School Children's Intestinal Parasite and Nutritional Status One Year after Complementary School Garden, Nutrition, Water, Sanitation, and Hygiene Interventions in Burkina Faso

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Abstract. The potential health benefits of combined agricultural, nutrition, water, sanitation, and hygiene (WASH) interventions are poorly understood. We aimed to determine whether complementary school garden, nutrition, and WASH interventions reduce intestinal parasites and improve school children's nutritional status in two regions of Burkina Faso. A cluster-randomized controlled trial was conducted in the Plateau Central and Center-Ouest regions of Burkina Faso. A total of 360 randomly selected children, aged 8–15 years, had complete baseline and end-line survey data. Mixed regression models were used to assess the impact of the interventions, controlling for baseline characteristics. The prevalence of intestinal parasitic infections decreased both in intervention and control schools, but the decrease was significantly higher in the intervention schools related to the control schools (odds ratio [OR] of the intervention effect = 0.2, 95% confidence interval [CI] = 0.1–0.5). Indices of undernutrition did not decrease at end-line in intervention schools. Safe handwashing practices before eating and the use of latrines at schools were significantly higher in the intervention schools than in the control schools at end-line (OR = 6.9, 95% CI = 1.4–34.4, and OR = 14.9, 95% CI = 1.4–153.9, respectively). Parameters of water quality remained unchanged. A combination of agricultural, nutritional, and WASH-related interventions embedded in the social–ecological systems and delivered through the school platform improved several child health outcomes, including intestinal parasitic infections and some WASH-related behaviors. Sustained interventions with stronger household and community-based components are, however, needed to improve school children's health in the long-term.

INTRODUCTION

Undernutrition and intestinal parasitic infections remain considerable health issues among school-aged children in Burkina Faso.^{1–4} There are far-reaching negative consequences of undernutrition and ill-health among children, affecting their physical well-being and educational potentials, which undermine social, political, and economic benefits for communities as a whole.⁵

School children's nutritional status and prevalence of intestinal parasitic infections are governed by social–ecological systems, since these health conditions are influenced by human behavior (e.g., dietary practices, open defecation, unsafe hygienic practices, and patterns of unprotected surface water contacts) and ecological characteristics (e.g., agricultural systems and access to clean water).^{6,7} Undernutrition and intestinal parasitic infections are closely interlinked and share several common risk factors, including a lack of access to clean water, improved sanitation, and adequate hygiene (WASH).^{8–10} Chronic exposure to a contaminated environment due to unsafe WASH conditions (e.g., to feces contaminated with protozoan cysts or helminth eggs) can cause diarrhea or asymptomatic infection¹¹; which in turn can lead to loss of nutrients, malabsorption, impaired digestion, and ultimately a decline in childhood growth.^{12–14} It follows that multisectoral programs are crucial to address child undernutrition and disease-related causes and consequences.¹⁵ Schools are an ideal entry point for multisectoral agriculture, nutrition, and WASH programs.¹⁶ Besides being an obvious place to educate children on healthy diets, schools

can promote practical and positive changes in personal hygiene, nutrition, and health by 1) increasing food availability and diversity with school gardens¹⁷; 2) offering well balanced and nutritious meals through a school feeding program (in which parts of the garden produce could be used)¹⁸; and 3) promoting handwashing with soap and safe sanitary behaviors.^{16,19} Yet, there is scarce evidence of the effects of school-based programs on school children's intestinal parasitic infection and nutritional status.^{20,21} There is also insufficient evidence of combined approaches across the nutrition, health, agriculture, education, and WASH sectors addressing proximate and underlying determinants of undernutrition in children.^{16,22–26}

To address this issue, a multisectoral project entitled “Vegetables go to School: improving nutrition through agricultural diversification” (VgtS) was developed in five countries to determine school children's health in face of implementing school vegetable gardens and other school-based health, nutritional, and environmental interventions.²⁷ As part of the VgtS project, a cluster-randomized controlled trial was implemented in Burkina Faso. Here, we report findings on the impacts of complementary school garden, nutrition, and WASH interventions on school children's intestinal parasitic infections and nutritional status, including WASH-related behaviors to discuss the findings along the hypothesis of the program impacts.

MATERIALS AND METHODS

Ethical considerations. Data reported here stem from a cluster-randomized controlled trial that has been registered with the clinical trial registry ISRCTN (identifier: 17968589). The study protocol was approved by the “Ethikkommission Nordwest-und Zentralschweiz” in Switzerland (reference no. 2014-161) and by the “Comité d’Ethique pour la Recherche en

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Santé, Ministère de la Recherche Scientifique et de l'Innovation, et Ministère de la Santé" in Burkina Faso (reference no. 2015-02-026).

Parents or guardians of children were asked for written informed consent (fingerprint for illiterate parents/guardians), whereas children assented orally. Study participation was voluntary, and hence, children could withdraw anytime without further obligation. Results were communicated to all participants. Specific treatments against parasitic infections were provided free of charge. Mildly and moderately anemic children (hemoglobin [Hb] < 11.5 g/dL for children aged 8–11 years and Hb < 12 g/dL for children aged 12–14 years, including girls aged 15 years, and Hb < 13 g/dL for boys aged 15 years) were referred to a local health center and treated with iron supplements for 40 days. Children found with severe anemia (Hb < 8 g/dL) and severely malnourished children were referred to a local health center for further investigation, following national guidelines.^{28,29} The Consolidated Standards of Reporting Trials (CONSORT) guidelines were applied to report the results of this study.^{30,31} The CONSORT checklist is provided as supplemental information (Supplemental Table 1).

