Albendazole Treatment Improves Work Capacity in Women Smallholder Farmers Infected with Hookworm: A Double-Blind Randomized Control Trial

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Abstract. An estimated 4.7 billion people live in regions exposed to soil-transmitted helminths, intestinal parasites that have significant impacts on the health of women smallholder farmers. The goal of this trial was to determine whether treatment with albendazole impacts the work capacity of these farmers. This is a prospective double-blind, randomized effectiveness trial. Participants ($N = 250$) were randomly selected from safe motherhood groups in the Democratic Republic of Congo. Prevalence/intensity of hookworm infection, hemoglobin, and demographics was obtained. At study (Time = 0), participants were randomized into treatment (albendazole 400 mg) and placebo (similar placebo tablet) groups. A step test was administered as a proxy metric for work capacity. Work capacity was defined as Δ heart rate before and after 3 minutes of step testing, in beats per minute. At study (time = 7 months), the step test was repeated and work capacity remeasured. The Δ work capacity (time = 0 minus time = 7 months) was the primary outcome. Investigators/field assistants were blinded to who was enrolled in groups, hookworm status, and step test results. Regression showed highly significant interactive effects of hookworm status and treatment group relative to Δ work capacity after controlling for resting pulse rate and age ($P < 0.002$). Estimated marginal means for work capacity (WC) for each of four groups (hookworm positive plus placebo, hookworm positive plus treatment, hookworm negative plus placebo, and hookworm negative plus treatment) showed women who were hookworm positive and received treatment decreased heart rate by 9.744 (95% confidence interval [CI]: 6.42, 13.07) beats per minute (increased WC), whereas women who were hookworm positive and received placebo saw a nonsignificant decrease of 0.034 (95% CI: -3.16 , 3.84) beats per minute. Treatment with albendazole was associated with improved aerobic work capacity posttreatment. Given modest costs of drug distributions, risk benefits of periodic deworming warrants further study in larger controlled trials.

INTRODUCTION

This project proposal was developed in response to the Gates Foundation's Grand Challenges Explorations Program. The specific Grand Challenges topic was Labor Saving Strategies and Innovations for Women Smallholder Farmers, and the target group was women smallholder farmers living in the eastern Democratic Republic of Congo (DRC).

Hookworm. An estimated 4.7 billion people worldwide live in regions with high potential for exposure to soil-transmitted helminths (STH), a group of intestinal parasites that include *Ascaris lumbricoides*, *Trichuris trichiura*, and hookworms (*Necator americanus* and *Ancylostoma* spp.), each of which can have significant impacts on the health and nutritional status of exposed populations.^{1–6}

Hookworm is transmitted in places that do not have adequate control of human waste or access to sanitation. Hookworm eggs are excreted in the feces of infected people and on successive molts to third-stage larvae, become infectious to humans via skin penetration, or in the case of *Ancylostoma* spp., following oral ingestion.⁷ Much of hookworm's health impact is mediated through intestinal hemorrhage caused by adult parasites, which attach to the gut mucosa and feed on blood from lacerated capillaries.^{4–6} Intestinal blood loss leads to—or exacerbates—iron deficiency (ID) and eventually to ID anemia (IDA).^{2,6,8,9} Because of menstrual blood losses, the large iron demands of pregnancy, and the often low iron

content of their diets, many women of childbearing age are at risk of ID even without hookworm exposure. Any blood loss associated with hookworm infection could exacerbate pre-existing ID.¹⁰ Women living in many agricultural areas are at even greater risk because of increased exposure to contaminated soil and inadequate sanitation facilities.¹¹

Work capacity (WC). Iron deficiency with or without anemia has been associated with lower aerobic WC.^{12–15} Iron deficiency anemia can, therefore, impact an individual's ability to perform income-generating tasks (work output), which can in turn threaten the livelihood and food security of the subsistence farmer.^{16,17} The World Health Organization (WHO) estimates an annual loss of 19.7 million disability-adjusted life years (1.3% of the global total) attributable to IDA, with the highest burden in Africa (25%). In 10 different developing countries, the median annual economic loss due to IDA has been estimated at 4% of gross domestic product, a burden potentially attributable in part to morbidity caused by hookworm infection.^{18,19}

Treatment of hookworm-infected individuals with albendazole is associated with short-term increases in blood hemoglobin levels and with a related decrease in the prevalence of anemia.²⁰ Increases in hemoglobin levels due to treatment have been associated with significant gains in adult labor productivity, as measured in Kenyan road construction workers and in Bangladeshi women plantation tea pickers.^{21,22} Little information is known about the WC or overall labor productivity of women smallholder subsistence farmers in endemic areas or if they would achieve similar benefits from treatment.

