

1 **Intestinal parasites among rural school children in southern Ethiopia: A cross-sectional**  
2 **multilevel and zero-inflated regression model**

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## 15 **Abstract**

16 **Background:** Over 28 million school-aged children are at risk of intestinal parasite infection in Ethiopia. Few studies have  
17 investigated household-level risk factors or applied multilevel analysis to account for the nested data structure. This study aimed to  
18 assess the prevalence, intensity, and risk factors of parasite infection among schoolchildren in rural South Ethiopia.

19 **Methodology/Principal Findings:** Using multistage random sampling, we recruited 864 students in the Wonago district. We  
20 applied multilevel-logistic and zero-inflated negative binomial regression models (ZINB). Risk factors were concentrated at the  
21 individual level; school-level and class-level variables explained less than 5% of the variance. The overall intestinal parasite  
22 prevalence was 56% (479/850); *Trichuris trichiura* prevalence was 75.2% (360/479); and *Ascaris lumbricoides* prevalence was 33.2%  
23 (159/479). The rate of infection increased among children with anemia (AOR: 1.45 [95% CI: 1.04, 2.03]), wasting (AOR: 1.73 [95%  
24 CI: (1.04, 2.90)], mothers who had no formal education (AOR: 1.08 [95% CI: 1.25, 3.47]), and those in households using open  
25 containers for water storage (AOR: 2.06 [95% CI: 1.07, 3.99]). In the ZINB model, *A. lumbricoides* infection intensity increased with  
26 increasing age (AOR: 1.08 [95% CI: 1.01, 1.16]) and unclean fingernails (AOR: 1.47 [95% CI: 1.07, 2.03]). Handwashing with soap  
27 (AOR: 0.68 [95% CI: 0.48, 0.95]), de-worming treatment [AOR: 0.57 (95% CI: 0.33, 0.98)], and using water from protected sources  
28 [AOR: 0.46 (95% CI: 0.28, 0.77)] were found to be protective against parasitic infection.

29 **Conclusions/Significance:** After controlling for clustering effects at the school and class levels and accounting for excess zeros  
30 in fecal egg counts, we found an association between parasite infections and the following variables: age, wasting, anemia, unclean  
31 fingernails, handwashing, de-worming treatment, mother's education, household water source, and water storage protection.  
32 Improving hygiene behavior, providing safe water at school and home, and strengthening de-worming programs is required to  
33 improve the health of schoolchildren in rural Gedeo.

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### 36 **Author summary**

37 Intestinal parasite infections are common among school-aged children in Ethiopia. Several cross-sectional studies have investigated  
38 the prevalence and risk factors of these intestinal parasite infections. However, most were conducted in an urban setting in northern  
39 Ethiopia; they collected household-level risk factor information from the children, not the parents; and they restricted intestinal  
40 parasite infection data to binary outcomes. Therefore, we aimed to assess the prevalence and intensity of intestinal parasite infections  
41 and the related individual-, household-, and school-level risk factors among rural schoolchildren in southern Ethiopia. Using a  
42 multivariate, multilevel, regression model, we found minimal variation across class- and school-level factors for intestinal parasite  
43 infection prevalence. We found associations between intestinal parasite infections and most individual-level factors and some

44 household-level factors. Therefore, interventions focusing on the individual, household, and school should be implemented to reduce  
45 the prevalence of infection and parasite load among schoolchildren.

## 46 **Introduction**

47 More than 1.5 billion people around the world are affected by intestinal parasites, including over 568 million schoolchildren who are  
48 at risk (1). In 2015, an approximately 88 million individuals, including 28 million school-aged children, were at risk for intestinal  
49 parasite infection in Ethiopia (2). Roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*), and hookworm (*Ancylostoma*  
50 *duodenale* and *Necator americanus*) are the most common intestinal helminth infections that chronically infect children (3) .  
51 Neglected tropical diseases tend to receive less attention and funding than malaria or TB research (3, 4), although the economic and  
52 health burdens of these infections exceed those for other diseases (4, 5). Anemia, poor physical and intellectual development, and  
53 impaired cognitive function can occur with these infections (6, 7). The risk factors of intestinal parasite infections include poverty (8),  
54 mothers' education, untrimmed fingernails, walking barefoot, unsanitary toilet areas, not washing hands before eating or after visiting  
55 the toilet, eating raw or undercooked vegetables or meat, lack of hygiene facilities, and drinking water from unsafe sources (9). In  
56 developing countries, control measures can be difficult to implement due to water and sanitation problems (10).  
57 In Ethiopia, the prevalence of intestinal parasite infection among schoolchildren ranges between 18% and 81% (8, 11-17), with the  
58 highest rate of infection (81%) recorded in the southern region (17). The government of Ethiopia is expanding schooling to make  
59 education more relevant to all children and meet their nutritional and health needs (18). This strategy includes facilitating and

60 implementing a de-worming service every six months and improving water, hygiene, and sanitation facilities (19). However, many  
61 school-aged children continue to be affected by parasitic infections (20-22). Moreover, most schools have no handwashing facilities,  
62 and hygienic behavior is inadequate (23).

63 School-based, cross-sectional studies have been used to study the prevalence and predictors of intestinal parasite infections (8, 11-17).  
64 Many of these studies have been conducted in urban settings in northern Ethiopia, and they focused on school feeding programs (24)  
65 and infection prevalence (25). Unfortunately, they did not assess potential household risk factors or adequately address the nested  
66 structure of school data (i.e., individuals nested within the same classes, which are nested within the same schools). Furthermore, most  
67 interpreted the intestinal parasite infection data in terms of binary outcomes (e.g., presence and absence).

68 Few studies have assessed the prevalence of intestinal parasite infections in southern Ethiopia (17). This paper therefore aimed to  
69 assess the prevalence and intensity of intestinal parasite infections among rural school children in the Wonago District of South  
70 Ethiopia, as well as the individual-, household-, and school-level factors that contribute to these infections. In addition to the binary  
71 outcome variable, we considered intestinal parasite egg concentration in the stool specimen. Using a multivariate, multilevel,  
72 regression model, we identified factors contributing to variations in the prevalence of intestinal parasite infections in this population.