Complementary school garden, nutrition, and WASH interventions. The interventions consisted of four main components. The first component included the provision of seeds and small gardening tools and agricultural trainings given to 12 teachers and four school directors for the school garden activities, which commenced in early 2015. The second component consisted of WASH interventions at schools with several subcomponents: 1) installation of latrines, 2) rehabilitation of water pumps, 3) installation of handwashing stations and toolkits to make soap, and 4) installation of safe drinking water stations in classrooms. The third component

entailed the educational behavior change strategy provided to 1) teachers and school directors with materials developed for teaching in classroom 1–2 times a week starting in October 2015 and to 2) community representatives (in total 16) with monthly trainings at schools on hygiene and nutrition launched in November 2015. The fourth component consisted of providing treatments to children found anemic or infected with intestinal parasites (i.e., 15–50 mg/kg single dose of metronidazole for five consecutive days against intestinal protozoa infection, a triple dose of 400 mg albendazole against soil-transmitted helminth infections, a 40 mg/kg single dose of praziquantel against schistosomiasis, and four tablets of niclosamide of 500 mg in two doses for six consecutive days to treat *Hymenolepis nana*) in both intervention and control schools, following national guidelines.^{28,29} All program components were fully implemented within 7 months of the end of the baseline survey.

Sample size, sampling method, and study design. The study was originally designed as cross-sectional baseline survey with 85% power to detect a difference in the prevalence of intestinal parasitic infection rates (with $P < 0.05$) as primary outcome measure in the comparison between high- and low-risk children at eight schools for a true odds ratio (OR) of at least 2 with a coefficient of variation of 10% in $\ln(\text{OR})$ across schools. A Monte Carlo simulation (5,000 iterations) led to a minimal sample size of 400 children aged 8–14 years, assuming a prevalence of intestinal parasitic infections of 40%, a coefficient of variation of 10% across schools and a proportion of high-risk children of 25%. The eight schools to participate in this study were randomly selected from the 30 VgtS project schools in Burkina Faso. At baseline, 55–60 children (boys and girls in ratio 1:1) were randomly selected in

TABLE 1
Characteristics of the study cohort in the two regions of Burkina Faso at the baseline survey in February/March 2015

		Total	Intervention schools	Control schools	P value
Children's demographic characteristics*		n (%)	n (%)	n (%)	
Age of children†					0.052
Girls		178 (49.4)	85 (48.3)	93 (50.5)	0.670
Boys		182 (50.6)	91 (51.7)	91 (49.5)	
Age group 1 (8–11 years)		233 (64.7)	95 (54.0)	138 (75.1)	0.095
Age group 2 (12–14 years)		127 (35.3)	81 (46.0)	46 (25.0)	
Caregivers' demographic and education characteristics					0.111
Caregiver's age‡					0.001
No formal schooling		268 (74.4)	145 (82.4)	123 (66.9)	
Primary education		57 (15.8)	21 (11.9)	36 (19.6)	
Secondary or higher education		35 (9.7)	10 (5.7)	25 (13.6)	
Main occupation of head of household					0.673
Agriculture		324 (90.0)	157 (89.2)	167 (90.8)	
Merchant		6 (1.7)	1 (0.6)	5 (2.7)	
Civil service		9 (2.5)	6 (3.4)	3 (1.6)	
Others (housework, retirement or no employment)		21 (5.8)	12 (6.8)	9 (4.9)	
Socioeconomic domains					
Roof material	Simple (natural and baked clay)	328 (89.7)	168 (95.4)	160 (87.0)	0.043
	Metal cover	32 (10.3)	8 (4.6)	24 (13.0)	
Wall material	Simple (natural clay)	337 (93.6)	166 (94.3)	171 (92.9)	0.923
	Baked or cemented clay	23 (6.4)	10 (5.7)	13 (7.1)	
Floor material	Simple (clay, sand, mud, straw)	241 (66.9)	114 (64.8)	127 (69.0)	0.506
	Baked or cemented clay	119 (33.1)	62 (35.2)	57 (31.0)	
Energy used	Simple (charcoal, firewood)	352 (97.8)	176 (98.9)	178 (96.7)	0.417
	Electricity and gas	8 (2.2)	2 (1.1)	6 (3.3)	

Statistical significance was defined at a level of 5% (bold values where $P < 0.05$).

* Mixed linear models were used to compare age and mixed logistic and mixed ordinal regression models with random intercepts at the level of schools to compare binary and ordinal variables, respectively.

† Mean age of 11.0 (± 1.4) years; 11.4 (± 1.3) years in the intervention schools and 10.6 (± 1.4) years in the control schools.

‡ Mean age of 44.9 (± 14.0) years; 46.4 (± 14.3) years in the intervention schools and 43.5 (± 13.7) years in the control schools.

each of the sampled schools assuming a 15% dropout rate. The eligibility criteria for children to participate at baseline were 1) school children aged between 8 and 14 years; 2) parents/caregivers of the children providing written informed consent; and 3) children providing oral assent.

This study reports a secondary analysis of a sample of children followed more than 1 year to assess and compare individual and cluster effects of a package of health interventions. There were eight schools included in a baseline cross-sectional survey. The schools were randomly and evenly allocated by the study investigators to two study arms ("intervention" and "control" group). Four schools were part of the intervention group: two schools in the Plateau Central region, and two schools in the Center-Ouest Region (Figure 1). Four schools served as controls; with two schools in each of the respective regions. To control for the effect of seasonal fluctuations on specific health conditions, the two surveys were spaced by approximately 1 year (February 2015 and March 2016).