Albendazole distribution in the DRC. Globally, billions of albendazole doses have been pledged by large pharmaceutical

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companies through drug donation programs, which are administered through the WHO and Ministries of Health (MOH) to control hookworm and other STH infections. The MOH in Kinshasa, the DRC began mass distribution of albendazole in late 2015 to school children in the Maniema Province. The DRC is thought to have a high prevalence of STH, but little information is available on regional disease burden. At this time, women of childbearing years will not be included in the MOH campaign, despite the fact that the DRC has one of the highest maternal mortality rates in the world (754 maternal deaths per 10,000 births), presumably due in part to IDA (M. Salmon, unpublished data).²³

Study purpose. The purpose of this study was to determine the impact of single-dose treatment of albendazole on the capacity of women smallholder farmers in the DRC to perform subsistence agricultural labor as measured by an exercise tolerance test as proxy for WC.

METHODS

This was a double-blind, prospective, randomized effectiveness trial. Participants were recruited from safe motherhood groups and randomized into treatment ($N = 125$) and placebo groups ($N = 125$). Treatment groups received 400 mg albendazole and the placebo group received an identical tablet of no therapeutic benefit. An exercise tolerance test was

performed and then repeated 7 months posttreatment. The difference between the results of the two tests was calculated and used to measure change in WC. All field personnel, including investigators, social workers, and field assistants, were blinded as to who was enrolled in the treatment versus placebo groups, participant hookworm (or other helminth) status, and results of the exercise tolerance test throughout the study time period.

Democratic Republic of Congo study site. The study took place in Kindu, Maniema Province, DRC, in the villages of Lasoko and Libenga. Anecdotal information including MOH reports and disease burden reviews led us to believe that this was an area of high prevalence of hookworm.^{4,6,24}

Study participants and randomization. A total of 296 of 1,289 women smallholding farmers living in Maniema Province near the city of Kindu were randomly selected from two safe motherhood groups. The group list was randomized using the Excel™ software (Microsoft, Bellevue, WA) random number generator, with each member assigned a number 1–1,289. Of the women on the list, 250 were contacted successfully by local social workers and 46 could not be reached. No one refused to participate in the study. These women were further randomized to treatment and placebo groups by an every other one method as they presented to Basoko and Libenga health centers (Figures 1 and 2).

FIGURE 1. Consolidated standards of reporting trials diagram of flow of participants as they moved through the study.

FIGURE 2. Study site location Kindu, the Democratic Republic of Congo. Kindu is central in the Maniema Province located near the banks of the Congo River. Terrain is jungle and agricultural subsistence efforts include cassava, bananas, groundnuts, vegetables, oranges, and avocado. This figure appears in color at www.ajtmh.org.

Exclusion criteria. Exclusion criteria included women who were in the first or third trimester of pregnancy or women with symptoms of acute malaria (fever and general malaise), age < 16 years or > 50 years, who had abnormal vital signs, or who had a muscular or neurologic defect that would preclude them from safely stepping on and off a stair. Dates were determined by women self-reporting their last menstrual period.

Outcome measures. The capacity to do work was measured by a proxy metric termed WC, wherein a participant's change in heart rate (HR) before and after an exercise tolerance test (YMCA step test) was measured. The change in WC (Δ WC) from time = 0 to time = 7 months was the primary measurable outcome. Secondary outcomes were level of anemia as measured by mean blood hemoglobin (< 12 g/dL), association between anemia and hookworm infection status, and prevalence and intensity of hookworm infection, as measured by eggs per gram of feces using the Kato–Katz method.²⁵

