health policymakers depend on this type of information when deciding how to allocate resources to different disease types, in general, and how to allocate for STH control and treatment, in particular.

Because of high STH prevalence, China is an especially suitable setting in which to conduct such additional research. According to Wang et al. (2013), 40 percent of school-aged children in rural areas of Guizhou province are infected with one or more types of three STHs: *Ascaris lumbricoides* (ascaris), *Ancylostoma duodenale* (hookworm), and *Trichuris trichuria* (whipworm). In some villages, the prevalence is as high as 80 percent. Similarly high prevalence has also been reported elsewhere in China, such as in rural Guangxi and Hainan provinces (Shang, 2011).

The uncertainty in the international literature about the link between STH infections and child outcomes is reflected in the China-specific literature. Of six total China-based studies, five measured the link between STH infection and child health (either physical development or hemoglobin levels). Three of these (Shen et al., 1996;

Shang, 2011; Wang et al., 2013) found a significant negative correlation between STH infection and children's health, while two found no correlation (Ma et al., 1999; Guo and Li, 2003). None of the six studies measured school performance, although three attempted to measure the relationship between STH infections and cognitive ability using formal tests; however, the sample sizes in these studies were small, ranging from 140 to 200 children in 2 to 11 communities or clusters. With such small sample sizes, it is statistically impossible to produce meaningful results. In short, in the context of China—as in the rest of the world—there is uncertainty about the relationship between STH infections and child outcomes.

In this paper we will answer questions raised by the Cochrane report (Taylor-Robinson et al., 2012) and build evidence on the relationship between STH infections and health outcomes in children in rural China. To achieve this goal, we have three objectives. First, we will document the prevalence of STHs in the study areas, thus better defining the severity of the STH problem in poor areas of rural China. Second, we will document the levels of cognitive ability, nutritional indicators and school performance among our sample children in order to assess how children in poor rural areas fare in terms of these measured outcomes. Finally, we will examine the links between STH infection and cognitive ability, nutritional indicators, and school performance.

2. Methods

Sample Selection

We collected the data used in May of 2013 as part of a wide-scale survey of elementary school-aged children in Guizhou province. Our study was conducted in seven rural counties in Qiandongnan prefecture. We chose our sample to include poor and ethnic minorities who are at higher risk for STH infection. Based on rural per capita income levels reported in Guizhou Statistical Yearbook (2012), the research team randomly selected a total of seven rural counties from the poorest half of the counties (8 out of 16) in Qiangdongnan. According to the statistics, the average rural individual in our sample areas has a per capita income (at 4625 yuan) in the bottom quartile of China's rural income (at 7917 yuan) distribution (CNBS, 2013).

Once we chose the sample counties, we selected the sample townships and villages. In each county, we included all townships except for the township which houses the county government. We did not include the township housing the county government because it is always wealthier and more urban than a typical rural township. A total of 112 townships were selected. Then sample villages within each township were selected. Since our survey would take place in schools, we obtained a list of all the 9-11 year old children attending the central primary school in each township. We classified all 9-11 year old children by their home village, and then randomly selected 20 sample children from the home village with the largest number of children at that school. We excluded villages that housed the local township government, since these villages are typically wealthier and more urban than a typical village. If the home village had fewer than 20 children in our age group attending the school, we randomly selected children from the

next-largest village to fill in the gap. Overall, a total of 20 school children were randomly chosen from either one or two villages in each township. A total of 2,240 children from 146 villages and 112 townships were chosen as sample students.

Data Collection

The survey team collected four types of information: data from a socioeconomic survey; scores on a test of cognitive ability; measures of child health (including STH infection status, height, weight, and hemoglobin levels); and school performance (as measured by absenteeism and performance on a standardized math test).