Outcome definition and measurement. The study measured outcomes using a combination of child anthropometry, specimen (stool and blood) testing, sampling and testing of drinking water, and structured questionnaires. Training and all field activities were overseen by the study investigators (AMK, SD, SE). The baseline survey was conducted between February 2 and 19, 2015, and the end-line survey was

conducted between February 15, and March 2, 2016. The same field and laboratory procedures were used in the baseline and end-line surveys, which have been described in detail elsewhere.^{3,27}

Main outcomes were defined and measured as follows. In a first step, children's weight and height were measured following standard procedures.³² Second, Hb concentration was determined using a HemoCue® 201+ testing device (HemoCue Hb 201 System; HemoCue AB, Ängelholm, Sweden).³³ Third, a single stool sample was collected from each child on two consecutive days, subjected to the Kato-Katz technique (duplicate thick smears, using standard 41.7 mg templates) and a formalin-ether concentration technique for the diagnosis of helminths and intestinal protozoa.^{34,35} Urine samples were examined for microhematuria using reagent strips (Hemastix, Siemens Healthcare Diagnostics GmbH; Eschborn, Germany). A urine filtration method was used to examine urine samples under a microscope for the presence and number of *Schistosoma haematobium* eggs.³⁶ Helminth infection intensity was according to World Health Organization (WHO) criteria.³⁷ Fourth, drinking water samples from the same cohort of children and households as at baseline were analyzed for the presence of bacterial indicators of fecal contamination, using the membrane filtration technique.³⁸ Fifth, a questionnaire was administrated at schools and households using tablets (Samsung Galaxy note 10.1 N8010)

FIGURE 1. Study sites of the cluster-randomized controlled trial in a cohort of children in two regions of Burkina Faso, February/March 2015 and 1 year later.

to investigate children's health knowledge, attitudes, and practices (KAP) and household socioeconomic characteristics,^{2,27,39} using open data kit (ODK) software.⁴⁰

Statistical analysis. Data were double entered into Excel, version 2010 (Microsoft Corp.; Redmond, WA). Anthropometric indices (i.e., stunting [low height-for-age], thinness (low body mass index [BMI]-for-age) and underweight [low weight-for-age]) were calculated with the WHO reference for children aged 5–19 years, using AnthroPlus, version 1.0.4 (WHO; Geneva, Switzerland). Undernutrition was defined as a summary measure including any of these three nutritional indices defined as z-score < -2. Children were classified as overweight if BMI-for-age z-score was > 1.⁴¹

Three types of questions were addressed with different statistical models. Step 1: cross-sectional estimates of prevalences and their differences between study groups were assessed with logistic regression analyses. Baseline and end-line prevalences were computed, including 95% confidence intervals (CIs) for each of the study groups, without adjusting for potential confounders. Robust variance estimates were used to take into account clustering within schools. In parallel, a mixed logistic regression model with random intercepts for schools was used to compare baseline and end-line prevalences between intervention and control schools. As our study groups significantly differed in terms of children's age, caregiver's educational attainment, and economic characteristics, we also conducted a factor analysis to characterize household socioeconomic status (SES) from a list of recorded household assets, housing materials, main energy sources used, and caregiver's educational

achievement.⁴² Two factors reflecting household SES were retained. Each factor score was then categorized into tertile classes. The following analyses were run with additional adjustments for the two categorical SES variables and age of participating children.

Step 2: changes in prevalence from baseline to end-line were estimated and the differences between study groups assessed using mixed logistic regression models with binary baseline and end-line outcomes as repeated observations. These models included random intercepts for schools and children, the aforementioned variables, the fixed factors period, and study group, as well as the interaction between the two fixed factors. Intervention effects on prevalence changes were measured by the OR of this interaction. Mixed linear regression models with random intercepts for schools, the factor study group, and adjustments for SES and children's age were applied to assess intervention effects on the changes in continuous variables (e.g., weight and height).

Step 3: incidence and persistence of adverse health outcomes (i.e., indices of undernutrition or intestinal parasite infections) among children with or without the respective outcome at baseline were assessed using mixed logistic regression models. These models included the factor study group, the two SES variables and children's age, with random intercepts at the level of schools (see Supplemental Tables 2 and 3). Statistical significance was defined at a level of 5%. Statistical analyses were conducted with STATA, version 13.0 (Stata Corporation; College Station, TX).

TABLE 2

Changes of intestinal parasitic infections in a cohort of school children in two regions of Burkina Faso, in February/March 2015 and one year later