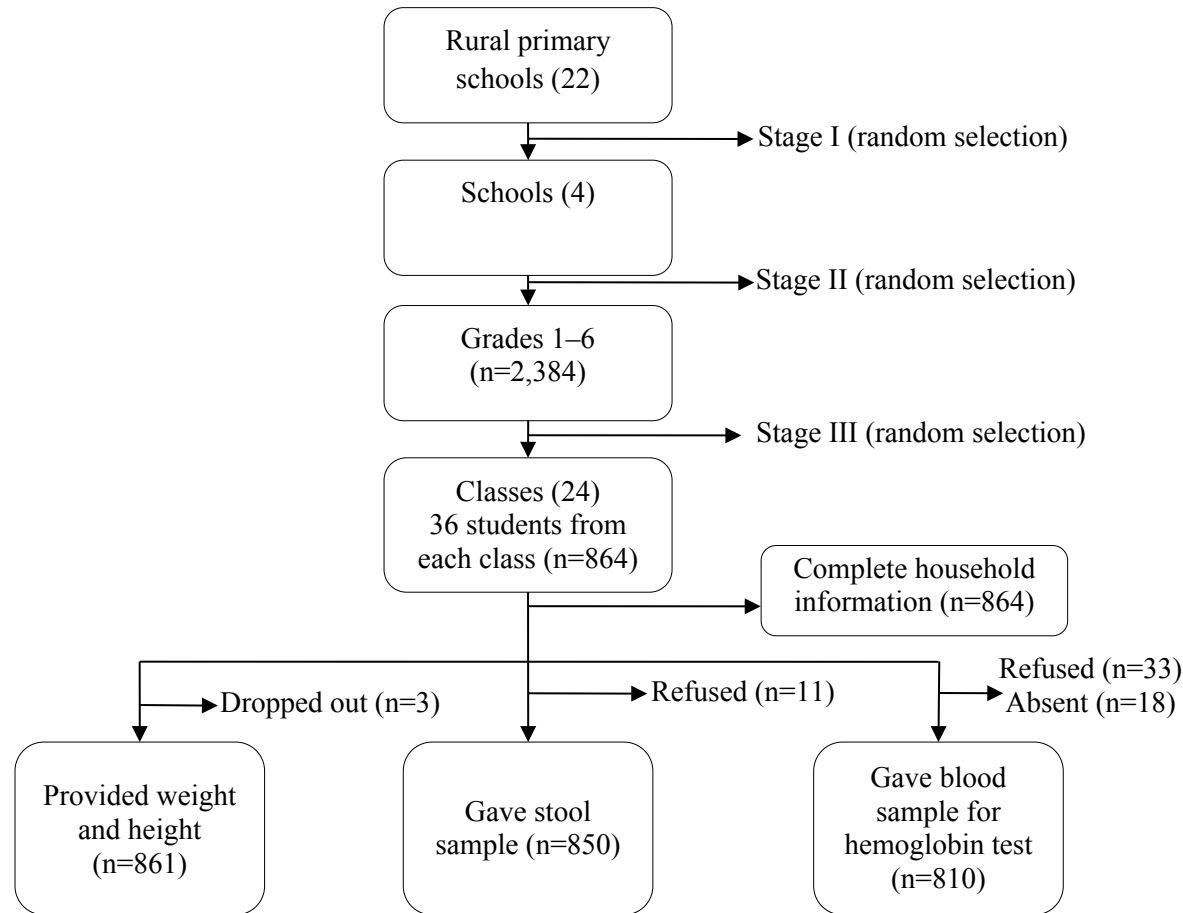
## 73 **Method**

### 74 **Study design and setting**

75 We conducted this cross-sectional study from February 2017 to June 2017 in the Wonago district of the Gedeo Zone in the southern  
76 region of Ethiopia. The district is 375 km south of Addis Ababa, the capital city of Ethiopia. The district has 17 rural and 4 urban  
77 *kebeles*, which is the smallest administrative unit. In 2014, Wonago's population was estimated at 143,989 people: 71,663 (49.8%)  
78 men and 72,326 (50.2%) women. The population density of the district is 1,014 persons per square kilometer, making it one of the  
79 most densely populated areas in Ethiopia. The district has 26 government health facilities (6 health centers and 20 health posts), 2  
80 private clinics and 2 drug stores, and more than 36,000 students in 3 urban and 22 rural primary schools. Most residents depend on  
81 cash crops of coffee, fruits, and *ensete* (*Ensete ventricosum*).

### 82 **Participants**

83 We recruited students aged 5–14 years who gave consent and whose parents or guardians gave consent to participate. Using a three-  
84 stage cluster sampling method, we assigned schools to level one, classes to level two, and students to level three. We replaced  
85 participants who dropped out of school after the selection process with participants of similar class, sex, and age. We selected only one  
86 child per household and collected household information from the parent or guardian. Figure 1 shows the recruitment process and  
87 participant profile.



88

89 **Figure 1: Study recruitment profile, Wonago district, Gedeo zone, southern Ethiopia, 2017**

90 **Sample size**

91 We calculated the sample size using OpenEpi software (26), assuming a 95% confidence interval (CI), maximum sample sizes based  
92 on proportions of different variables (e.g., underweight [59.7%], stunting [30.7%], wasting [37.2%], intestinal parasite [27.7%], and

93 skin infection [50%]), 5% precision, and design effect 2 due to multistage sampling. We also calculated the sample size using  
94 outcome-associated variables, such as undernutrition (32.2% prevalence of stunting among female participants), intestinal parasites  
95 (52.6% among children who did not wash their hands before meals), and skin infection (21.8% among children aged 6–10 years). To  
96 yield the maximum sample size, we calculated 50% for skin infection (12, 27-29). After adding a 10% non-response rate, we reached  
97 a final sample size of 845, the minimum required sample size. We then randomly recruited 864 students.

## 98 **Variables and measurements**

99 We used a multilevel logistic regression model to analyze three separate binary outcome variables: the presence or absence of any  
100 intestinal parasite infections, the presence or absence of *T. trichiura*, and the presence or absence of *A. lumbricoides*. Two separate  
101 count models also were constructed for the *T. trichiura* and *A. lumbricoides* fecal egg counts. The association between the over-  
102 dispersed count outcome with excess zeros and the potential predictors of *T. trichiura* and *A. lumbricoides* infection was determined  
103 using a zero-inflated negative binomial (ZINB) regression model (30).

104 The intensity of parasite infection was measured according to density of eggs in stool samples. Using the Kato-Katz technique, each  
105 parasite egg was multiplied by 24 to quantify the result in eggs per gram (epg) of stool (31). Infection intensity was defined as light  
106 (<5,000 epg for *A. lumbricoides*; <1,000 epg for *T. trichiura*; and <2,000 epg for hookworm) or moderate ( $\geq$ 5,000 epg for *A.*  
107 *lumbricoides*;  $\geq$ 1,000 epg for *T. trichiura*; and  $\geq$ 2,000 epg for hookworm) (32).



108 We assessed individual, parent, and household exposure variables. The individual child factors included sex, age, hygiene behavior,  
109 loss of appetite in the past month, de-worming treatment in the past 6 months, anemia ( $< 11.5\text{g/dl}$  for those aged 5–11 and  $< 12\text{g/dl}$  for  
110 those aged 12–14), stunting (height-for-age Z scores below -2 SD), and wasting (body-mass-index-for-age Z scores below -2 SD).  
111 Parent factors included the educational level of the mother and father. Household factors included the wealth index, which was  
112 constructed using principal component analysis of 15 household assets (electricity, radio, television, mobile phone, table, chair, bed,  
113 separate kitchen, cooking place, own land, bank account, toilet facility, floor type, and roof type); family size; source of drinking  
114 water; container used to store water; and use of treated water. School factors included access to health education on personal hygiene,  
115 absence from school in the past month, and participation in the school food program.