Socioeconomic survey

The socioeconomic survey collected data on children and parents' basic demographic information, as well as data on each child's self-reported health, home and school sanitation behavior, and a series of basic questions about household conditions. The survey also asked both whether the child had taken anti-helminth medication in the past 6 months and whether they had taken it in the past 12 months. The school children completed the survey themselves under the direct monitoring of trained enumerators from the Chinese Academy of Sciences and Guizhou University of Finances and Economics.

Cognitive ability

Cognitive ability was assessed using a battery of four sub-tests taken from the Mandarin-language version of the Wechsler Intelligence Scale for Children Fourth Edition (WISC-IV). Since research suggests that children's working memory and processing speed are those areas of cognitive ability most likely to be affected by STH infection (Nokes et al., 1992; Shang, 2011), we focused our efforts on measuring these two outcomes. In WISC-IV, the working memory index (WMI) is assessed through two core subtests: Digit Span, and Letter Number Sequencing. The Processing Speed Index (PSI) is assessed through two other core subtests: Coding, and Symbol Search. Raw scores obtained from these core subtests were converted to age-scaled index scores using tables of norms in the WISC-IV Chinese version's administration and scoring manual through King-May Psychological Assessment Technology Development, Ltd., the only company that is licensed by NCS Pearson, Inc. to translate / adapt, publish and distribute the Chinese version of the WISC-IV in China.

Each of the 2,240 sample children was individually administered the four core sub-tests by trained examiners.

Health Indicators

We focus on three health indicators: hemoglobin concentrations (Hb), height and weight. Hemoglobin levels were measured on-site using HemoCue Hb 201+ systems. Height and weight measurements were also taken on site, following WHO standard protocol (de Onis et al., 2004). The children were measured in light clothing without shoes, hats or accessories. Weight was measured with a calibrated electronic scale recommended by scholars from the West China School of Public Health of Sichuan

University. Body height was measured using a standard tape measure. The nursing team was trained to ensure that the weighing station was set up on level ground to ensure accuracy of the equipment. Two nurses manned each measurement station, with one responsible for preparing subjects for measurement (removing shoes, offering instruction, reassuring parents, positioning children, etc.) and the other responsible for conducting and recording the measurements.

School performance

We focus on two measures of school performance: a standardized math test administered by the study team (Trends in International Mathematics and Science Study, or TIMSS), and school absenteeism, as reported by each student's homeroom teacher in official school records. To analyze the absenteeism data, we created a dummy variable that is equal to one if a student had ever been absent since the beginning of the semester, and zero otherwise.

Stool sample collection and testing

The study team collected two stool samples from each child in our sample, one stool sample per day for two consecutive days. Samples were picked up once per day by the study team, and were stored in a temperature-controlled cooler until collection. At the time of collection, members of the study team transported all stool samples in a temperature-controlled cooler to the laboratory of the local Center for Disease Control (CDC) located at the county seat. All stool samples were tested the same day on which they were collected. A total of 2,180 children produced at least one stool sample, and 75 percent of children produced two stool samples.

All stool samples were analyzed using the Kato-Katz smear method for *Ascaris lumbricoides* (Ascaris), *Trichuris trichuria* (whipworm), and *Ancylostoma duodenale* or *Necator americanus* (hookworm). Two smears were taken from each stool sample: one smear was tested the same day on-site, while the other was treated using a formaldehyde preservation technique and sent to the headquarters of the National Institute for Parasitic Diseases in Shanghai for a quality check. Children were considered positive for STH infection if either one of their stool samples tested positive for one or more types of STH.

Ethical Approval

This study received ethical approval from the Stanford University Institutional Review Board (IRB) (Protocol ID 25027), and from the Sichuan University Ethical Review Board (Protocol ID 2013009-01). All participating children gave their assent for their involvement in the study, and the children's legal guardians gave their consent for both their own and their children's involvement. Children who were found to have severe anemia were referred to the local hospital for treatment.

Statistical analysis

Iron status was determined based on finger prick blood analysis for hemoglobin (Hb). Following internationally accepted standards, anemia was defined as Hb<115 g/L (Centers for Disease Control and Prevention, 1998; Life Sciences Research Office, 1984).