		Intervention schools		Control schools		Intervention effect§
		Baseline (2015)	End-line (2016)	Baseline (2015)	End-line (2016)	
Sample size (n)		176	176	184	184	
Total intestinal parasites††	Prevalence†	90.3 (80.0, 95.6)	61.9 (51.6, 71.3)	81.5 (70.0, 89.3)	72.3 (59.8, 82.1)	0.2 (0.1, 0.5)**
	OR‡		0.1 (0.1, 0.3)***		0.6 (0.3, 1.0)	
Total intestinal protozoa	Prevalence†	88.6 (80.8, 93.5)	57.4 (43.2, 70.5)	79.9 (66.7, 88.7)	70.1 (56.1, 81.2)	0.2 (0.1, 0.5)***
	OR‡		0.1 (0.1, 0.3)***		0.6 (0.3, 1.0)	
<i>Entamoeba histolytica/</i>	Prevalence†	69.9 (58.6, 79.2)	36.9 (29.8, 44.6)	62.5 (42.1, 79.3)	47.8 (33.2, 62.8)	0.5 (0.2, 0.9)*
<i>Entamoeba dispar</i>	OR‡		0.2 (0.1, 0.4)***		0.5 (0.3, 0.8)**	
<i>Giardia intestinalis</i>	Prevalence†	30.1 (22.1, 39.5)	25.0 (15.9, 37.0)	26.6 (23.2, 30.4)	25.0 (15.7, 37.3)	0.8 (0.4, 1.7)
	OR‡		0.8 (0.4, 1.3)		1.0 (0.6, 1.7)	
<i>Trichomonas intestinalis</i>	Prevalence†	27.8 (22.4, 34.1)	11.9 (5.6, 26.7)	19.6 (15.5, 24.3)	13.0 (9.4, 17.8)	0.5 (0.2, 1.2)
	OR‡		0.3 (0.2, 0.6)***		0.6 (0.3, 1.0)	
<i>Entamoeba coli</i>	Prevalence†	34.1 (28.3, 40.4)	15.9 (9.0, 26.5)	40.8 (35.8, 45.9)	26.1 (19.7, 33.7)	0.7 (0.3, 1.4)
	OR‡		0.3 (0.2, 0.6)***		0.5 (0.3, 0.8)**	
Total helminths	Prevalence†	11.4 (5.9, 20.7)	8.0 (3.5, 17.2)	9.8 (3.6, 23.8)	10.3 (5.7, 18.1)	0.5 (0.1, 1.7)
	OR††		0.5 (0.2, 1.3)		1.1 (0.5, 2.6)	
<i>Hymenolepis nana</i> ¶	Prevalence†	7.4 (4.1, 12.9)	5.1 (2.1, 12.0)	6.0 (1.4, 21.9)	5.4 (2.3, 12.5)	0.7 (0.2, 2.7)
	OR††		0.7 (0.3, 1.6)		0.9 (0.4, 2.2)	
<i>Schistosoma haematobium</i>	Prevalence†	4.0 (1.3, 11.9)	2.8 (0.7, 10.7)	2.7 (0.4, 14.8)	4.9 (1.8, 12.5)	0.3 (0.1, 1.9)
	OR††		0.7 (0.2, 2.3)		2.0 (0.6, 6.9)	

CI = confidence interval; EPG = eggs per gram of stool; OR = odds ratio; SES = socioeconomic status.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

† Data are % (95% CI). The CIs are adjusted for clustering within schools by using robust standard errors.

‡ ORs refer to the period effects. Mixed logistic regression models were adjusted for the two categorical SES variables and children's age.

§ ORs refer to the intervention effect defined as ratio between the period effects in intervention and in control schools including random intercepts for schools and children and with adjustment for SES and children's age.

¶ The mixed logistic regression model did not include random intercepts for children due to the low number of children with the respective outcome.

|| Triple interactions involving the factors period and survey arm along with one of the additional variables sex, age group, and prevalence of adverse health outcomes at baseline (i.e., being stunted, thin, and anemic) were also tested in mixed logistic regression models with random intercepts for schools and children, adjusted for the two categorical SES variables. The only significant triple interaction was found for age group, where the intervention effect was significantly greater in children aged 9–12 years (OR = 0.1, 95% CI 0.0–0.9, $P = 0.041$).

†† The mixed logistic regression model was not adjusted for SES variables or children's age, as no convergence in the regression models were achieved.

‡‡ Three children were infected with hookworm, one with *Balantidium coli*, and one with *Schistosoma mansoni* at baseline. None of these parasite species were found 1 year later. One child was found infected with *Entamoeba hartmanni* in the end-line survey. All helminth infection prevalences were of low intensity at baseline (*S. mansoni* 1–99 EPG of stool; *Hymenolepis nana* and hookworm 1–1,999 EPG, *Schistosoma haematobium* < 50 eggs/10 mL of urine). At end-line, one case of moderate and one heavy *H. nana* infection (2,000–9,999 EPG, and ≥ 10,000 EPG, respectively) were found; as well as two cases of heavy *S. haematobium* infection (≥ 50 eggs/10 mL of urine, 0.6%).

TABLE 3
Changes of nutritional indicators in the study cohort in two regions of Burkina Faso, in February/March 2015 and one year later