116 Stool samples were collected, processed, and examined using standard procedures (33, 34). Samples were collected in the early  
117 morning at school and stored in stool cups labeled with an identification code, name, sex, age, and date. Specimens then were  
118 transported in a cold-box with frozen ice-packs to the nearest health facility, Dilla University Teaching and Referral Hospital, where  
119 Kato-Katz and formalin-ether concentration techniques were used to conduct stool tests. Single, 41.7-mg thick, Kato-Katz smears  
120 were prepared from each stool sample on the same day of specimen collection. Then, 1 g of stool was preserved in 10% formalin  
121 solution and processed using the formalin-ether concentration technique (35). The slides were examined by three experienced  
122 laboratory technicians. The result of each parasite species from two diagnostic techniques was recorded separately.

123 Individual and household factors were collected from the child or the child's parents or guardians via interviews and observations of  
124 housing conditions. Hemoglobin concentrations were measured from capillary blood samples using a HemoCue Analyser Hb 301  
125 (Angelholm, Sweden) (36). Anthropometric indices for height-for-age and body-mass-index-for-age also were calculated.

## 126 **Data quality control and statistical methods**

127 To minimize potential bias and validate the measurement tools prior to actual data collection, a pre-test was conducted on 42 primary  
128 schoolchildren in other schools not selected for this study. Ten trained enumerators used a pretested, structured questionnaire that was  
129 primarily adapted and developed in English and then translated into the local language (*Gedeoffa*). Supervisors checked the data  
130 onsite for completeness and consistency.

131 All Kato-Katz slides were examined within one hour of preparation to minimize bias. To reduce possible bias introduced during  
132 outcome measurement, 10% of the test results were re-examined in a blinded fashion to ensure reproducibility of the results. Kappa  
133 statistics (STATA 14 software) were used to estimate reliability of the inter-rater agreement of the two readers. Kappa values were  
134 defined as follows: poor=0.01–0.2; fair=0.21–0.4; moderate=0.41–0.6; good=0.61–0.8; and perfect=0.81–1 (37). Kappa values were  
135 considered statistically at  $P < 0.05$ . The reliability (Kappa values) were as follows: *A. lumbricoides*, 0.83 [0.72 – 0.95; 95% CI]; *T.*  
136 *trichiura*, 0.88 [0.78 – 0.98; 95% CI]; *Taenia species*, 0.87 [0.76 – 0.98; 95% CI]; and hookworm, 0.86 [0.74 - 98; 95% CI].

137 Agreement among readers was good ( $P < .001$ ). Among discordant results between the two readers, 6 were for *A. lumbricoides*, 5 for *T.*  
138 *trichiura*, 5 for *Taenia*, and 5 for hookworm. In these cases, a third reader was used to confirm the analysis.

139 Descriptive statistics including frequency, percentage, mean, median, range, interquartile range, and standard deviation were  
140 calculated to describe relevant variables. Cross tabulation was used to calculate the proportion of categorical variables in relation to  
141 outcome variables for any intestinal parasite infection, for *T. trichiura* infection, and for *A. lumbricoides* infection.  
142 A wealth index was constructed by using principal component analysis to code the previously listed 15 household assets as 0 (absent)  
143 or 1 (present). Internal consistency of the 15 variables was determined (Cronbach alpha of 0.78 and Kaiser-Meyer-Olkin sampling  
144 adequacy of 0.8). The socioeconomic indicators (poor, middle, and rich) were categorized based on the first component explaining  
145 28.3% of the variance in the data with an Eigen value of 4.1.

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### 147 **Multilevel, mixed-effect logistic regression for modelling infection risk**

148 We used three data hierarchies: school-level, class-level, and individual-level (child or parent). Student participants were clustered  
149 within the same class, and classes were nested within schools. We included school and class levels during analysis and assessed  
150 potential confounding and effect modifications using multivariate, multilevel regression and stratified analysis. Prior to the  
151 multivariate regression, we checked collinearity among exposure variables. We used the presence and absence of any intestinal  
152 parasite, of *T. trichiura* infection, and of *A. lumbricoides* infection as separate outcome variables and conducted the analysis using a  
153 multilevel logistic regression model. For all predictors, we applied a simple, bivariate, logistic regression without considering a  
154 random effect and a multilevel, logistic regression model with random school and class effects.

155 Five models were constructed for each outcome variable (any intestinal parasite or *T. trichiura*, or *A. lumbricoides* infection). Model I  
156 (empty) had no covariate indicating whether to consider the random-effect model. Model II contained the individual child factors.  
157 Model III contained the individual child and individual parent factors. Model IV contained household, individual child, and individual  
158 parent factors. Finally, Model V used multilevel, multivariate, logistic regression to assess individual, household, and school factors.  
159 Exposure variables with P values  $<.25$  in the bivariate multilevel logistic regression model were introduced into the model II, model  
160 III and model IV.

161 Variables in model V included individual child factors (sex, age, loss of appetite in past month, nail trimming, handwashing with soap  
162 before meals, wasting, and anemia), individual parent factors (mother's educational status), household factors (wealth, source of  
163 drinking water, container used to store water, treated water), and school factors (participation in school feeding program). Covariate  
164 variables (e.g., sex, age, nail trimming, handwashing with soap before meals, wealth, source of drinking water, using treated water,  
165 and participation in a school feeding program) with P values  $>.25$  in the bivariate regression model were retained in the final model to  
166 control for confounding.

167 Variables in model V for *T. trichiura* infection included individual child factors (sex, age, loss of appetite in past month, eating  
168 uncooked vegetable, wasting, and anemia), individual parent factors (mother's educational status), household factors (wealth, family  
169 size, and container used to store water), and school factors (participation in school feeding program). Covariate variables (e.g., sex,  
170 age, and wealth) with P values  $>.25$  in the bivariate regression model were retained in the final model to control for confounding.

171 Variables in model V for *A. lumbricoides* infection included individual child factors (sex, age, nail trimming, dirt in fingernail, loss of  
172 appetite in past month, handwashing with soap after using latrine, de-worming treatment in past 6 months, and anemia), individual  
173 parent factors (mother's educational status), household factors (wealth and source of drinking water), and school factors (participation  
174 in school feeding program). Covariate variables (e.g., sex, nail trimming, and wealth) with P values  $>.25$  in the bivariate regression  
175 model were retained in the final model to control for confounding.