Study design. At study start, participants presented to their local health center on a preselected date where demographic questionnaires were completed, consent forms were signed (described below), vital signs collected, hemoglobin tested, and pregnancy tests done. A travel reimbursement of \$5.00 was given to each participant to compensate for travel-related expenses. Pregnancy tests were conducted using babi One Step HCG™ (BlueCross, Beijing, China). Women thought to be in their first trimester were precautionarily excluded from drug administration and women in their third trimester were

excluded from the exercise tolerance portion of study. Vital signs (blood pressure, HR, and respiratory rate) were measured by trained study personnel. If a resting vital sign was grossly abnormal and thought to be clinically significant, the participant was referred to the health center nursing staff with the fee waived for that visit. Hemoglobin was measured using point-of-care methodology with HemoCue™ (Angleholm, Sweden), with the machine calibrated daily before use. Study participants with a blood hemoglobin level < 12 g/dL were provided a 3-month supply of WHO-recommended daily oral iron supplementation (80 mg) along with instructions for use.²⁶

Participants not excluded by the aforementioned exclusion protocols were considered enrolled in the study and randomized into two groups as they presented to the health clinic, where they received either albendazole (400 mg capsules, GlaxoSmithKline, Middlesex, United Kingdom) or a placebo tablet (Belvidere Laboratories, Belvidere, NJ). Stool samples were collected for examination of hookworm (Kato Katz technique; Vestergaard Frandsen, Aarhus, Denmark) using containers delivered to participating women the night before the morning study enrollment and stool collection. Collected stool containers were assigned a number and all other identifiers were removed. The containers were transported to a mobile laboratory where stool analysis was completed by a trained laboratory technician. World Health Organization categorization was used to define low (1–2,000 eggs per gram

[EPG]-, moderate (2,001–4,000 EPG)-, and high (> 4,000 EPG)-intensity hookworm infection. The results were sealed.

The YMCA step test was conducted at time = 0 to measure preliminary WC and repeated at time = 7 months. The difference in WC between the two YMCA step tests (Δ WC) defined the improvement or diminution of each study participant's capacity to do work and was the primary outcome of this study. A \$5.00 travel reimbursement was distributed for each visit.

At the end of the second YMCA step test (time = 7 months), each participant and all members of the participant's household were given a dose of albendazole. Women who had been successfully contacted before the beginning of the study, but who were considered high risk for enrollment, were also recontacted at time = 7 months and given albendazole for themselves and all the members of their household.

Demographic questionnaire. Questionnaires were conducted in the local language by trained social workers during private interviews with participants. Information collected included the following: work/labor history (i.e., amount and degree of recent work/labor in farming and self-perceived work tolerance); medical and nutritional history (i.e., recent acute or chronic illnesses; dietary intake, especially iron-rich foods; previous antihelminthic drug treatment; use of mosquito nets; and use of footwear); family demographics (i.e., the number of children born/live and the number persons living in home); dietary/food security (i.e., weekly dietary intake and perception on security of access to food); and sanitation/exposure (i.e., access to toilet facilities, mosquito net, and shoe usage

habits). Questions chosen were adapted from previous work by Humphries et al.²⁷

Outcome measure: YMCA step test protocol. The YMCA step test protocol was followed, with participants standing and facing the step and marching up and down the step as required to a metronome to ensure cadence (Figure 3). After 3 minutes, the activity was stopped and the participant was asked to sit on the step. The HR was measured after a 5-second delay by counting the radial pulse for one full minute.

Work capacity metric. Work capacity was defined as the change between resting HR (HR_{rest}) and after step test HR ($HR_{postexercise}$):

$$WC = HR_{postexercise} - HR_{resting} \quad [1]$$

The change in WC between time = 0 and time = 7 months (Δ WC) was used as a proxy metric for change in capacity to do work: positive values of Δ WC indicate improved WC, with negative values indicating diminished WC.

$$\Delta WC = WC_{Time=0} - WC_{Time=7 \text{ months}} \quad [2]$$

Ethics and ethical considerations. The study protocol was approved by the Western Internal Review Board (Seattle WA), Health Education Action Leadership Africa Hospital Internal Review Board, Kindu General Hospital IRB, and the Ministry of Health, DRC. Written consent was obtained from participants after explaining study intent and risk and benefits of participation in local language, Kiswahili or French, depending on the preferred language.

FIGURE 3. Young Men's Christian Association step test and step test coach. The purpose of this photograph was to demonstrate the step test and the woman being photographed agreed to have her photograph taken and published. Authors who took the photograph identified themselves as such and the woman was a paid coach and not a participant in the study. This figure appears in color at www.ajtmh.org.

Participants were given time to ask questions. All participants and their families were treated at the end of the study. This study was registered through ClinicalTrials.gov (Identifier: NCT02102321).