		Intervention schools		Control schools		Intervention effect§
		Baseline (2015)	End-line (2016)	Baseline (2015)	End-line (2016)	
Sample size (n)		176	176	184	184	
Logistic models (binary outcomes)						OR (95% CI)
Total undernutrition*	Prevalence†	43.2 (34.8, 52.0)	46.0 (37.9, 54.4)	30.4 (17.4, 47.5)	33.7 (18.8, 52.8)	0.9 (0.3, 3.9)
	OR††		1.5 (0.7, 3.5)		1.7 (0.7, 3.9)	
Stunting (low height-for-age)¶	Prevalence†	38.1 (27.6, 49.8)	42.0 (33.6, 51.0)	23.4 (11.7, 41.3)	26.1 (13.3, 44.7)	1.2 (0.6, 2.3)
	OR‡		0.8 (0.5, 1.2)		0.6 (0.4, 1.1)	
Thinness (low BMI-for-age)¶	Prevalence†	12.5 (9.7, 16.0)	14.8 (9.4, 22.4)	10.9 (6.2, 18.3)	12.5 (7.7, 19.6)	1.1 (0.4, 2.8)
	OR‡		0.8 (0.4, 1.6)		0.8 (0.4, 1.5)	
Underweight (low weight-for-age)	Prevalence†	0.6 (0.1, 3.3)	0.0 (0) n/a	1.1 (0.4, 3.2)	0.0 (0) n/a	n/a
	OR‡					
Overweight (high BMI-for-age)¶	Prevalence†	1.1 (0.2, 6.6)	0.6 (0.0, 3.3)	3.3 (1.0, 9.5)	5.4 (2.1, 13.6)	0 (0.0, 4.0)
	OR‡		0.3 (0.0, 8.0)		5.6 (0.4, 71.0)	
Anemia	Prevalence†	30.7 (25.4, 36.5)	35.8 (26.2, 46.7)	26.6 (21.6, 32.4)	37.0 (25.8, 49.7)	0.7 (0.4, 1.5)
	OR‡		1.0 (0.6, 1.7)		1.4 (0.8, 2.4)	
Linear models (continuous outcomes)						△-change (95% CI)‡‡
Change in height-for-age (stunting)						0.00 (−0.07, 0.08)§§
Change in BMI-for-age (thinness)						0.05 (−0.08, 0.17)
Height gain (cm)						0.02 (−0.04, 0.09)§§
Weight gain (kg)						0.03 (−0.05, 0.11)§§
Change in hemoglobin level (g/dL)						−0.17 (−0.36, 0.02)§§

BMI = body mass index; CI = confidence interval; Hb = hemoglobin; n/a = not applicable; OR = odds ratio; SES = socioeconomic status.

* The category of total undernutrition includes all children classified as stunted (low height-for-age), thin (low BMI-for-age) or underweight (low weight-for-age) with z-scores < −2.

† Data are % (95% CI). The CIs are adjusted for clustering within schools by using robust standard errors.

‡ ORs refer to the period effects. Mixed logistic regression models including random intercepts for schools and children were adjusted for the two categorical SES variables and children's age.

§ ORs refer to the intervention effect defined as ratio between the period effects in intervention and in control schools including random intercepts for schools and children and with adjustment for SES variables and children's age.

¶ The mixed logistic regression model did not include random intercepts for children due to the low number of children with the respective outcome.

|| The category of anemia includes all children classified as anemic (mild, moderate, and severe) based on the concentrations of Hb determined in a finger prick blood sample. The cutoffs for anemia are age specific: Hb < 11.5 g/dL for children aged 8–11 years, and Hb < 12 g/dL for children aged 12–14 years, including for girls aged 15 years, and Hb < 13 g/dL for boys aged 15 years.

†† The mixed logistic regression model was not adjusted for SES variables or children's age, as no convergence in the regression models was achieved.

‡‡ Mixed linear regression models including random intercepts for schools were adjusted for SES variables and children's age. The △-change stands for the estimated effect of the intervention on the mean of the respective change with the 95% CI.

§§ The mean changes of weight (0.89; 0.46, 1.33, $P < 0.001$), height (0.65; 0.17, 1.14, $P = 0.008$), height-for-age z-score (0.17; 0.09, 0.26, $P < 0.001$) and Hb (0.31; 0.02, 0.60, $P = 0.034$) were significantly larger in girls than in boys.

RESULTS

Compliance and characteristics of study population.

Complete datasets were available for 385 children and the equivalent of parents/caregivers at baseline. Overall, 25 children were lost to follow-up. The final analysis included 360 children and caregivers; 176 in intervention and 184 in control schools with complete datasets (Figure 2). Key characteristics of children and their households included in the study sample are shown in Table 1, stratified by study arm. Sociodemographic and economic characteristics between the two groups were similar, with the exception of parents/caregivers' educational attainment and their housing characteristics (roof material), which were significantly lower in the intervention group ($P = 0.001$ and $P = 0.043$, respectively) (Table 1).

Changes of intestinal parasitic infections in children. At baseline, children in intervention schools showed a higher prevalence of total parasite, total intestinal protozoa, and total helminth infections than children in control schools ($P = 0.031$, 0.050, and 0.807, respectively). We observed declines of intestinal protozoa infections from 88.6% to 57.4% in the intervention schools and from 79.9% to 70.1% in control schools with an intervention effect (OR = 0.2, 95% CI = 0.1–0.5, $P < 0.001$). Total helminth infections decreased in intervention schools (from 11.4% in 2015 to 8.0% in 2016),

whereas it was stable in control schools (9.8% in 2015, 10.3% in 2016). These changes were not significantly different (OR = 0.5, 95% CI = 0.1–1.7, $P = 0.265$) (Table 2). Of note, when stratifying the analyses of the change in intestinal parasitic infections by risk factors at baseline (i.e., stunting, thinness, and anemia), the intervention effects were slightly higher among children not being stunted or anemic; however, the differences lacked statistical significance ($P > 0.2$).