### 176 **Zero-inflated negative binomial regression for modelling infection intensity**

177 To examine potential factors associated with infection intensity, a count model was applied using the fecal egg counts for *T. trichiura*  
178 and *A. lumbricoides* infections. A Poisson model was appropriate for count data, but the assumption of equal variance and mean did  
179 not fit to our data, because the mean of *A. lumbricoides* and *T. trichiura* eggs was higher than the variance. Moreover, one-part models  
180 tend to underestimate the frequencies of zeros and to bias estimation of the covariate effect size (38). Furthermore, our data showed  
181 about 81% (691) of excess zeroes for the *A. lumbricoides* fecal egg count and 57.7% (490) for the *T. trichiura* eggs count. The alpha  
182 dispersion parameter was significant for *T. trichiura* at 0.53 (95% CI: 0.45–0.61) and for *A. lumbricoides* infection at 0.47 (95% CI:  
183 0.05, 0.37). Therefore, the excess zeroes in these data indicate that a zero-inflated model was appropriate. The zero-inflated negative  
184 binomial (ZINB) regression model is a two-part model that models count variables with inflated zeros and an over-dispersed count  
185 outcome (39). The ZINB model also assumes that the excess zero counts come from a logit model and the counts from a negative  
186 binomial model.

## 187 **Measure of effect and model fitness**

188 Results were calculated as crude odds ratios and adjusted odds ratios with a 95% CI. Predictors with P values <.05 in the final  
189 multilevel, multivariate regression model were reported as statistically significant. The Vuong test was used to compare the ZINB  
190 model with a standard negative binomial model and a likelihood ratio test to compare ZINB with a zero-inflated Poisson regression  
191 model. The Vuong and likelihood ratio tests with  $P < .05$  favored the ZINB model (38). Model fitness was checked using  $-2 \log$   
192 likelihood (deviance) and Akaike information criterion. The model with the lowest deviance and Akaike information criterion was  
193 used as the final model (38, 40).

## 194 **Ethical approval and consent to participate**

195 The institutional review board at the College of Medicine and Health Sciences of Hawassa University (IRB/005/09) and the Regional  
196 Ethical Committee of Western Norway (2016/1900/REK vest) provided ethical clearance. The Gedeo Zone Health Department and  
197 District Education Office provided a letter of permission. School directors and teachers participated in discussions. We obtained  
198 informed written (signed) and verbal (thumb print) consent from study participants' parents or guardians and permission (assent) from  
199 children aged 12 years and older before the interviews. The participants' privacy and confidentiality were maintained. Children  
200 diagnosed as anemic and who tested positive for intestinal parasites were referred to the nearest health institution for treatment  
201 according to the standard national guidelines (41).

## 202 **Result**

### 203 **Demographic and socio-economic status of schoolchildren and their parents**

204 The mean age of the 861 schoolchildren (483 boys and 378 girls) was 11.4 (95% CI: 11.3–11.5) years, ranging from 7 to 14 years.

205 About 88.4% (761/861) of mothers and 48.8% (420/861) of fathers never attended school. S1 Table summarizes the demographic and  
206 socioeconomic statuses of the schoolchildren and their parents.

### 207 **Prevalence of anemia, stunting, and wasting**

208 Anemia occurred in 29.6% (240/810 children, 95% CI: 26.6–32.9), among whom 85% (204/240) were mildly anemic and 15%

209 (36/240) were moderately anemic. About 32% (278/861, 95% CI: 29.2–35.5) had stunting, of which 37.4% (104/278) were severely  
210 stunted. Ten percent (85/861, 95% CI: 8.0–12.1) had wasting.

### 211 **Prevalence rates of intestinal parasites**

212 Intestinal parasites were found in 56% (479/850) of children. Of those, 57.6% (276/479) were boys, and 30% (144/479) had multiple  
213 infections. The most frequent intestinal parasites were *T. trichiura* (75.2%; 360/479), followed by *A. lumbricoides* (33.2%; 159/479),  
214 *Taenia* species (18.2%; 87/479), hookworm species (7.7%; 37/479), *Strongyloides stercoralis* (4.4%; 21/479), and *Hymenolepis nana*  
215 (0.4%; 2/479). The mean egg intensity was 284.7 epg for *A. lumbricoides* (95% CI: 119.5–449.9), 156.4 epg for *T. trichiura* (95% CI:  
216 127.1–185.7), 134.4 epg for *Taenia* species (95% CI: 117.4–151.4), 83.7 epg for hookworm (95% CI: 68.3–99.1), and 46.0 epg for *S.*

217 *stercoralis* (95% CI: 26.0–65.9. Almost all diagnosed infections were light intensity. The S2 Table of supplementary data shows the  
218 proportions of children infected with intestinal parasites in relation to individual, household, and school factors.

219 *Taenia* infections were higher among children with unclean fingernails (41.4%; 36/87) than those with clean fingernails (58.6%;  
220 51/87) (Chi square=15.3; P<.001). *Taenia* infections were also higher among children residing in households with no toilet facility  
221 (93%; 81/87) than those with a facility (7%; 6/87) (Chi square=5; P<.05). Similarly, hookworm infections were higher among children  
222 aged 10–14 years (67.6%; 25/37) than those aged 7–9 (32.4%; 12/37) (Chi square=5; P<.05). A zero epg count was observed among  
223 81.3% (691/850) of children for *A. lumbricoides* and among 57.6% (490/850) for *T. trichiura*. The S3 and S4 supplementary tables  
224 summarize the mean, median, standard deviation, and interquartile range of *T. trichiura* and *A. lumbricoides* infections for each  
225 exposure variable.

## 226 **Risk factors for any intestinal parasite infections**

227 Intestinal parasite infection predictors were estimated using a multivariate, multi-level, mixed-effect, logistic regression analysis. The  
228 intra-cluster correlation value, calculated in the empty model with no covariate, was 1.2% at the school and class levels and 0.1% in  
229 the final model, indicating unexplained variations of intestinal parasite infections prevalence at the school and class levels.

230 In the bivariate, multi-level, mixed-effect, logistic regression model, the following factors had significant associations with intestinal  
231 parasite infection: loss of appetite in the past month, wasting, anemia, having a mother or guardian with no formal education, and  
232 using an open container for water storage. In the multivariate, multi-level, mixed-effect, logistic regression model analysis, the risk of



233 intestinal parasite infection was higher among children with loss of appetite in the past month (AOR: 1.89 [95% CI: 1.16, 3.08]),  
 234 wasting (AOR: 1.73 [95% CI: (1.04, 2.90)]), anemia (AOR: 1.45 [95% CI: 1.04, 2.03]), a mother or guardian with no formal education  
 235 (AOR: 1.08 [95% CI: 1.25, 3.47]), and open containers for water storage (AOR: 2.06 [95% CI: 1.07, 3.99]). However, no significant  
 236 differences were observed between intestinal parasite infections and sex, age, nail trimming, handwashing before meals, eating  
 237 undercooked vegetables, wealth, source of drinking water, using treated water at home, or participation in a school feeding program.  
 238 Table 1 and 2 shows the details

