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Original Article

Effectiveness of single-dose albendazole against soil-transmitted helminth infection in children: A longitudinal study in a tribal dominated district of Odisha, India

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***Background & objectives*: Soil-transmitted helminth (STH) infections, primarily caused by *Ascarislum bricoides, Trichuris trichiura,* and *Ancyclostoma duodenale*, significantly impact child growth and cognitive development in endemic regions. This study aimed to evaluate the effectiveness of a single 400 mg dose of albendazole in treating STH infections among children aged 1-15 yr in Nabarangpur, Odisha, India, and to assess the influence of socio-demographic factors on treatment outcomes.**

***Methods*: This longitudinal study included 1246 children across 18 clusters. Among them, 203 STH-positive children received albendazole, with stool samples collected on Days 14, 28, and 42 post-treatment. Egg counts were measured using the Kato-Katz method. Cure rates and egg reduction rates (ERR) were calculated, and repeated measures ANOVA was used to assess the impact of schooling, gender, tribal status, and geography on treatment efficacy.**

***Results*: Albendazole demonstrated high effectiveness in reducing egg counts, with an ERR of 96.2 per cent for *A. lumbricoides* and 93.8 per cent for *A. duodenale.* Cure rates were suboptimal, at 66.7 per cent and 52.94 per cent, respectively, falling below WHO-recommended thresholds. Gender and geographic location influenced baseline egg counts, with females and children in Nabarangpur showing higher initial burdens. Reductions were consistent across schooling and tribal groups.**

***Interpretations & conclusions*: Although albendazole effectively reduced infection intensity, its lower cure rates for hookworms highlight the need for region-specific and gender-sensitive interventions. Integrating treatment with WASH (Water, Sanitation, and Hygiene) programs and health education may improve long-term control. Monitoring resistance patterns and exploring combination therapies could further enhance treatment efficacy.**

Key words Albendazole efficacy - ascariasis - cure rate - egg reduction rate - hookworm - soil-transmitted helminth

Soil-transmitted helminth (STH) infection among children is a major health problem globally and is mainly caused by the three most common types of helminths: *Ascaris lumbricoides* (Roundworm),

[#]Equal contribution

Trichuristrichiura (whipworm), and *Ancylostoma duodenale* (Hookworm). The primary intervention against STH infections is regular administration of anthelmintic drugs, with the World Health Organization (WHO) recommending pyrantel, levamisole, mebendazole, and albendazole as standard treatments[1]. Albendazole is commonly used, but its effectiveness varies by helminth species. A meta-analysis reported that a single 400-mg oral dose of albendazole had an average cure rate of 28 per cent against *T. trichiura*[2]. However, albendazole shows high efficacy against *A. lumbricoides* and *A. duodenale*, with egg reduction rates (ERR) of 99.8 per cent and 93.6 per cent, respectively, as demonstrated in a study from Peru[3].

India bears the highest burden of STH globally, with approximately 600 million children at risk[4]. In the state of Odisha, where poverty, limited sanitation, and lack of hygiene are prevalent, STH rates are high. A study conducted in the urban slums of Bhubaneswar, Odisha, found an overall STH prevalence of 13.3 per cent, with rates of 62.5 per cent among children aged 6–12 yr, half of whom had received albendazole within the previous six months[5]. To address this issue, the WHO has set a goal to control STH infections in high-risk populations by 2030, focusing on preventive chemotherapy to reduce both prevalence and associated morbidity[6].

Since February 2015, the Government of India's National Mass Deworming Program has aimed to deworm children (aged 1–19) in schools and *Anganwadi* centers with a single 400 mg dose of albendazole[7]. The Government of Odisha implements the biannual round (February and August) of oral albendazole administration (400 mg) to students enrolled in the 6th to 12th standard[7]. Despite efforts to control STH infections, they remain a significant public health issue due to their high prevalence and associated health impacts. While some studies have reported STH resistance to albendazole in certain areas, evidence from tribal regions remains limited. The current longitudinal study aimed to estimate the effectiveness of albendazole tablets against STH infection among children (1-15 yr) from tribal areas, and help us understand its relationship with different sociodemographic factors and types of STH.