Physical indicators of height and weight were used to construct height-for-age z-scores (HAZ) and Body Mass Index (BMI)-for-age z-scores using WHO AnthroPlus, a software application of the WHO Reference 2007 for children aged 5-19 years that is used to monitor the growth of school-aged children and adolescents (WHO, 2009). We followed internationally recognized cutoffs (WHO, 2006) to consider children whose

HAZ or BMI-for-age z-score to fall more than two standard deviations below the international mean to be stunted or underweight, respectively.

Raw scores obtained from the four core subtests of the WISC-IV were converted to age-scaled index scores using tables of norms in the Mandarin version of the WISC-IV administration and scoring manual. Two index scores are considered for analysis: Working Memory Index (WMI) and Processing Speed Index (PSI). Scores are divided into internationally-recognized ranges. A score of 90-110 is considered "average"; a score of 80-89 is considered "low average"; a score of 70-79 is considered "borderline"; and a score of below 70 is considered "extremely low" and at risk for intellectual disabilities or mental retardation.

All statistical analyses were performed using STATA 12.0. P-values below 0.05 were considered statistically significant. The statistical significance of differences in all outcomes by subgroup populations was assessed using ANOVA in STATA. STATA's multiple linear regression model and probit regression model were both used in the multivariate analysis. We included the following variables as potential confounders in the multivariate analysis: gender, age, boarding status, minority status, sanitation behaviors, and household characteristics. Definitions of key variables to be used in the rest of the paper are presented in Appendix Table 1.

3. Results

We examined 2,180 school-aged children. In our sample, 46 percent of the students were female and 54 percent were male, a ratio similar to those found in most

poor areas in China (CNBS, 2012). The average age is 10.6 years. A total of 26 percent of sample students board at school.

The background characteristics of the sample by infection status are presented in Table 1. There are no significant differences between the infected and uninfected group in terms of deworming history or gender. However, infected children are more likely to be older, to board at school, and to be a member of the Dong, Miao, or Shui ethnic minority groups. Infected children are also significantly more likely than uninfected children to eat uncooked meat, drink unboiled water, and to live in households with a dirt floor. Uninfected children are significantly more likely than infected children to wash their hands after using the toilet, to live in households with a private latrine, to have a higher household income, and to have better educated parents.

STH prevalence

Overall, 42 percent of sample children were infected with one or more of the three types of STH (Table 2). The most prevalent type of STH in the survey areas is *Ascaris* (31 percent), followed by *Trichuris* (22 percent), and finally by hookworm (1 percent). The results of the quality check show a 69 percent correlation between the results from the two testing centers (p=0.0000).

Cognitive Ability

A total of 63 percent of children had a Working Memory Index (WMI) that was either “extremely low” (<70) or “borderline” (70-79). The breakdown shows that 13 percent of children scored “extremely low” on the WMI portion of the test, and 50 percent of children scored in the “borderline” range.

A total of 36 percent of children had a Processing Speed Index (PSI) that was either “extremely low” (<70) or “borderline” (70-79). The breakdown shows that 10 percent of children scored “extremely low” on the PSI portion of the test, and 26 percent of children scored in the “borderline” range.

Nutritional indicators

We find that 16 percent of our sample children are anemic (Table 2), 28 percent are stunted (HAZ < -2), and 6 percent are underweight (BMI-for-age < -2).

School performance

The average child in our sample earned a failing score on the TIMSS test (score < 60), scoring an average of 52.6 out of 100 on the TIMSS test (Table 2). Around 13 percent of children in our sample had been absent from school at least once during the most recent semester.