239 **Table 1:** Multilevel, logistic, regression analysis of predictors of intestinal parasite infection among schoolchildren in the Wonago district of  
 240 southern Ethiopia, 2017

Variables		Intestinal parasite		Adjusted OR (95% CI)				
		Yes (%)	No (%)	Model I	Model II	Model III	Model IV	Model V
Sex	Boys	276 (57.6)	203 (42.4)	-	1.0	1.0	1.0	1.0
	Girls	203 (54.7)	168 (45.3)	-	.96 (.72, 1.28)	.97 (.72, 1.30)	.98 (.74, 1.32)	.98 (.74, 1.32)
Age in years	7-9	92 (58.6)	65 (41.4)	-	1.19 (.82, 1.74)	1.17 (.81, 1.71)	1.13 (.77, 1.65)	1.13 (.77, 1.65)
	10-14	387 (55.8)	306 (44.2)	-	1.0	1.0	1.0	1.0
Fingernails trimmed	Yes	386 (55.5)	309 (44.5)	-	.85 (.52, 1.39)	.85 (.58, 1.26)	.84 (.57, 1.24)	.84 (.57, 1.24)
	No	93 (60)	62 (40)	-	1.0	1.0	1.0	1.0
Dirt on fingers	Yes	121 (58.5)	86 (41.6)	-	1.0	-	-	-
	No	358 (55.7)	285 (44.3)	-	1.03 (.66, 1.60)	-	-	-
Handwashing	Always	63 (61.8)	39 (38.2)	-	1.30 (.76, 2.24)	1.31 (.78, 2.18)	-	-

with soap after latrine	Sometimes	264 (54.9)	217 (45.1)	-	1.06 (.72, 1.56)	1.09 (.78, 1.53)	-	-
	Never	152 (56.9)	115 (43.1)	-	1,0	1,0	-	-
Handwashing before meals	Yes	466 (56.2)	363 (43.8)	-	.68 (.27, 1.72)	.69 (.27, 1.75)	.72 (.28, 1.83)	.72 (.28, 1.83)
	No	13 (61.9)	8 (38.1)	-	1,0	1,0	1,0	1,0
Eats uncooked vegetables	Yes	125 (60)	83 (40)	-	1.27 (.88, 1.82)	1.31 (.92, 1.86)	1.35 (.95, 1.92)	1.35 (.95, 1.92)
	No	354 (55.1)	288 (44.9)	-	1,0	1,0	1,0	1,0
Loss of appetite in past month	Yes	82 (67.8)	39 (32.2)	-	1.77 (1.10, 2.85)*	1.89 (1.18, 3.04)*	1.89 (1.16, 3.08)*	1.89 (1.16, 3.08)*
	No	397 (54.5)	332 (45.5)	-				1.0
Body mass index-for-age (wasting)	≥ -2 Z-score	422 (55.0)	345 (45.0)	-	1.0	1.0	1.0	1.0
	<-2 Z-score	57 (68.7)	26 (31.3)	-	1.73 (1.04, 2.88)*	1.68 (1.01, 2.79)*	1.73 (1.04, 2.90)*	1.73 (1.04, 2.90)*
Anemia	No	306 (54)	261 (46)	-	1.0	1.0	1.0	1.0
	Yes	150 (63)	88 (37)	-	1.52 (1.09, 2.12)*	1.49 (1.07, 2.07)*	1.45 (1.04, 2.03)*	1.45 (1.04, 2.03)*
De-worming drug past six months	Yes	109 (57.4)	81 (42.6)	-	.99 (.67, 1.47)	-	-	-
	No	370 (56)	290 (44)	-	1.0	-	-	-

241 AIC: Akaike information criterion; CI: confidence interval; NS: Not significant; OR: odds ratio; \*\*P<.01, \*P<.05

242

243 **Table 2:** Multilevel, logistic, regression analysis of predictors of intestinal parasite infection among schoolchildren in the Wonago district of

244 southern Ethiopia, 2017

<b>Individual parent factors</b>								
Mother's education level	Never entered school	392 (58.5)	278 (41.5)	-	-	2.07 (1.26, 3.41)**	2.08 (1.25, 3.47)**	2.08 (1.25, 3.47)**
	Read and write only	47 (58)	34 (41.9)	-	-	1.97 (.97, 4.02)	1.91 (.92, 3.97)	1.91 (0.92, 3.97)
	Primary	38 (40)	57 (60)	-	-	1.0	1.0	1.0

	and above							
<b>Household factors</b>								
Wealth	Poor	165 (57.9)	120 (42.1)	-	-	-	.99 (.69, 1.43)	.99 (.69, 1.43)
	Middle	165 (56.3)	128 (43.7)	-	-	-	1.08 (.74, 1.58)	1.08 (.74, 1.58)
	Rich	149 (54.8)	123 (45.2)	-	-	-	1.0	1.0
Source of drinking water	Unprotected	213 (58.8)	149 (41.2)		-	-	.98 (.67, 1.44)	1.02 (.69, 1.49)
	Protected	266 (54.5)	222 (45.5)	-	-	-	1.0	1.0
Water storage container	Closed container	440 (55.3)	356 (44.7)	-	-	-	1.0	1.0
	Open container	39 (72.2)	15 (27.8)	-	-	-	2.06 (1.07, 3.99)*	2.06(1.07, 3.99)*
Using treated water at home	Yes	60 (56)	47 (44)	-	-	-	1.07 (.68, 1.68)	1.07 (.68, 1.68)
	No	419 (56.4)	324 (43.6)	-	-	-	1.0	1.0
<b>School factor</b>								
Participates in school food program	No	250 (58.7)	176 (41.3)	-	-	-	-	1.0
	Yes	229 (54)	195 (46)	-	-	-	-	.98 (.66, 1.46)
<b>Variation and model fitness</b>								
Variance	School level			0.04	0.023	0.002	0.003	0.003
	Class level			NS	NS	NS	NS	NS
Intra-cluster correlation	School			1.2%	1%	0.1%	0.1%	0.1%
	Class			1.2%	1%	0.1%	0.1%	0.1%
<b>Model fitness</b>								
	-2log likelihood			1160	1076	1062	1057	1056
	AIC			1165	1104	1089	1091	1093

245 AIC: Akaike information criterion; CI: confidence interval; NS: Not significant; OR: odds ratio; \*\*P<.01, \*P<.05

246

247 **Risk factors for *T. trichiura* and *A. lumbricoides* infections**

248 The intra-cluster correlation value calculated in Model V for *T. trichiura* was low and insignificant, indicated that the variability in  
249 this infection prevalence was not attributable to class or school factors. The S5 Table of supplementary data shows the results of these  
250 tests. Similarly, the variability in *A. lumbricoides* prevalence at the school-level was insignificant. However, the intra-cluster  
251 correlation value calculated in Model V for *A. lumbricoides* infection indicated that 3.2% of the variability in this infection prevalence  
252 was attributable to class factors. The S6 Table of supplementary data shows the results.