Study power. The minimal sample size was calculated at 50 persons per group (control and treatment). A 30% loss to follow-up was expected to occur because of three anticipated causes: injury, pregnancy, and illness. Therefore, a minimum of 66 persons was the target recruitment goal for each group. This sample size is based on the following assumptions: alpha (α) = 0.1, beta (β) = 0.2, expected range of hemoglobin in general population = [7.0, 18.0] g/dL, standard deviation of hemoglobin in general population = 3.0 g/dL, minimum clinically significant effect ≥ 1.5 g/dL, and standard effect size: $E/S = 1.5/3 = 0.5$. We then doubled the recruitment number to 264 as DRC and Maniema Province were in an active conflict area and there was the added risk of large sectors of the population needing to move quickly if the fighting moved to their area. We rounded the 264 up to 300.

Statistical analysis. Only those study participants who had complete data for all critical metrics were included in the regression analysis ($N = 154$). We compared key variables (participant age and baseline resting HR) for participants with complete and incomplete data, and means were not significantly different for the two groups. Multivariate regression was used to test the interactive effect of hookworm status and treatment group on change in WC, after controlling for baseline resting HR and participant age. The multivariate regression model was theory driven. We tested both an ordinary least squares model and a maximum likelihood model, and results were virtually identical, so the ordinary least square is presented. Model diagnostics identified a significant correlation (0.59) between Δ WC and baseline resting HR; we tested model fit with and without that variable. Residuals and model R^2 when participant baseline resting HR was excluded demonstrated a poor model fit (i.e., extensive residuals > 3 and nonsignificant model $R^2 = 0.055$, $P = 0.085$). By contrast, model fit parameters were improved with the inclusion of participant baseline resting HR (regression residuals were normally distributed and model $R^2 = 0.45$, $P < 0.001$). Thus, participant baseline resting HR was considered to make an important contribution to the model and was retained. We used the margins command in Stata to estimate the mean Δ WC at the group level. Marginal means are preferred, particularly when interaction terms are included (Williams, Ref). Marginal mean Δ WC was calculated for each of the four groups (hookworm positive plus placebo, hookworm positive plus treatment, hookworm negative plus placebo, and hookworm negative plus treatment) (Stata™ version 12, StataCorp LP, College Station, TX).

Data dissemination. Individual WC results were provided to study participants at the 7-month study visit and again at a 1-year site visit dedicated to result discussions. Results were also disseminated via meetings with MOH in Kindu, Maniema Province and with the director of Neglected Tropical Disease Program of the National Ministry of Health in Kinshasa.

RESULTS

Demographic data. There were 296 participants selected from the safe motherhood randomized lists, of which 250 were recruited, and 46 could not be contacted. All were small

farmers growing multiple types of crops; the majority did not feel secure regarding food status (Tables 1 and 2).

Soil-transmitted helminth prevalence and distribution.

The prevalence of hookworm was 50% (124/250) with mean intensity of 286 ± 352 epg and intensity ranging from 24 to 2,400 epg. Ninety-nine percent of infected participants were classified as low intensity ($< 2,000$ epg), with 85% of infected participants having less than 500 epg and 60% of the total epg burden being carried by participants with < 500 epg. Forty percent of the total epg burden was carried by the 40% of the study population who had > 500 epg. Testing for other relevant STH was not performed because of limitations in technical capacity.

Factors associated with hookworm infection status at baseline. Sixty-six percent (65.9%) of participants were anemic with a hemoglobin level less than 12 mg/dL. Of these, 35% had a hemoglobin less than 11 mg/dL and 15.4% less than 10 mg/dL. Regression analysis showed no correlation between hookworm infection status (or intensity) and anemia, and those receiving iron supplementation were evenly distributed across the placebo and treatment groups. There was no statistically significant association between type of latrine use (public or private) and prevalence or intensity of hookworm at either site. Nor was there any correlation between mosquito net use and prevalence or intensity of hookworm infection. There was no statistical relationship between shoe ownership and hookworm infection status ($P = 0.07$).