Changes of anthropometric indices and anemia in children. The rates of undernutrition, stunting, and thinness were slightly higher in intervention schools compared with control schools at baseline, but the difference showed no statistical significance (all $P > 0.05$). At the end-line survey, stunting and thinness were both higher in the intervention schools (38.1% in 2015, 42.0% in 2016 for stunting; 12.5% in 2015, 14.8% in 2016 for thinness) and in the control schools (23.4% in 2015, 26.1% in 2016 for stunting; 10.9% in 2015, 12.5% in 2016 for thinness) compared with the baseline prevalences. Overweight decreased in intervention schools from 1.1% in 2015 to 0.6% in 2016 and increased in control schools from 3.3% in 2015 to 5.4% in 2016. However, no statistically significant intervention effect on any of the nutritional indices, including children's weight or height gain, was found. Anemia increased in both intervention (from 30.7% in 2015 to 35.8% in 2016) and control schools (from 26.6% in 2015 to 37.0% in 2016) over the course of the

FIGURE 2. CONSORT flowchart: enrollment, intervention allocation, and end-line analysis. This figure appears in color at www.ajtmh.org.

study, but the changes were not significantly different (Table 3).

Changes of fecal contamination in drinking water. *Escherichia coli*-positive samples from households significantly decreased, both in intervention sites (OR = 0.3, 95% CI = 0.1–1.0, $P = 0.049$) and control sites (OR = 0.2, 95% CI = 0.1–0.7, $P = 0.015$). There was a significant decrease in household drinking water samples contaminated with fecal streptococci in intervention sites (OR = 0.1, 95% CI = 0.0–0.6, $P = 0.011$), whereas the decline was less pronounced in control sites (OR = 0.2, 95% CI = 0.0–1.1, $P = 0.068$). Samples contaminated with fecal streptococci from children's drinking water cups also significantly decreased in intervention sites (OR = 0.2, 95% CI = 0.1–0.7, $P = 0.007$), whereas the change in control sites lacked statistical significance (OR = 0.3, 95% CI = 0.1–1.4, $P = 0.136$). No statistically significant differences were observed between intervention and control sites for any of the water quality parameters (Table 4).

Changes of health KAP. Handwashing after playing and after defecation significantly increased in intervention schools (OR = 5.7, 95% CI = 2.6–12.2, $P < 0.001$ for handwashing after

playing, OR = 7.4, 95% CI = 3.9–14.1, $P < 0.001$ for handwashing after defecation) and in control schools (OR = 3.1, 95% CI = 1.4–6.8, $P = 0.004$ for handwashing after playing, OR = 3.6, 95% CI = 2.0–6.5, $P < 0.001$ for handwashing after defecation). A significant beneficial intervention effect was found for handwashing before eating (OR = 6.9, 95% CI = 1.4–34.4, $P = 0.018$) and the use of latrines at schools (OR = 14.9, 95% CI = 1.4–153.9, $P = 0.024$) (Table 5).

DISCUSSION

There is a lack of evidence on the potential benefits of combined school garden, nutrition, and WASH interventions on school children's intestinal parasitic infections and nutritional status.^{16,22–26} Results presented here from the parasitologic assessments among school children in two regions of Burkina Faso suggest that VgtS project-related interventions reduced intestinal protozoa infections, but only marginally improved helminth infections. No measurable improvements in nutritional indices among school children were observed. Environmental assessments showed no improvements in water quality parameters.

TABLE 4

Changes of drinking water contamination in a subsample of households and children's drinking water samples in two regions of Burkina Faso, in February/March 2015 and one year later

		Intervention sites		Control sites		Intervention effect§
		2015	2016	2015	2016	
Sample size (n)	Households	46	46	45	45	
	Children's cups	54	54	53	53	
	Study sites	4	4	4	4	
Water contamination households						
Coliform bacteria	Prevalence†	93.5 (80.6, 98.0)	95.7 (88.9, 98.4)	95.6 (87.4, 98.5)	95.6 (77.0, 99.3)	1.5 (0.1, 23.3)
	OR¶	1.0	1.5 (0.2, 9.6)	1.0	1.0 (0.1, 7.4)	
<i>Escherichia coli</i>	Prevalence†	56.5 (37.0, 74.2)	34.8 (24.1, 47.3)	71.1 (53.4, 84.1)	46.7 (28.5, 65.7)	1.6 (0.3, 7.3)
	OR‡	1.0	0.3 (0.1, 1.0)*	1.0	0.2 (0.1, 0.7)*	
Fecal streptococci	Prevalence†	95.7 (88.9, 98.4)	76.1 (50.5, 90.8)	91.1 (69.2, 97.9)	77.8 (62.7, 87.9)	0.4 (0.1, 4.0)
	OR‡	1.0	0.1 (0.0, 0.6)*	1.0	0.2 (0.0, 1.1)	
Water contamination children's drinking water cups						
Coliform bacteria	Prevalence†	90.7 (84.0, 94.8)	81.5 (66.6, 90.7)	88.7 (68.9, 96.5)	90.6 (83.6, 94.8)	0.3 (0.1, 2.0)
	OR¶	1.0	0.4 (0.1, 1.4)	1.0	1.2 (0.3, 4.5)	
<i>E. coli</i>	Prevalence†	42.6 (19.8, 69.0)	25.9 (12.4, 46.4)	52.8 (37.4, 67.7)	30.2 (15.4, 50.7)	1.1 (0.3, 3.8)
	OR‡	1.0	0.4 (0.2, 1.1)	1.0	0.4 (0.2, 1.0)	
Fecal streptococci	Prevalence†	87.0 (78.7, 92.4)	61.1 (49.8, 71.4)	90.6 (74.5, 96.9)	77.4 (51.3, 91.7)	0.6 (0.1, 3.2)
	OR‡	1.0	0.2 (0.1, 0.7)**	1.0	0.3 (0.1, 1.4)	

CI = confidence interval; OR = odds ratio; SES = socioeconomic status.

* $P < 0.05$; ** $P < 0.01$.