Links between STH infection and cognitive ability, nutritional indicators, and school performance

STH Infection and Cognitive Ability

There are significant differences in children’s cognitive ability between infected children and uninfected children (Table 2). Our data show that the mean WMI of infected children is 76.6, significantly lower than that of the uninfected group (80.0, $p < 0.005$). Moreover, 71 percent of infected children had an “extremely low” or “borderline” WMI, significantly higher than that of uninfected children (57 percent, $p < 0.005$). These differences remain statistically significant after controlling for confounding factors (Table 3).

Our data show that the mean PSI of infected children is 83.4, significantly lower than that of the uninfected group (88.1, $p < 0.005$). Moreover, 45 percent of infected children in the infected group had an "extremely low" or "borderline" PSI, significantly higher than that of uninfected children (29 percent, $p < 0.005$). These differences remain statistically significant after controlling for confounding factors (Table 3).

STH Infection and Nutritional Indicators

There are significant differences in mean anemia rate between infected and uninfected children (Table 2). The anemia rate among infected children is 19 percent, significantly higher than that among the uninfected group (15 percent, $p < 0.05$). After controlling for confounding factors, we find that infected children are significantly more likely to be anemic than are uninfected children (Table 3).

There are significant group differences in height-for-age z-scores (HAZ) between infected and uninfected children (Table 2). The mean HAZ among infected children is -1.59, compared with -1.25 among uninfected children ($p < 0.005$). An average of 34 percent of infected children are stunted, compared with 23 percent of uninfected children ($p < 0.005$). After controlling for confounding factors, the difference in HAZ remains statistically significant (Table 3, $p < 0.005$).

The mean BMI-for-age z-score among infected children is -0.64, compared with -0.55 among uninfected children ($p < 0.05$). The proportion of underweight does not vary significantly between infected and uninfected children. After controlling for confounding factors, the difference in BMI-for-age z-scores remains statistically significant (Table 3, $p < 0.1$).

STH Infection and School Performance

The absence rate among infected children is 16 percent, compared to 11 percent among uninfected children ($p < 0.005$). This difference remains statistically significant after controlling for confounding factors (Table 3, $p < 0.05$).

The mean TIMSS score among infected children is 47.5, compared with 56.4 among uninfected children ($p < 0.005$). A total of 70 percent of infected children failed the TIMSS test (scores < 60), compared with 56 percent of uninfected children ($p < 0.005$). These differences remain statistically significant after controlling for confounding factors (Table 3, $p < 0.005$).

4. Discussion

In this paper we document the prevalence of STHs using results from stool sampling and socioeconomic testing of 2,180 school children living in seven nationally-designated poverty counties in Qiandongnan prefecture in Guizhou province. We observed that 42 percent of the sample children were infected with one or more of the three types of STH—*Ascaris*, *Trichuris*, and hookworm. This prevalence is consistent with previous, smaller-scale studies in China (Shang, 2011; Wang et al., 2013), but is more than twice the observed STH prevalence from the National Survey on Current Status of the Important Parasitic Diseases in Human Population in 2004 (MOH, 2005). According to the WHO treatment guidelines, the prevalence we document warrants mass treatment.

We also document children's cognitive ability, nutritional indicators and school performance. Our data show that sample children are lagging far behind the international

standard in terms of each of these measured outcomes. We further found that after controlling for a set of socioeconomic confounders, children infected with one or more STHs have worse cognitive ability, worse nutritional status, and worse school performance than their uninfected peers.

Our study has several limitations. First, due to budgetary constraints, we collected two stool samples per child (on consecutive days), rather than three samples per child. While we believe that two samples adequately allows for the cyclical nature of roundworms' egg laying patterns, three samples may have allowed for even greater sensitivity in the detection of the true rates of infection. Second, while we made every effort to keep samples refrigerated for as long as possible between sample production and laboratory testing, the samples were not produced on site, and therefore children may have waited up to several hours before delivering their samples to the nearest refrigeration facilities (either at the village clinic or at the school). This waiting period was outside of our control, but may have contributed to the degradation of hookworm eggs. Since both of these limitations may have resulted in an underestimate of total STH prevalence, the estimates presented here should be considered to be a lower bound.