Materials & Methods

This longitudinal study was undertaken by the department of Epidemiology, ICMR- Regional Medical Research Centre, Bhubaneswar, Odisha, India, after obtaining the ethical approval from its Institutional Ethics Committee. The objectives and procedures of the study were thoroughly explained to parents, school teachers, frontline healthcare workers, and community leaders to ensure transparency and understanding. Prior to enrollment, written informed consent was obtained from the parents or legal guardians of the participating children, along with their assent. Participants were assured that their involvement was voluntary, with the right to withdraw at any point in time. Confidentiality was ensured, and all data were anonymized for analysis. A stool sample collection kit was provided to the parents and detailed on how to collect the morning sample.

Study design and setting: The present study was carried among children (1-15 yr) from a 18 different clusters/ villages of Nabarangpur district, a tribal-dominated district of Odisha. Using the multi-stage sampling method, three out of 10 blocks in the district were randomly selected. Six clusters/villages were selected from each block *i.e* a total of 18 clusters were selected using the probability proportional to size (PPS) method. From each cluster, 80 or more children were randomly selected and recruited under the study with support from local health administration and frontline health care providers through house-to-house visits.

Sample size: Considering the reported prevalence of STH infection in India at 13.3 per cent[5], confidence level of 95 per cent, absolute precision of 2.5 per cent and design effect of 1.5, the desired sample size was estimated to be 1063. Assuming a 20 per cent non-response rate, the sample size was estimated at 1329 and rounded up to 1400. To ensure adequate representation, 18 clusters were selected, targeting to recruit 80 participants (children aged 1–15 yr) per cluster. Children were eligible if they were permanent residents of the selected clusters and their parents or guardians provided written informed consent. Children were excluded if they were absent during the household survey, if consent was not obtained, or if they had received anti-helminthic treatment within the three months preceding data collection.

Stool sample collection and investigation for STH: Morning stool samples were collected from study participants. Routine microscopic examination was conducted to identify the presence of STH infections. For each positive sample, two aliquots were prepared for further analysis. The first aliquot was used for the

quantitative identification of helminth eggs using the standard Kato-Katz thick smear technique, while the second aliquot was stored for future investigation.

A small quantity of collected fresh stool sample was filled in the template that was placed on the slide using a spatula. The template was removed after the known amount of excrement settled on the slide. The sample was covered with a cellophane strip that has been soaked in 3 per cent Methylene blue solution. Then it was lightly pressed to distribute the sample equally on the slide and left for 30 min to set. Slides were examined under the microscope in the laboratory. The infection rate of STHs was determined by calculating the average number of eggs per Kato-Katz slide, which was then multiplied by 24 to estimate the number of eggs per gram (EPG) of stool. All results were documented, and the infection intensities were categorized according to World Health Organization (WHO) thresholds into light, moderate, and heavy infections[8].

Drug administration and follow up: The identified STH-positive children were administered with single dose anthelmintic drug albendazole 400 mg (tablet Noworm) and syrup to the children below 5 yr supervised by the trained *anganwadi* workers across the three blocks of Nabarangpur simultaneously. The children were kept under observation for a minimum of 2 h and were asked to report if any side effects were observed.

Following treatment, stool samples were collected from each participant at 14-day intervals for three consecutive follow ups (D14, D28 and D42). These samples were examined in the laboratory using the same techniques as at baseline to detect the presence of parasite eggs. This systematic monitoring aimed to assess both the immediate and sustained effects of albendazole on parasite clearance. All findings, including any side effects and changes in egg counts, were meticulously recorded for further analysis to evaluate treatment effectiveness and resistance development.

Data management and analysis: All collected data were entered into the statistical software R (version 4.4.1) for analysis, using modules based on the WHO child growth standards for descriptive statistics and to evaluate the effectiveness of albendazole. The fecal egg count reduction rate (FECRR) was calculated for each participant using a standard formula[9]. The average cure rate (CR) and egg reduction rate (ERR) among children infected with STH were determined using the Kato-Katz smear technique following the administration of tablet albendazole at 14-day intervals over three treatment cycles.

$$\text{FECRR \%} = 100 \times [1-(\text{Arithmetic mean of follow up faecal egg count/arithmetic mean baseline faecal egg count})]$$

$$\text{CR \%} = 100 \times (\text{Number of negative children after treatment/total no. of positive before treatment})$$

$$\text{Number needed to treat (NNT)} = 1/\text{cure rate}$$

Results

Participant flow: A total of 1246 stool samples were collected from 1489 enrolled children in Nabarangpur district (drop out 16.3%). Of these, 203 were positive for STH infection and were administered a single 400 mg dose of albendazole. Follow-up stool samples were collected at 14, 28, and 42 days post-treatment. The flow of participants through enrolment, baseline positivity, and follow-up is shown in figure 1.