† Data are % (95% CI). The CIs are adjusted for clustering within schools by using robust standard errors.

‡ ORs refer to the period effects. Mixed logistic regression models were adjusted for the two categorical SES variables and children's age.

§ ORs refer to the intervention effect defined as ratio between the period effects in intervention and in control schools, with adjustment for SES variables and children's age.

¶ The mixed logistic regression model was not adjusted for SES variables or children's age, as no convergence in the regression models was achieved.

There are two main categories of interventions to address undernutrition in children: nutrition-specific interventions and nutrition-sensitive interventions.^{20,23} Although nutrition-specific interventions aim to address the immediate causes of undernutrition (inadequate dietary intake and disease), the

objective of nutrition-sensitive interventions is to target the underlying determinants of undernutrition. The current evidence base for interventions to improve children's nutritional status is primarily part of nutrition-specific interventions; showing beneficial effects on children's anthropometric

TABLE 5

Changes in key indicators from the health questionnaire in a cohort of children in two regions of Burkina Faso, in February/March 2015 and one year later

		Intervention schools		Control schools		Intervention effect¶
		Baseline (2015)	End-line (2016)	Baseline (2015)	End-line (2016)	
Sample size (n)		176	176	184	184	
Selected KAP† indicators						
Before eating	Prevalence‡	82.4 (59.6, 93.7)	97.7 (95.7, 98.8)	93.5 (89.7, 95.9)	96.2 (92.1, 98.2)	6.9 (1.4, 34.4)*
	OR§		13.2 (3.5, 49.6)***		1.9 (0.7, 5.4)	
After playing	Prevalence‡	6.3 (3.0, 12.7)	25.0 (21.5, 28.9)	8.2 (5.3, 12.3)	15.8 (10.6, 22.7)	1.8 (0.6, 5.1)
	OR§		5.7 (2.6, 12.2)***		3.1 (1.4, 6.8)**	
After eating	Prevalence‡	11.9 (8.8, 16.0)	17.0 (9.0, 29.8)	16.8 (9.8, 27.5)	12.5 (7.8, 19.4)	1.8 (0.7, 4.9)
	OR§		1.2 (0.6, 2.5)		0.7 (0.3, 1.4)	
After defecation	Prevalence‡	20.5 (14.1, 28.6)	52.8 (44.5, 61.0)	22.8 (18.8, 27.4)	45.1 (37.1, 53.4)	2.1 (1.0, 4.5)
	OR§		7.4 (3.9, 14.1)***		3.6 (2.0, 6.5)***	
Do not wash hands	Prevalence‡	8.0 (2.0, 27.2)	0.6 (0.1, 3.3)	0 (0.0)	0 (0.0)	n/a
	OR§		0.1 (0.0, 0.8)**		n/a	
With water only	Prevalence‡	92.0 (89.2, 94.2)	90.9 (86.5, 94.0)	87.0 (76.1, 93.3)	88.0 (72.9, 95.3)	0.8 (0.3, 2.3)
	OR§		1.1 (0.5, 2.6)		1.4 (0.7, 3.1)	
With water and soap	Prevalence‡	73.9 (53.7, 87.3)	78.4 (63.7, 88.3)	85.3 (75.1, 91.8)	83.7 (73.7, 90.4)	1.4 (0.6, 3.2)
	OR§		1.2 (0.7, 2.1)		0.8 (0.4, 1.5)	
With ash	Prevalence‡	4.0 (0.7, 19.9)	3.4 (0.9, 12.5)	2.7 (0.4, 16.6)	3.3 (1.4, 7.4)	0.7 (0.1, 5.6)
	OR§		1.0 (0.2, 4.3)		1.5 (0.3, 7.8)	
With mud	Prevalence‡	8.0 (3.3, 18.1)	0 (0.0)	8.7 (6.0, 12.4)	0 (0.0)	n/a
	OR§		n/a		n/a	
Use of latrines at school	Prevalence‡	91.5 (83.4, 95.8)	99.4 (96.7, 99.9)	69.0 (29.5, 92.2)	72.8 (25.9, 95.3)	14.9 (1.4, 153.9)*
	OR§		18.4 (2.0, 169.8)*		1.2 (0.5, 3.1)	
Open defecation	Prevalence‡	6.3 (3.0, 12.6)	0 (0.0)	22.3 (5.5, 58.6)	20.1 (2.5, 71.0)	n/a
	OR§		n/a		1.2 (0.5, 2.8)	

CI = confidence interval; Hb = hemoglobin; n/a = not applicable; OR = odds ratio; SES = socioeconomic status.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

† Knowledge, attitudes and practices.

‡ Data are % (95% CI). The CIs are adjusted for clustering within schools by using robust standard errors.

§ ORs refer to the period effects. Mixed logistic regression models were adjusted for the two categorical SES variables and children's age.