Our study shows that STH infection still poses a significant health challenge among children living in poor, rural, ethnic areas of southwest China. These findings raise the question of why such a fundamental and easily treated health condition is not being adequately addressed. Answering this question is beyond the scope of the current study; however, we suggest that China's health and education policy makers apply WHO treatment guidelines and pursue a policy of regular treatment for all school-aged children living in these areas.

Given the important linkages we find between STH infection and a number of important child health and educational outcomes, we hope that our results will contribute positively to the debate surrounding the recent Cochrane report (Taylor-Robinson et al., 2012). Although our results are correlational, we believe that the strength of the correlations is striking, and indicates a need for more rigorous research on the impacts of STH treatment on child outcomes.

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Table 1. Background characteristics by status of STH infection, values are mean (SD)

Variable	Full sample (N=2179)	Children Uninfected (n=1267)	Children Infected (n=912)	P-Value H0: (2)=(3)
	(1)	(2)	(3)	(4)
Individual characteristics				
(1) Dewormed 6 months	0.12(0.32)	0.12(0.32)	0.12(0.32)	0.9533
(2) Dewormed 12 months	0.18(0.38)	0.18(0.38)	0.17(0.38)	0.5773
(3) Female	0.46(0.50)	0.48(0.5)	0.44(0.5)	0.1376
(4) Age	10.6(0.90)	10.5(0.9)	10.6(0.9)	0.0030***
(5) Boarder	0.26(0.44)	0.24(0.42)	0.3(0.46)	0.0019***
(6) Minority	0.90(0.30)	0.90(0.30)	0.9(0.29)	0.7535
(7) --Dong	0.45(0.50)	0.51(0.5)	0.37(0.48)	0.0000***
(8) --Miao	0.37(0.48)	0.32(0.47)	0.43(0.5)	0.0000***
(9) --Shui	0.04(0.19)	0.02(0.15)	0.06(0.23)	0.0000***
(10) --Zhuang	0.02(0.13)	0.02(0.14)	0.01(0.12)	0.3355
(11) --Other minority	0.03(0.16)	0.02(0.15)	0.03(0.17)	0.3927
Eating and sanitation				
(12) Wash hands before eating	0.84(0.36)	0.85(0.36)	0.84(0.37)	0.4437
(13) Wash hands after using toilet	0.87(0.34)	0.89(0.32)	0.84(0.36)	0.0032***
(14) Never Eat uncooked vegetables	0.31(0.46)	0.31(0.46)	0.31(0.46)	0.7532
(15) Never Eat uncooked meat	0.62(0.48)	0.68(0.47)	0.54(0.5)	0.0000***
(16) Never Drink un-boiled water	0.07(0.25)	0.06(0.24)	0.08(0.27)	0.0564*
(17) Never Bare feet	0.33(0.47)	0.33(0.47)	0.33(0.47)	0.9452
(18) Dirt floor	0.16(0.36)	0.13(0.33)	0.2(0.4)	0.0000***
(19) Own toilet	0.85(0.36)	0.89(0.32)	0.79(0.4)	0.0000***
(20) Dirt-based latrine	0.21(0.41)	0.19(0.39)	0.25(0.43)	0.0003***
(21) Use night soil	0.64(0.48)	0.67(0.47)	0.6(0.49)	0.0009***
Household characteristics				
(22) Household size	5.3(1.4)	5.3(1.4)	5.2(1.4)	0.0132**
(23) Siblings	1.2(0.9)	1.2(0.9)	1.2(1)	0.2977
(24) Medium wealth tercile	0.37(0.48)	0.37(0.48)	0.37(0.48)	0.9272
(25) High wealth tercile	0.23(0.42)	0.28(0.45)	0.17(0.37)	0.0000***
(26) Neither parent present	0.30(0.46)	0.34(0.47)	0.25(0.43)	0.0000***
(27) Mother's education	0.07(0.25)	0.08(0.28)	0.05(0.22)	0.0017***
(28) Father's education	0.12(0.32)	0.13(0.34)	0.09(0.29)	0.0061***

Source: Authors' survey.