The status for prevalence of soil-transmitted helminth (STH) positivity cases and in three different study sites of Nabarangpur district is depicted in figure 2.

Baseline characteristics: Mean age of 203 children positive for STH infection was 5.5 (±1.4) yr, and 50 per cent were boys. For analysis, age was grouped into 1–5 yr (pre-school age) and 6–15 yr (school-going age). Baseline average egg counts across socio-demographic groups are presented in table I. Higher baseline burdens were observed among older children, males, those from Nabarangpur block, children attending school, those living in kutcha houses, and children practicing open defecation.

Primary and secondary outcomes: Based on the number of helminthic eggs, the severity of the illness was assessed. Egg counts between 1-4999, 5000–49999, and ≥50000 were deemed to be mild, moderate, and severe respectively, for *A. lumbricoides*. Egg counts for hookworm were classified as mild, moderate, or severe based on egg counts between 1 and 1999, 2000–3999, and ≥4000, respectively[10]. Species-specific treatment responses are summarized in table II. *A. duodenale* was the most prevalent species (67.4%), followed by *A. lumbricoides* (32.0%), with one mixed infection. For *A. lumbricoides*, the FECRR was 96.2 per cent (meeting

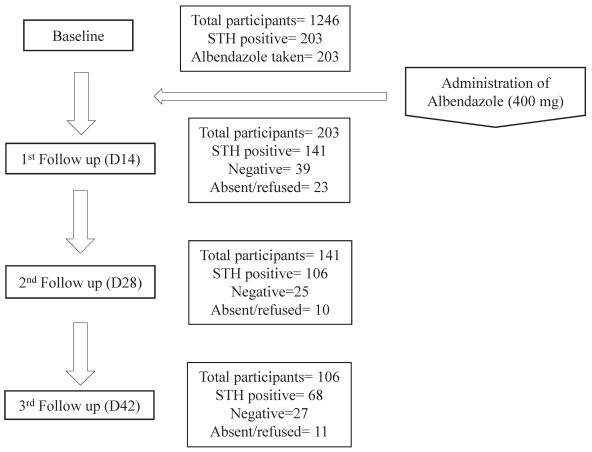

Fig. 1. Flow of participant through enrolment, baseline and follow up. STH, soil transmitted helminth.

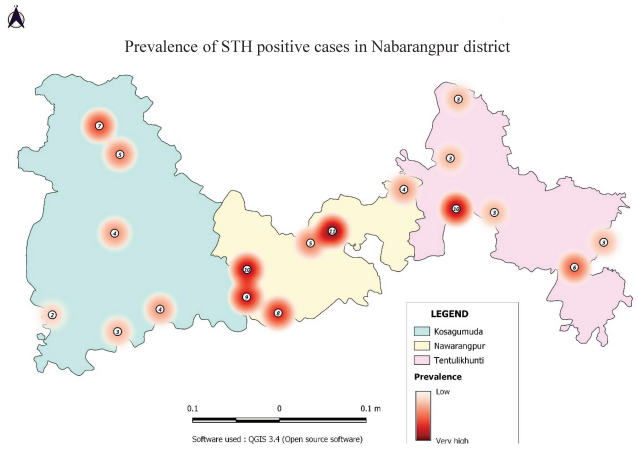

Fig. 2. Prevalence of Soil transmitted helminth (STH) positive cases in Nabarangapur District, Odisha, India. *Source*: QGIS 3.4 (open source software). The figure is generated by the authors only for this study and is not adopted from any literature source.

the WHO threshold of ≥95%), while the CR was 66.7 per cent (below the WHO-recommended ≥95%). For *A. duodenale*, the FECRR was 93.8 per cent (meeting the WHO threshold of ≥90%), but the CR was only 52.9 per cent. The single mixed infection showed a FECRR of 93.9 per cent and a CR of 0 per cent.

Trends in egg count reduction from baseline to days 14, 28, and 42 are shown in table III. Both age groups demonstrated significant declines, with higher baseline counts in older children. Girls had higher baseline egg counts than boys, though both sexes showed significant reductions (P= 0.025). Geographic differences were evident, with children from Nabarangpur block having the highest baseline counts, and significant reductions were observed across all blocks (P = 0.001). Schooling status was not significantly associated with reductions, although children without schooling had the highest baseline values.