¶ ORs refer to the intervention effect defined as ratio between the period effects in intervention and in control schools, with adjustment for SES variables and children's age.

|| This result is principally due to one school in the control group, where latrine use was denied by 93.5% of the children at end-line, while the prevalence of reported latrine use was otherwise 85.8% across all intervention and control schools at end-line.

indices.²⁰ For example, in a study conducted in India with 7- to 9-year-old children receiving fortified foods rich in seven micronutrients, a beneficial effect on linear growth at 12 months follow-up was found.⁴³ Another study conducted with children aged 6–11 years in Tanzania who received a fortified beverage with 10 µm nutrients found that children's weight and height significantly improved in the intervention group at a 6-month follow-up.⁴⁴ Even though nutrition-specific interventions in school children have shown to be effective in reversing or improving negative health consequences,^{43–45} there is little evidence of multisectoral and nutrition-sensitive approaches (e.g., improving access to safe and hygienic environments and to diverse diets),²⁶ such as the VgtS project.²⁷ More recently, Prentice and others (2013)⁴⁸ argued that adolescence represents an additional window of opportunity during which growth-promoting interventions might have beneficial life course and intergenerational effects. However, these arguments have been opposed by Leroy and others,⁴⁹ for inadequately using changes in z-scores over time to define catch-up growth, highlighting that current evidence is still controversial on whether interventions in older children can induce catch-up growth.^{46,47}

The significant decrease in total intestinal parasitic infections, particularly total intestinal protozoa infections, in both intervention and control schools is partially explained by antiparasitic drugs provided to infected children after the baseline survey. However, the stronger decrease in the intervention schools related to the control schools may be indicative for the positive effects of the implemented WASH interventions.^{13,50} Our study thus confirms the effectiveness of school-based programs to reduce intestinal parasitic infections among school children. Other school-based health programs, for example, the "Fit for School" approach implemented since 2008 in the Philippines, showed similar beneficial effects in terms of reducing the prevalence of intestinal parasitic infections.²¹ This school-based program included a package of several health interventions (e.g., handwashing with soap, improving water supplies and sanitary services, and biannual deworming), which has shown lasting effects on soil-transmitted helminth infections among school children.²¹

Schools are considered a convenient platform for concerted multisectoral public health action.^{15,21} Combined school garden, nutrition, and WASH programs, facilitated through the education sector and supported by the health, sanitation, and agriculture sectors, have potential benefits across and beyond these sectors.^{51,52} However, the overall modest effects found on school children's intestinal parasite and nutritional status in our study requires a reconsideration of the program design. First, since school-going children spend time not only at school and their home, but also in potentially risky environments (e.g., rivers, lakes, and contaminated fields for open defecation), multiple interventions at various entry points are needed.^{26,53–55} Although children can be effective promoters of health messages received at school to their family members,^{53,56} our findings are in line with previous studies showing that uptake and translation of health messages to effective behavior changes at their homes may be difficult to achieve (as changing practices takes time; e.g., to safely store and treat drinking water, but also due to key constraints such as water scarcity).^{53–55} A closer involvement of communities and households in school-based programs with a stronger household and community component might

be necessary to achieve sustained and meaningful long-term effects for children's health and well-being.^{7,13}

Additionally, more comprehensive nutritional and agricultural interventions may be needed given the high rates of undernutrition found in our study regions. As the school feeding program (it is a governmental social protection program providing primarily staple foods to schools)⁵⁷ was not operational during the VgtS program implementation phase in our study sites, harvested vegetables were rarely prepared for consumption at schools. Hence, by widening the intervention approach from schools to the larger community and linking the school garden to home and community gardens,²⁶ vegetable production could be increased and used for consumption at children's homes. This approach was pursued in a 2-year integrated agriculture and nutrition program in Burkina Faso (2010–2012).^{26,58} The program design included homestead food production (micronutrient rich fruits and vegetables), coupled with a behavior change communication component. The key results from the program evaluation (2016) showed a significant reduction of underweight in mothers and wasting in children aged 3–12 months.^{26,58} Hence, multisectoral nutrition-sensitive interventions offer a unique opportunity; however, more sustained programs linking school-, home-, and community-based interventions tailored to the social-ecological contexts in Burkina Faso are needed to improve school children's health status on a long-term basis.²³ Taken together, the baseline and end-line data collected provided a benchmark for assessing changes in school children's health status over a 1-year period. By conducting repeated cross-sectional surveys in a cohort of children, this study has provided setting-specific data on school children's intestinal parasite infections and nutritional status, and calls for longer-term studies addressing school children's health through multisectoral and multistakeholder school- and community-based programs. The described study methodology presents a suitable approach for evaluating school-based health programs in settings where there is a paucity of health data among school-aged children.²⁷ The present study is among a few evaluations in sub-Saharan Africa that provides new evidence that school-based interventions can improve children's health.^{59,60}

There are several limitations to our study. First, considering the positive short-term impacts on children's parasitic infection status and the potential for longer-term benefits for children's nutritional outcomes, integrated agriculture, nutrition, and WASH programs should be implemented and the effects monitored over longer periods. The 5–6 months allocated here (due to delayed project implementation and end of the project phase in 2016) limit to unveil a potentially larger benefit in improving children's health.^{26,61} Second, hygiene and sanitary practices of children were self-reported and behavior change was not directly observed. Children may have over- or under-reported proper hygiene practices at baseline or end-line.⁶² Third, the power calculation of this study was conducted to address the initial cross-sectional hypothesis with the aim of comparing the prevalence of intestinal parasitic infection between children considered at high or at low risk of infection. The study therefore had limited power to test effects of the subsequent interventions, which is also reflected in the relatively wide CIs of our results. Fourth, we did not collect data on malaria, which might have provided a deeper understanding for the results pertaining to anemia. Fifth, the

diagnosis of helminths using the Kato–Katz technique with only one thick smear per specimen at baseline had a lower sensitivity than the duplicate thick smears used at end-line survey one year later. The reported values at baseline might therefore be biased downward.⁶³ Finally, the findings may be specific for the selected schools with similar characteristics and may not be representative for a wider area and other regions in Burkina Faso.

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