TABLE 1
Food and agricultural sociodemographic characteristics

Sanitation	Kindu
Pit latrine (no plumbing in area)	
Public	109
Private	99
Unknown/no answer	41
Bush or forest	1
Food security	Kindu
Meat (how many times a week)	
Less than once	177
Two times	50
More than twice	2
Unknown/no answer	21
Vegetables (how many times a week)	
Less than once	0
Two times	27
More than twice	119
Unknown/no answer	4
Do you feel secure in food access (yes/no)	
Yes	116
No	134
Agriculture	Kindu
Do you own or work in field?	
Field owner	183
Field rent	27
Do not work in fields	4
Unknown/no answer	36
Hours per day in field	
< 5	0
5–10	203
> 10	38
Unknown/no answer	9
Animal daily contact	
Chicken	123
Cow	0
Pigs	22
Goat	25

TABLE 2
Malaria and intestinal parasite history

Medical treatment in past year	Kindu
Intestinal parasites	
Yes	122
No	125
Do not know	3
Parasites-medication	
Do not know	161
Mebendazole	51
Albendazole	5
Other	5
Unknown/no answer	28
Malaria last 3 months	Kindu
Yes	192
No	55
Unknown/no answer	3
Malaria type of care	
Quinine	120
Amodiaquine	0
ACT	16
Fansidar	16
Nothing	15
Other	1
Took medication but do not know the name	24
Unknown/no answer	58
Malaria-source of care	
Nothing	22
Traditional	1
Health center (clinic)	80
Family	41
Hospitalized	13
Pharmacy only	35
Unknown/no answer	58

Work capacity. There were 78 placebo group participants and 76 treatment group participants who had complete data. Among study subjects with complete data who completed step tests at time = 0 and time = 7 months ($N = 154$), baseline resting heart rate was slightly lower in hookworm positive women who received the placebo (Table 3). After controlling for baseline resting pulse rate and participant age, there was an interactive effect of hookworm status and treatment group relative to Δ WC (Table 4). Estimated marginal means for WC for each of the four groups (hookworm positive, placebo, hookworm positive plus treatment, hookworm minus plus placebo, and hookworm minus plus treatment) showed women who were hookworm positive and received treatment exhibited an increased WC of 9.71 (95% confidence interval [CI]: 6.31, 13.11) beats per minute, whereas women who were hookworm positive and received the placebo saw a non-significant increase of 0.37 (95% CI: -3.16, 3.90) beats per minute. We did not demonstrate a benefit in WC across the entire study population, of whom approximately half were infected with hookworm (Table 4).

DISCUSSION

Little empirical data exist on STH prevalence and burden of disease in the DRC. Using fecal microscopy, we measured hookworm prevalence and intensity of women smallholder farmers in central DRC. Hookworm prevalence was 50%, with nearly all infections categorized as low intensity according to WHO standards, with 99% of infected participants having burden intensity < 2,000 epg and 60% < 500 epg. Fifty percent of the total epg burden was supported by the 40% of the population with > 500 epg.

The measure of WC and relationship to hookworm treatment has also not been studied previously in this population. We used HR measured immediately following an aerobic challenge (YMCA step test) as the relevant indicator of cardiovascular fitness, which was our metric for WC. After giving our randomized population hookworm treatment versus placebo, we demonstrated a reduction in HR (pre- and post-controlled exercise) from study start compared with study close, which reflects improved WC.

Before this study, it was unknown if subsistence farmers would exhibit improved fitness levels following treatment with albendazole or mebendazole. Although deworming treatment has previously been associated with improved WC, these studies were characterized by greater hookworm intensity and more pronounced levels of anemia.^{21,22} The present study demonstrates that even in the absence of anemia or high worm burdens, deworming has the potential to improve WC in women of childbearing age.

The heart rate was felt to adequately reflect aerobic capacity. Typically, the maximum oxygen uptake during exercise (VO_2 max) is considered the reliable metric to evaluate the intensity of aerobic capacity (cardiovascular fitness/WC).²⁸ Determination of VO_2 max is, however, restricted to equipped laboratory sites because of equipment needs and difficult experimental protocols. Because of its established relationship to VO_2 max, exercise-induced HR is often used instead to measure fitness.^{29,30} For example, the exercise intensity recommendations of the American College of Sports Medicine (ACSM 2001) are based on using VO_2 max as the reference measure and HR as a proxy.³¹

The exact mechanism(s) by which albendazole treatment improved WC are not known, although it is likely that its effect has to do with either cure or reduction in intensity of helminth infection.³² Although cure rates against hookworm vary widely, fecal egg reduction rates following albendazole treatment typically exceed 80% for hookworm in most endemic communities.^{33,34} Although there are no data on the effectiveness of albendazole in Congo, we presume that the drug would have comparable efficacy in this endemic population.