Additional analyses: The impact of socio-demographic factors on egg count reduction is illustrated in figure 3 and supplementary figures 1, 2 and 3. Repeated measures ANOVA showed no significant effect of schooling (P=0.479), though children without schooling had higher baseline counts (Supplementary Fig. 1). Gender had a significant effect (P=0.025), with girls showing higher counts at all time points (Supplementary Fig.2). Tribal status did not significantly influence reductions (P=0.307) (Supplementary Fig. 3). Geography significantly interacted with time (P=0.001), with all blocks showing significant reductions, and Nabarangpur block having the highest baseline burden.

Discussion

This study evaluated the therapeutic effectiveness of a single 400 mg dose of albendazole against soil-transmitted helminth infections among children in a tribal-dominated district of Odisha. Albendazole achieved high fecal egg count reduction rates (FECRR) for *A. lumbricoides* (96.2%) and *A. duodenale* (93.8%), meeting WHO thresholds for drug efficacy. However, the cure rates (CR) were substantially lower—66.7 per cent for *A. lumbricoides* and 52.9 per cent for *A. duodenale*—which fell short of the ≥95 per cent recommended by WHO[11]. These findings suggest that while albendazole effectively reduces infection intensity, its ability to completely clear infections in this population is limited.

The reduced cure rates observed in our study are consistent with previous reports showing that albendazole's effectiveness varies by helminth species[12,13]. Similar to our results, studies in Ghana and Ethiopia documented poor cure rates for hookworm despite high FECRR values[13,14]. Reduced cure rates for *A. lumbricoides* have also been reported, suggesting that albendazole alone may not be sufficient for comprehensive control[15]. A study in Peru confirmed variable outcomes, with better performance of albendazole against *A. lumbricoides* compared to hookworm, while work in the Dominican Republic highlighted low cure rates in preschool-aged children[15,16]. A recent multi-site study from India also indicated emerging resistance, with suboptimal cure rates observed for both *A. lumbricoides* and hookworm[17]. Collectively, these findings raise concerns

Table I. Variation in positivity and average egg count by socio-demographic characteristics for soil transmitted helminth (STH)(N=1246)

Socio-demographic characteristic		No. of samples collected baseline (N=1246) n (%)	No. positive baseline (N=65) n (%)	*A. lumbricoides* (RW)		*A. duodenale*	
				No. positive baseline (N=65) n (%)	Baseline mean egg count ± SD	No. positive baseline (N=137) n (%)	Baseline mean egg count ± SD
Age (yr)	1–5	537 (43)	63 (12)	22 (34)	1206.5 ± 1377.3	41 (30)	986.3 ± 1225.0
	>5–15	709 (57)	140 (20)	43 (66)	979.4 ± 912.7	96 (70)	1589.5 ± 2326.9
Gender	Girls	617 (50)	83 (13)	26 (40)	1112.3 ± 1053.3	56 (41)	1629.4 ± 2094.2
	Boys	629 (50)	120 (19)	39 (60)	1018.9 ± 1120.4	81 (59)	1256.5 ± 2058.6
Geography (Block)	Nabarangpur	515 (41)	126 (24)	44 (68)	1316.7 ± 1221.6	81 (59)	1932.4 ± 2531.9
	Tentulikunti	417 (33)	52 (12)	16 (25)	512.8 ± 318.5	36 (26)	483.9 ± 279.6
	Kosagumuda	314 (25)	25 (8)	5 (8)	504.0 ± 401.2	20 (15)	954.0 ± 799.7
Schooling	Pre-school	492 (39)	46 (9)	17 (26)	1088.5 ± 1478.5	29 (21)	948.4 ± 1128.1
	School	706 (57)	140 (20)	43 (66)	979.4 ± 912.7	96 (70)	1589.5 ± 2326.9
	No school	48 (4)	17 (35)	5 (8)	1608.0 ± 977.4	12 (9)	1078.0 ± 1484.9
Caste (overall only)	ST	470 (38)	84 (18)	28 (43)	1325.5 ± 2290.1	56 (41)	1186.3 ± 2030.7
	SC	550 (44)	86 (15)	24 (37)	1280.7 ± 1510.6	61 (44)	1165.1 ± 1387.6
	OBC	193 (15)	28 (14)	14 (22)	1615.4 ± 1740.5	14 (10)	1459.8 ± 1634.1
	GEN	33 (3)	5 (15)	0 (0)	1980.2 ± 2250.6	5 (4)	1831.0 ± 2126.0
House type (overall only)	*Kutcha*	581 (47)	103 (18)	27 (42)	1390.8 ± 1980.3	75 (55)	1240.2 ± 1857.1
	Pucca	665 (53)	100 (15)	31 (48)	1335.6 ± 1770.2	69 (50)	1219.4 ± 1655.2
Open defecation (overall only)	Yes	1067 (86)	175 (16)	53 (81)	1445.2 ± 1900.4	121 (88)	1292.8 ± 1767.2
	No	179 (14)	28 (16)	5 (8)	890.2 ± 1288.0	23 (17)	799.8 ± 1203.0