253 All significant variables in the bivariate, multilevel, mixed-effect model also were significant in the multivariate model. The risk of *T.*  
254 *trichiura* infection was higher among children with loss of appetite in the past month (AOR: 1.76 [95% CI: 1.15, 2.71]), wasting  
255 (AOR: 1.73 [95% CI: 1.07, 2.78]), anemia (AOR: 1.53 [95% CI: 1.11, 2.12]), a mother or guardian with no formal education (AOR:  
256 1.94 [95% CI: 1.18, 3.19]), and participation in the school food program (AOR: 1.55 [95% CI: 1.13, 2.12]). Furthermore, there were  
257 no statistically significant differences between *T. trichiura* infection and sex, age, nail trimming, handwashing, eating uncooked  
258 vegetable, receiving de-worming treatment in the past 6 months, or wealth. The S4 Table of supplementary data shows the results.

259 All significant variables in the bivariate, multilevel, mixed-effect model also were significant in the multivariate model. The odds of  
260 *A. lumbricoides* infection increased by 92% among anemic children (AOR: 1.92 [95% CI: 1.29, 2.88]). The odds were lower among  
261 children who received de-worming treatment in the past 6 months [AOR: 0.57 (95% CI: 0.33, 0.98)] and who used water from a  
262 protected source [AOR: 0.46 (95% CI: 0.28, 0.77)]. There were no statistically significant differences between *A. lumbricoides*

263 infections and age, nail trimming, handwashing, wealth, source of drinking water, and participation in a school food program. The S5  
264 Table of supplementary data shows the results.

## 265 **Zero-inflated negative binomial regression**

### 266 **Negative binomial count model for *T. trichiura* and *A. lumbricoides* infections**

267 As shown in Tables 3 and 4, girls had increased intensity of *T. trichiura* infection (AOR: 1.23 [95% CI: 1.04, 1.45]). The intensity of  
268 infection with *A. lumbricoides* (AOR: 1.08 [95% CI: 1.01, 1.16]) increased with increasing age, whereas using open container for  
269 water storage at home (AOR: 1.59 [95% CI: 1.14, 2.22]) increased *T. trichiura* infection intensity. Dirty fingernails (AOR: 1.47 [95%  
270 CI: 1.07, 2.03]) were associated with increased intensity of *A. lumbricoides* infection. A habit of nail trimming (AOR: .56 [95% CI:  
271 0.39, 0.79]) and handwashing with soap after using the latrine (AOR: 0.68 [95% CI: 0.48, 0.95]) lowered the intensity of *A.*  
272 *lumbricoides* infection. The epg of *A. lumbricoides* was higher among children in school feeding programs (AOR: 1.97 [95% CI: 1.49,  
273 2.61]).

### 274 **Logit model for predicting excess zeros for *T. trichiura* and *A. lumbricoides* infections**

275 The odds of zero epg counts for *T. trichiura* (AOR: 1.13 [95% CI: 1.03, 1.25]) and *A. lumbricoides* (AOR: 1.20 [95% CI: 1.06, 1.36])  
276 increased with increasing hemoglobin concentrations. The odds of zero epg counts for *A. lumbricoides* eggs decreased with increasing  
277 age (AOR: 0.90 [95% CI: 0.81, 0.99]), whereas the odds increased among children who had received a de-worming drug in the past 6  
278 months (AOR: 1.68 [95% CI: 1.01, 2.78]). The odds of zero epg counts for *T. trichiura* decreased for children who reported loss of

279 appetite in the past month (AOR: 0.52 [95% CI: 0.34, 0.81]), wasting (AOR: 0.59 [95% CI: 0.36, 0.94]), eating uncooked vegetables  
 280 (AOR: 0.70 [95% CI: .50, .99]), a mother or guardian with no formal education (AOR: 0.56 [95% CI: 0.34, 0.92]), and participation  
 281 in a school feeding program (AOR: 0.56 [95% CI: 0.41, 0.78]). However, no significant difference was observed between *T. trichiura*  
 282 infections and age, nail trimming, or wealth. No statistically significant differences were observed between *A. lumbricoides* infections  
 283 and sex, mother’s educational, or wealth.

284 **Table 3:** Zero-inflated negative binomial regression model for *T. trichiura* fecal egg count among schoolchildren in the Wonago district, southern  
 285 Ethiopia, 2017 (n=850)

Variables		Zero-inflated negative binomial model			
				Negative binomial part	Zero-inflated part
Individual child factors		Mean (SD) eggs per gram>0	Median (IQR) eggs per gram>0	Infection intensity AOR (95% CI)	Infection probability AOR (95% CI)
Sex	Boys	138.6 (113.5)	120 (72-168)	1.0	1.0
	Girls	181.8 (406.2)	120 (72-168)	1.23 (1.04, 1.45)*	1.06 (.79, 1.43)
Age in years		11.4 (1.9)		1.01 (.97, 1.05)	1.07 (.98, 1.15)
Fingernails trimmed	Yes	145.6 (111.4)	120 (72-168)	.82 (.61, 1.09)	.92 (.57, 1.49)
	No	205.2 (603.2)	108 (72-144)	1.0	1.0
Dirt on fingernails	Yes	185.1 (510.6)	120 (72-168)	1.10 (.85, 1.43)	.87 (.56, 1.35)
	No	146.6 (114.2)	120 (72-168)	1.0	1.0
Habit of eating	Yes	146.3 (116.9)	120 (72-168)	1.05 (.86, 1.27)	.70 (.50, .99)*

uncooked vegetable	No	160.3 (315.8)	120 (72-168)	1.0	1.0
Loss of appetite in past month	Yes	143.2 (109.5)	120 (72-168)	.95 (.75, 1.21)	.52 (.34, .81)**
	No	159.1 (297.6)	120 (72-168)	1.0	1.0
Hemoglobin concentration		12.6 (1.6)		.96 (.91, 1.01)	1.13 (1.03, 1.25)*
Body mass index-for-age (wasting)	≥ -2 Z-score	157.8 (292.2)	120 (72-168)	1.0	1.0
	<-2 Z-score	147.3 (104.1)	120 (72-168)	1.10 (.86, 1.41)	.59 (.36, .94)*
Mother's education	Never entered school	160.6 (301.2)	120 (72-168)	1.18(.86, 1.61)	.56 (.34, .92)*
	Read and write only	146.2 (105.9)	120 (72-168)	1.19 (.80, 1.78)	.64 (.32, 1.26)
	Primary and above	123.6 (70.0)	120 (72-168)	1.0	1.0
Wealth status	Poor	157.8 (130.7)	144 (72-192)	.99 (.81, 1.22)	.98 (.68, 1.41)
	Middle-class	134.0 (85.6)	120 (72-168)	.92 (.74, 1.14)	.95 (.66, 1.38)
	Rich	178.1 (460.2)	96 (72-168)	1.0	1.0
Water storage	Closed container	150.9 (281.7)	120 (72-168)	1.0	1.0
	Open container	226.6 (161.2)	168 (120-336)	1.59(1.14, 2.22)**	.82 (.44, 1.49)
Participates in school food program	No	135.7 (100.7)	120 (72-168)	1.0	1.0
	Yes	173.9 (362.1)	120 (72-168)	1.18 (.98, 1.42)	.56 (.41, .78)**
<b>Model fitness</b>				<b>Zero-inflated Poisson regression</b>	<b>Zero-inflated negative binomial regression</b>
-2 Log-likelihood				43126	4840
Likelihood ratio test				-	38000 (P < 0.001)
Vuong test				-	17.5 (P < 0.001)
Akaike information				43186	4902