TABLE 3
Unadjusted Variable means (95% CI) by treatment group and hookworm status

	Hookworm positive		Hookworm negative	
	Placebo ($N = 39$)	Treatment ($N = 38$)	Placebo ($N = 39$)	Treatment ($N = 38$)
Δ WC	2.97 (-1.24, 7.19)	9.16 (4.99, 13.32)	1.95 (-2.8, 6.69)	1.5 (-3.2, 6.2)
Baseline resting HR	82.5 (78.7, 86.3)	86.8 (82.5, 91.1)	88.90 (85.3, 92.5)	87.8 (83.4, 92.1)
Age	29.1 (26.4, 31.7)	30.3 (27.3, 33.4)	28.5 (26.1, 30.9)	29.1 (26.3, 31.9)

CI = confidence interval; HR = heart rate; WC = work capacity. Table of unadjusted, stratified values.

TABLE 4

Interaction between hookworm status and treatment group is associated with Δ WC

Variables	Coefficient	P value
Hookworm positive	-3.14	0.197
Treatment	-1.58	0.506
Hookworm positive by		
Treatment	10.92	0.001
Participant age	-0.26	0.014
Baseline resting heart rate	-0.72	0.000
Model R^2	0.45	—
Marginal mean Δ WC	Hookworm positive (95% CI)	Hookworm negative (95% CI)
Placebo	0.37 (-3.16, 3.90)	3.52 (0.15, 6.88)
Treatment	9.71 (6.31, 13.11)	1.93 (-1.51, 5.37)

CI = confidence interval; WC = work capacity. Ordinary least squares multivariate regression with change in WC as the dependent variable; model included theory-driven control variables (participant age and baseline resting heart rate), as well as treatment group, baseline hookworm status, and the interaction between baseline hookworm status and treatment group. Marginal mean Δ WC represents the change for each group holding other variables constant. If a woman was hookworm positive and treated, the predicted impact would be an increase in WC of 9.71 (i.e., an improvement in WC), holding all other variables constant. Because of the variations in participant age and baseline resting heart rates across communities, the adjusted means are provided. No impact from previous treatments for hookworm was significant, either prescribed or self-directed.

Because there was no correlation between levels of anemia and hookworm infection intensity, the mechanism underlying the observed improvement in WC is not likely based on an immediate increase in blood hemoglobin. The beneficial impact of deworming may also include improved nutrition and reduced gut inflammation.³⁵ Moreover, given that blood hemoglobin is not a highly sensitive marker of total body iron status, future studies warrant measurement of more sensitive indicators of iron stores, e.g., myoglobin, cytochrome C, ferritin, and hepcidin.³⁶

The study results are relevant to recent controversies regarding global control strategies for hookworm and other helminths, which have primarily relied on targeted mass drug administration of benzimidazole anthelmintics, albendazole, and mebendazole. Women of childbearing age are one of the age groups at risk identified by the WHO for preventive chemotherapy against STH; we hope that the result of this study demonstrating a beneficial effect in an area of low endemicity and in a short interval (7 months) would stimulate the establishment of effective control programs also in this group.

We did not demonstrate a benefit in WC across the entire study population as there was no benefit in the treated and uninfected women. However, the administration of deworming to the entire group at risk is the only practical way to control hookworm in the ones infected because of the cost related with the individual diagnosis.

Finally, the authors recognize that some hookworm-infected women received placebo during the course of the study period, an aspect of the experimental design that was carefully considered and ultimately approved by four independent IRB committees. Based on their assessment of the risks/benefits, inclusion of a placebo arm was considered justified to accurately assess the potential of albendazole to improve the WC of women small-scale farmers in a hookworm-endemic area.

Limitations. This study has certain limitations that must be considered. Because of technical limitations, we were unable to measure the potential effect of *Ascaris* and *Trichuris* infection status on WC. However, the randomized nature of the intervention and the fact that treatment proved beneficial only for those infected with worms affirm the potential benefit of deworming in this vulnerable population of women small-scale

farmers. Future studies are planned to address these limitations, building on preliminary data generated by this initial pilot study.

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