SD, standard deviation; ST, scheduled tribe; SC, scheduled caste; OBC, other backward class; GEN, general category

Table II. Distribution of STH species (N=203), baseline and post-treatment egg counts (epg), fecal egg reduction rate (FERR), and cure rate (CR) compared to WHO targets

Sl no.	Helminthtype	Species Percentage (N=203) n (%)	Average egg count (epg) at baseline Mean (SD)	Average egg count (epg) on 42nd day Mean (SD)	FERR (%)	WHO target for FERR, %	Cure rate (CR), %	WHO target for CR, %
1	*A. lumbricoides*	65 (32.01)	1004.15 (mild*)	39.15	96.2	≥95	66.7	≥95
2	*A. duodenale*	137 (67.4)	1231.83 (mild*)	76.68	93.8	≥90	52.94	≥95
3	Both	1 (0.49)	1560	96	93.9	___	0	___

*Infection intensity for *A. lumbricoides* ranged from 1–4999 epg and for *A. duodenale* from 1–1999 epg; all were classified as mild infections. Epg, eggs per gram; FERR,fecal egg count reduction rate; WHO, World Health Organization; CR,cure rate; RW, roundworm; HW, hookworm

about the long-term sustainability of albendazole monotherapy, particularly in high-transmission or resistant areas[18].

Our findings also align with systematic reviews and meta-analyses that concluded albendazole reduces infection intensity effectively but often fails to achieve high cure rates, especially for *T. trichiura* and hookworm[12,19,20]. Several factors could explain this discrepancy. Reinfection pressure is high in endemic areas with poor sanitation, and new infections may appear within weeks of treatment[14,21]. Nutritional status, especially iron deficiency, has been shown to affect treatment outcomes, and this may be particularly relevant for hookworm infections[13]. Pharmacological differences between parasites also play a role, with albendazole showing consistently lower activity against hookworm[12,15].

Subgroup analyses in our study provide additional context. Girls had significantly higher baseline egg counts compared to males, although both groups

Table III. Comparison of changes in average egg counts at different time points according to various sociodemographic characteristics (N = 203)

Characteristics	Avg. egg count Baseline (N=203) Mean (SD)	*P* value	Avg. egg count after 14 days (N=203) n (SD) (% decline)	*P* value	Avg. egg count after 28 days(N=141 n (SD) (% decline)	*P* value	Avg. egg count after 42 days(N=106) n (SD) (% decline)	*P* value
Age (yr)								
1-5	1063.2 (1273.5)	0.18	474 (533.3) (55.5)	0.82	204 (233.7) (80.8)	0.37	81.5 (116.7) (92.3)	0.06
>5-15	1401.8 (2007.9)		558 (1096.7) (60.2)		166 (196.7) (88.1)		56.5 (120.1) (95.9)	
Gender								
Female	1466.6 (1827)	0.15	599 (744.6) (59.2)	0.13	225 (244.7) (84.6)	0.04	90 (160.5) (93.8)	0.14
Male	1179.3 (1806.2)		487 (1076.3) (58.7)		147 (176.9) (87.5)		49.3 (82.1) (95.8)	
Geography								
Nabarangpur	1714.4 (2168.5)	<0.001	700 (1208.6) (59.2)	0.01	201 (234.8) (88.2)	0.02	69.3 (137.5) (95.9)	0.19
Tentulikhunti	492.7 (289.2)		221 (219.2) (55.2)		111 (141) (77.4)		41 (70.5) (91.6)	
Kosagumuda	864 (752.8)		463 (354.6) (46.4)		219 (185) (74.6)		91.2 (106.8) (89.4)	
Schooling								
Pre School	1000.1 (1254.4)	0.41	420.2 (430.2) (58.7)	0.61	197 (223.2) (80.9)	0.37	76 (99.9) (92.7)	0.28
School	1401.8 (2007.9)		558 (1096.7) (60.2)		166 (196.7) (88.1)		56.5 (120.1) (95.9)	
No School	1254.6 (1347.8)		620 (746.5) (49)		218 (264.2) (80.9)		93 (152.7) (91.7)	