286 criterion

287 AOR: adjusted odds ratio; CI: confidence interval; EPG: Egg per gram of stool; IQR: Interquartile ranges; SD: Standard deviation; \*\*\*P<.001 \*\*P<.01, \*P<.05

288 **Table 4:** Zero-inflated negative binomial regression model for *A. lumbricoides* infection eggs per gram count among schoolchildren in the  
 289 Wonago district, southern Ethiopia, 2017 (n=850)

Variables		Zero-inflated negative binomial model			
				Negative binomial part	Zero-inflated part
Individual child factors		Mean (SD) eggs per gram>0	Median (IQR) eggs per gram>0	Infection intensity AOR (95% CI)	Infection probability AOR (95% CI)
Sex	Boys	321.6 (1213.2)	120 (96-216)	1.03 (.81, 1.32)	.96 (.66, 1.41)
	Girls	232.4 (609.3)	120 (72-204)	1.0	1.0
Age in years		11.4 (1.9)		1.08 (1.01, 1.16)*	.90 (.81, .99)*
Fingernails trimmed	Yes	157.8 (107.5)	120 (72-216)	.56 (.39, .79)**	.66 (.36, 1.20)
	No	839.1 (2272.6)	120 (96-240)	1.0	1.0
Dirt on fingernails	Yes	582.5 (1797.7)	156 (108-216)	1.47 (1.07, 2.03)*	.64 (.37, 1.08)
	No	154.9 (112.1)	120 (72-192)	1.0	1.0
Handwashing after latrine use	Always	204 (142.0)	132 (72-360)	.94 (.61, 1.44)	.68 (.35, 1.30)
	Sometimes	347.8 (1366.2)	120 (72-192)	.68 (.48, .95)*	1.39 (.85, 2.27)
	Never	240.8 (628.2)	132 (72-216)	1.0	1.0
De-worming drug in past 6 months	Yes	200 (144.5)	120 (120-264)	1.03 (.76, 1.41)	1.68 (1.01, 2.78)*
	No	304.1 (1113.4)	120 (72-192)	1.0	1.0
Hemoglobin		12.6 (1.6)		.99 (.91, 1.07)	1.20 (1.06, 1.36)**



concentration					
Mother's education	Never entered school	226.3 (538.4)	120 (72-216)	1.10 (.66, 1.85)	.45 (.21, .96)*
	Read and write only	148.2 (78.8)	120 (96-216)	.89 (.49, 1.64)	.33 (.13, .84)*
	Primary and above	1314.7 (3557.6)	120 (96-192)	1.0	1.0
Wealth status	Poor	226.2 (512.7)	120 (72-216)	1.17 (.87, 1.58)	1.17 (.74, 1.86)
	Middle-class	386 (1538.8)	120 (72-216)	1.17 (.87, 1.58)	1.22(.77, 1.95)
	Rich	242.4 (665.4)	120 (72-192)	1.0	1.0
Participates in school food program	No	145.1 (79.1)	120 (72-192)	1.0	1.0
	Yes	482.4 (1547.6)	120 (84-228)	1.97 (1.49, 2.61)***	1.37 (.87, 2.15)
<b>Model fitness</b>				<b>Zero-inflated Poisson regression</b>	<b>Zero-inflated negative binomial regression</b>
-2 Log-likelihood				23788	2436
Likelihood ratio test					21000 (P<.001)
Vuong test					9.4 (P<.001)
Akaike information criterion				23845	2494

290 AOR: adjusted odds ratio; CI: confidence interval; EPG: Egg per gram of stool; IQR: Interquartile ranges; SD: Standard deviation; \*\*\*P<.001 \*\*P<.01, \*P<.05

291

## 292 **Discussion**

293 Intestinal parasite infections were found to be a public health problem among schoolchildren aged 7 to 11 years in the Gedeo zone of  
294 southern Ethiopia. Controlling for clustering effects at the school and class levels and accounting for excess zeros of fecal egg counts,  
295 we found that intestinal parasite infections were associated with increased age, girls, wasting, anemia, loss of appetite in past month,  
296 unclean fingernails, lack of nail trimming, lack of hand washing with soap after using the latrine, de-worming treatment, mothers'  
297 education levels, water source, and using uncovered water storage container at home. Variations attributable to both class and school-  
298 level factors for intestinal parasite infection prevalence were less than 5%, indicating minor influence.

299 We used a large and representative sample of schoolchildren and applied a multilevel, mixed-effect model and a ZINB model to  
300 identify risk factors for prevalence and intensity of intestinal parasite infections. Unlike previous studies, we directly involved parents  
301 of children to assess potential risk factors at the household level. We examined nutritional status and measured hemoglobin  
302 concentrations using two standard techniques, Kato-Kath and formalin-ether concentration, to enhance the detection of intestinal  
303 parasites. The dependence of clustered data within the school and class levels was measured and indicated using intra-cluster  
304 correlation. Unlike previous studies (8, 11-17), we also used a ZINB model to model infection prevalence and intensity.

305 Because of the cross-sectional nature of this study, causality between the outcome and the exposure variable cannot be determined  
306 with certainty. Multiple stool samples from each child could have enhanced the detection rate of intestinal parasite infection (42).

307 Unfortunately, we did not take multiple samples, but we used two different techniques to analyze a single stool sample, which could

308 have enhanced the detection rate. Furthermore, a species-specific diagnostic technique (43) and use of sensitive techniques, like  
309 polymerase chain reaction, could have improved the detection rate of intestinal parasite infections (44). The FLOTAC method has a  
310 higher sensitivity for hookworm detection, compared with the relatively low sensitivity of Kato-Katz and formalin-ether, and may  
311 have underestimated the prevalence of hookworm infection in this study (43, 45). We were unable to model most school-level risk  
312 factors, such as sanitation and hygiene, due to homogeneity issues.