Note: ***, **, and * indicate significance at 1 percent, 5 percent and 10 percent, respectively.

Table 2. Cognitive ability, nutritional indicators, and school performance, by status of STH infection. Values are mean (SD)

Variable	Full sample (N=2179)	Children Uninfected (n=1267)	Children Infected (n=912)	P-Value H0: (2)=(3)
	(1)	(2)	(3)	(4)
STH infection				
(1) Any worm	0.42(0.49)	0(0)	1(0)	
(2) Roundworm	0.31(0.46)	0(0)	0.73(0.44)	
(3) Hook worm	0.22(0.42)	0(0)	0.54(0.5)	
(4) Whip worm	0.01(0.07)	0(0)	0.01(0.11)	
Cognitive ability				
(5) Working memory index (WMI)	78.6(9.9)	80.0(10.4)	76.6(8.9)	0.0000***
(6) --Extremely low WMI (<70)	0.13(0.34)	0.11(0.31)	0.16(0.37)	0.0003***
(7) --Borderline WMI (70-79)	0.50(0.50)	0.46(0.50)	0.55(0.50)	0.0000***
(8) --Extremely low or Borderline WMI (<80)	0.63(0.48)	0.57(0.50)	0.71(0.45)	0.0000***
(9) Processing speed index (PSI)	86.2(13.1)	88.1(12.8)	83.4(13.1)	0.0000***
(10) --Extremely low PSI (<70)	0.10(0.3)	0.07(0.26)	0.14(0.35)	0.0000***
(11) --Borderline PSI (70-79)	0.26(0.44)	0.22(0.42)	0.30(0.46)	0.0000***
(12) --Extremely low or Borderline PSI (<80)	0.36(0.48)	0.29(0.46)	0.45(0.50)	0.0000***
Nutritional indicators				
(13) Anemic	0.16(0.37)	0.15(0.36)	0.19(0.39)	0.0216**
(14) HAZ	-1.39(1.04)	-1.25(1.04)	-1.59(1.01)	0.0000***
(15) --Stunted (HAZ<-2)	0.28(0.45)	0.23(0.42)	0.34(0.47)	0.0000***
(16) BmiAZ	-0.59(0.99)	-0.55(1.01)	-0.64(0.96)	0.0425**
(17) --Underweight (BmiAZ<-2)	0.06(0.25)	0.06(0.23)	0.07(0.26)	0.1899
School performance				
(18) School absence	0.13(0.34)	0.11(0.31)	0.16(0.37)	0.0004***
(19) Standardized math test score	52.6(22.0)	56.4(21.1)	47.5(22.3)	0.0000***
(20) --Failure Score<60)	0.62(0.49)	0.56(0.50)	0.70(0.46)	0.0000***

Source: Authors' survey.

Note: ***, **, and * indicate significance at 1 percent, 5 percent and 10 percent, respectively.

Table 3. Estimation of Correlation between STH Infection and Cognitive Ability, Nutritional Indicators, and School Performance

	Multivariate Adjusted Estimate of Difference in Mean (95% CI)*	P-Value
	(1)	(2)
Cognitive ability		
(1) Working memory index (WMI)	-2.249(-3.221, -1.277)	0.000
(2) Processing speed index (PSI)	-3.151(-4.456, -1.845)	0.000
Nutritional indicators		
(3) Anemic	0.033(-0.004, 0.070)	0.076
(4) HAZ	-0.231(-0.333, -0.128)	0.000
(5) BmiAZ	-0.084(-0.185, 0.016)	0.099
School performance		
(6) School absence	0.041(0.006, 0.077)	0.021
(7) Standardized math test score	-7.941(-10.195, -5.688)	0.000

Source: Authors' survey.