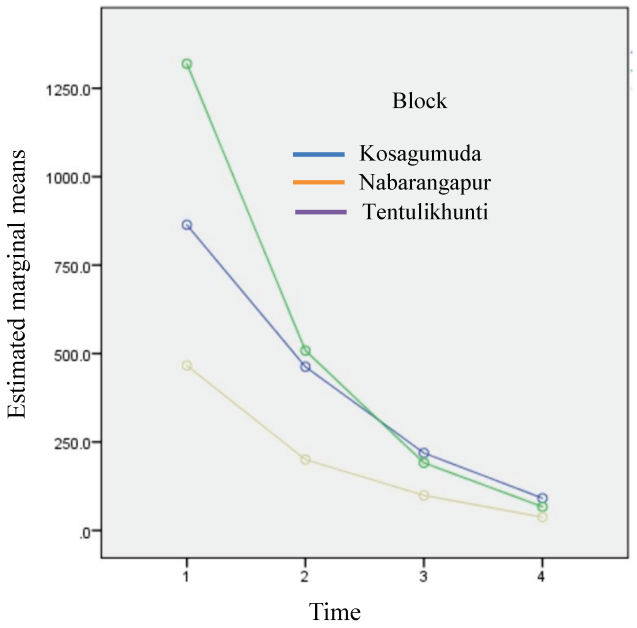

Fig. 3. Impact of socio-demographic factors on egg count reduction.

demonstrated significant reductions following treatment. This pattern is consistent with studies suggesting that gender-related factors influence infection intensity[13]. Geographic variation was another strong determinant, with children in Nabarangpur block showing the highest baseline counts, compared to lower levels in Kosagumuda and Tentulikhunti. Similar regional differences in treatment outcomes have been reported in other studies, reflecting the influence of local environmental and sanitation conditions[13,22,23]. Schooling and tribal status did not significantly influence treatment efficacy, consistent with previous research[24]. However, children without formal schooling had higher baseline counts, suggesting that educational interventions, including hygiene education, may reduce transmission risk[12,25].

The strengths of this study include its relatively large sample size, longitudinal design with repeated follow-up, and application of WHO-recommended diagnostic thresholds. However, limitations must be acknowledged. The 42-day follow-up may not fully capture reinfection dynamics or sustained efficacy. We examined only single-dose albendazole, although multiple-dose regimens and combination therapies have shown superior results[1,9,15]. Nutritional and immunological factors, known to influence treatment outcomes, were not assessed. Resistance testing was also not performed, despite recent evidence from India and other countries indicating reduced albendazole efficacy[17,18].

The implications for public health are important. While albendazole remains a valuable component of deworming programmes, the suboptimal cure rates for hookworm highlight the need for integrated control strategies. WASH (Water, Sanitation, and

Hygiene) interventions, alongside regular deworming, are critical for long-term impact[22]. Health education and community involvement have been shown to improve compliance and reduce reinfection[23,25]. Regular monitoring of drug efficacy using both cure and egg reduction rates is essential to detect early resistance[18,26]. In areas with persistently low cure rates, alternative regimens such as multi-dose albendazole or combination therapies with Ivermectin or oxantel pamoate should be considered[1,15,27].

Our findings underscore the need for region-specific and gender-sensitive approaches to STH control. Integration of albendazole treatment with WASH strategies, hygiene education, and continuous monitoring of drug efficacy will be essential for achieving sustainable reductions in STH prevalence and progressing toward global elimination targets.

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Conflicts of Interest: None.

Use of Artificial Intelligence (AI)-Assisted Technology for manuscript preparation: The authors confirm that there was no use of AI-assisted technology for assisting in the writing of the manuscript and no images were manipulated using AI.

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