313 The prevalence of intestinal parasite infections that we found was higher than previously found in southern Ethiopia (12, 24) but lower  
314 than other places (17, 46). Compared with the 24.6% prevalence found in Ethiopia (16), 26.3% in the Democratic Republic of Congo,  
315 and 26.5% found in Kenya (47, 48), we found a higher prevalence of *T. trichiura* infection. Our findings also revealed higher rates of  
316 *A. lumbricoides* infection compared with rates of 10.6% to 13% in other areas of southern Ethiopia (12, 49). The rate for hookworm  
317 infection in this study aligned with the 7.4% rate found during national mapping (49). However, it is lower than the 56.8% (16), 46.9%  
318 (50), and 18% reported in other regions of Ethiopia (24). All detected infections in this study were of light intensity (32), which is  
319 comparable with other studies in Ethiopia (24, 45, 51). Variations in intestinal parasite prevalence could be due to different diagnostic  
320 techniques and ecological settings.

321 Using the ZINB model, we observed increased intensity of *A. lumbricoides* infections and a decline in the probability of older children  
322 remaining free from this infection. Older children may participate in activities and environments that make them more prone to  
323 infection than younger children. In contrast, a previous study has reported a lower risk of intestinal parasite infection in the older age  
324 group (52). This reduced risk could be due to immunological and behavioral factors related to hygiene (53).

325 Nail and hand hygiene are well known individual factors affecting intestinal parasite infection prevalence and intensity (54). We found  
326 an increased intensity of *A. lumbricoides* infection among children with unclean finger nails, as has been reported by others (12, 15).  
327 Nail trimming and handwashing with soap after using the latrine led to reduced intensity of *A. lumbricoides* infection, similar to  
328 findings in other studies (8, 9, 14, 55). Eating uncooked vegetables has been reported as a risk factor for intestinal parasite infections  
329 (52). Our ZINB model indicated that eating uncooked vegetables lowered the probability of remaining free from *T. trichiura*  
330 infections. Ingesting contaminated raw vegetables could play an important role in transmitting intestinal parasites (56). Furthermore,  
331 receiving de-worming drugs in the past 6 months significantly increased the probability of children remaining free from *A.*  
332 *lumbricoides*, as has been observed in rural Bangladesh (57).

333 Despite a well-documented link between soil-transmitted helminth infections and undernutrition (58, 59), the evidence regarding this  
334 association varies. Some studies have reported the same risk of wasting and stunting among infected and non-infected children (11,  
335 60, 61). In agreement with other studies (62, 63), our study revealed higher rates of intestinal parasites among wasted children. These  
336 children often lose micronutrients, which can impair nutritional status and growth (58).

337 The observed association between intestinal parasite infection and anemia was expected, as intestinal parasites are risk factors for  
338 anemia (64-66). Reduced food intake because of inflammatory reactions induced by lesions in the intestinal mucosa and impaired iron  
339 absorption due to worm infections could partly explain this association (58, 67). Our zero-inflation model also indicated higher  
340 probability of children remaining free from *T. trichiura* and *A. lumbricoides* infections as their hemoglobin concentrations increase.  
341 The observed infection intensity in this study was light, and although light infection by *T. trichiura* and *A. lumbricoides* may not be

342 enough to produce significant blood loss, it may aggravate the condition (68). However, de Gier et al. found low hemoglobin  
343 concentrations among children with light *T. trichiura* infections (65). This finding could be affected by unmeasured factors, such as  
344 low dietary iron intake and malaria. Furthermore, we found high rates of intestinal parasite infection among children who reported a  
345 loss of appetite in the past month.

346 Intestinal parasite infection prevalence increased among children whose mothers had no formal education, similar to previous studies  
347 in Ethiopia (8, 12) and rural Mexico (69). This could be due to lack of knowledge about poor home sanitation and hygiene. Using  
348 piped water has been shown to influence the prevalence of *A. lumbricoides* infection (9). In this study, low rates of *A. lumbricoides*  
349 infection were observed among children living in households using a protected water source, indicating a possibility for contamination  
350 when water is not protected from soil-transmitted helminths eggs during transport and storage (70). We also observed a high risk of  
351 parasite infection, particularly *T. trichiura* infection, among children in households using open containers for water storage. Similar  
352 findings have been observed in Kenya (47). The high percentage of unimproved water sources and the practice of open defecation,  
353 particularly in rural Ethiopia, offer support for this finding (71). We indeed observed a high percentage of unimproved toilet facilities  
354 in the study households.

355 Children participating in school feeding programs had high rates of *T. trichiura* infection and increased intensity of *A. lumbricoides*  
356 infection. This finding suggests unsafe or unhygienic food preparation and poor sanitary facilities at schools in the study area. School  
357 sanitation and hygiene could affect this finding, though we were unable to show a link due to similarity of this potential exposure

358 variable. Furthermore, some schools had no access to safe water, putting those children at higher risk. Schools with feeding programs  
359 thus may be area at high risk of food insecurity and vulnerability to infection.

360 Although Ethiopia launched a national school-based de-worming program in 2015, soil-transmitted helminth infection remain high  
361 among schoolchildren in the rural areas. Variations attributable to both class- and school-level factors for intestinal parasites infection  
362 prevalence were low. Most individual and few household factors were found to be important predictors for intestinal parasite infection  
363 prevalence and intensity, and high rates of *T. trichiura* infection and intensity of *A. lumbricoides* among children in school feeding  
364 programs also were observed. Interventions that improve hygiene among schoolchildren can reduce the burden of intestinal parasite  
365 infection in settings such as Gedeo. Access to safe water at school and at home is a crucial part of infection reduction strategies.  
366 Periodic de-worming programs in schools must be strengthened. To that end, school teachers should work with health workers to  
367 provide health education about personal hygiene. Integrated intervention activities focusing on the individual, household, and school  
368 will reduce the burden of intestinal parasite infections.

## 369 **Supporting information**

370 **S1 Checklist. STROBE checklist.**

371 **S1 Table.** Demographic and socio-economic status of schoolchildren and their parents, Wonago district of southern Ethiopia, 2017\*

372 **S2 Table.** Distribution of intestinal parasite infection among schoolchildren in the Wonago district, Southern Ethiopia, 2017 (n=850)

373 **S3 Table.** The mean, median, standard deviation, and interquartile range of *T. trichiura* infection loads in egg per gram of stool among  
374 schoolchildren in the Wonago district, southern Ethiopia, 2017 (n=850)

375 **S4 Table.** The mean, median, standard deviation, and interquartile range of *A. lumbricoides* infection loads in egg per gram of stool  
376 among schoolchildren in the Wonago district, southern Ethiopia, 2017 (n=850)

377 **S5 Table.** Multilevel logistic regression analysis of predictors of *T. trichiura* infection among schoolchildren in the Wonago district of  
378 southern Ethiopia, 2017

379 **S6 Table.** Multilevel logistic regression analysis of predictors of *A. lumbricoides* infection among schoolchildren in the Wonago  
380 district of southern Ethiopia, 2017

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