Notes:

* Estimated with multivariate regressions adjusted for student characteristics (student gender, student age, whether the student boards at school, whether the student is Dong ethnic minority, whether the student is Miao ethnic minority, whether the student is Shui ethnic minority, whether the student is Zhuang ethnic minority, and whether the student is any other non-Han ethnic minority); student eating and sanitation habits (whether the student never eaten uncooked vegetables, whether the student never eaten uncooked meat, whether the student never drunk unboiled water); as well as household characteristic (household size, number of siblings, whether the household belongs to the medium wealth tercile, whether the household belongs to the high wealth tercile, whether neither parent lives with the child, whether the mother got at least senior high school education, and whether the father got at least senior high school education). Robust standard errors accounted for clustering at the township level.

Appendix Table 1. Variable Definition

Variable	Description
STH Infection	
Any worm	Child is infected with any of the three types of worms: roundworm, hook worm, whip worm (1=yes, 0=no)
Roundworm	Child is infected with round worm (1=yes, 0=no)
Hook worm	Child is infected with hook worm (1=yes, 0=no)
Whip worm	Child is infected with whip worm (1=yes, 0=no)
Cognitive ability	
Working memory index	Standardized working memory score that a child scored at the working memory module of the WISC-IV test
Processing speed index	Standardized processing speed score that a child scored at the working memory module of the WISC-IV test
Nutritional indicators	
Anemic	A child has Hb<115 g/L (1=yes, 0=no)
HAZ	Height for Age Z score
BmiAZ	BMI for Age Z score
School performance	
School absence	Child has ever been absent from school this semester (1=yes, 0=no)
Standardized math test score	% of 29 questions that a child answered correctly during the standardized math test
Correlates	
-Individual characteristics	
Dewormed 6 months	Child has taken anti-helminth medicine in past 6 months (1=yes, 0=no)
Dewormed 12 months	Child has taken anti-helminth medicine in past 12 months (1=yes, 0=no)
Female	Child is female (1=yes, 0=no)
Age	Age of child, years
Boarder	Boarding student this semester (1=yes, 0=no)
Minority	Child is non-Han ethnic minority (1=yes, 0=no)
--Dong	Child is Dong minority (1=yes, 0=no)
--Miao	Child is Miao minority (1=yes, 0=no)
--Shui	Child is Shui minority (1=yes, 0=no)
--Zhuang	Child is Zhuang minority (1=yes, 0=no)
--Other minority	Child is minority other than Dong, Miao, Shui, Zhuang and Yao (1=yes, 0=no)
Eating and sanitation	
Wash hands before eating	Wash hands before eating (1=at least sometimes, 0=no)
Wash hands after using toilet	Wash hands after using toilet (1=at least sometimes, 0=no)
Never ate uncooked vegetables	Never ate uncooked vegetables (1=never, 0=otherwise)
Never ate uncooked meat	Never ate uncooked meat (1=never, 0=otherwise)
Never drank un-boiled water	Never ate un-boiled water (1=never, 0=otherwise)
Bare feet	Child goes outdoor with bare feet in summer (1=never, 0=otherwise)
Dirt floor	First floor is dirt (1=yes, 0=no)
Own toilet	Household has own toilet (1=yes, 0=no)
Dirt-based latrine	Toilet has dirt-based latrine (1=yes, 0=no)
Use night soil	Household uses night soil in production (1=yes, 0=no)
Household characteristics	

Household size	No. of family members (person)
Siblings	No. of siblings (person)
Medium wealth tercile	The medium tercile ranked by pieces of durable goods owned by the household (1=yes, 0=no)
High wealth tercile	The highest tercile ranked by pieces of durable goods owned by the household (1=yes, 0=no)
Neither parent present	Neither parent lives with the child at present (1=neither, 0=otherwise)
Mother's education	Mother finished secondary school or above (1=yes, 0=no)
Father's education	Father finished secondary school or above (1=yes, 0=no)