

Original Article

Asian Pacific Journal of Tropical Medicine

apjtm.org

doi: 10.4103/apjtm.apjtm_700_23

Assessment of albendazole efficacy against *Ascaris lumbricoides* at three sites of Andhra Pradesh, Odisha, and Kerala in India

Vinay Garg[1], Ankur Garg[1], Shubha Garg[1]✉, Sudhir Kumar Jain[2], Tanzin Dikid[3], Saurabh Jain[4], Jitendra Manjhi[5], Antonio Montresor[6], Atul Goel[7]

[1]*Division of Parasitic Diseases, National Centre for Disease Control, Ministry of Health and Family Welfare, Government of India, 22-Sham Nath Marg, Civil Lines, New Delhi-110054, India*

[2]*National Centre for Disease Control, Ministry of Health and Family Welfare, Government of India, 22-Sham Nath Marg, Civil Lines, New Delhi-110054, India*

[3]*Epidemiology Division, National Centre for Disease Control, Ministry of Health and Family Welfare, Government of India, 22-Sham Nath Marg, Civil Lines, New Delhi-110054, India*

[4]*Department of Control of Neglected Tropical Diseases (NTD), World Health Organization (WHO), Av Appia 20 CH-1211, Geneva 27, Switzerland*

[5]*Department of Community & Family Medicine, AIIMS Kalyani, India*

[6]*Community and Primary Care-based Intervention, Department of Control of Neglected Tropical Diseases (NTD), World Health Organization (WHO), Av Appia 20 CH-1211, Geneva 27, Switzerland*

[7]*Director General of Health Sciences (DGHS) & Director, National Centre for Disease Control, Ministry of Health and Family Welfare, Government of India, 22-Sham Nath Marg, Civil Lines, New Delhi-110054, India*

ABSTRACT

Objective: To assess efficacy of albendazole against *Ascaris* (*A.*) *lumbricoides* among school-children at three sites of Rajahmundry, Sundergarh and Wayanad.

Methods: Sites were selected based on soil-transmitted helminths prevalence, different sociocultural-geographical characteristics and operational feasibility. 9-12 Years old children from 14 schools were included. The study was conducted in two rounds: baseline & follow up survey. All eligible children found positive for *A. lumbricoides* at baseline were administered supervised single tablet albendazole 400 mg under the National Deworming Day Initiative. During post-treatment follow-up survey, eligible children who provided second stool sample were included in the final analysis. Stool samples were examined using WHO recommended Kato-Katz technique. Efficacy was estimated based on cure rate (CR) and Fecal Egg Count Reduction Rate (FECRR) among children found positive in baseline and follow-up surveys.

Results: 328 Out of 625 (52.5%) were found positive for *A. lumbricoides* in the baseline survey and 85 out of 178 samples (47.8%) during post-treatment follow-up survey. Overall, the estimated CR was 52.2%. FECRR (95% *CI*) for albendazole was 72.6% (79.2%-66.0%). The FECRR was highest in East Godaveri [89.7% (96.8%-82.6%)], followed by Sundergarh [86.4% (95.3%-77.5%)] and Wayanad [69% (81.7%-56.4%)].

Conclusions: Our study confirmed overall reduction in FEC although with varying albendazole efficacy for *A. lumbricoides* infection at three different locations in India. However, these finding may be assessed in context of ongoing MDA under Filaria control program and further studies by *in vivo* as well as *in vitro* methods are required to reach to a conclusion on possible resistance if any.

KEYWORDS: Soil transmitted helminths; *Ascaris lumbricoides*; Albendazole; Efficacy

Significance

The present study was conducted in two rounds (baseline and follow-up survey) to access the efficacy of single oral dose of albendazole against *Ascaris* (*A.*) *lumbricoides* at three sites of India. In baseline survey, 328 out of 625 children found positive for *A. lumbricoides* and were given albendazole. In follow-up survey, 178 children submitted second stool samples and 85 turned positive for *A. lumbricoides*. Efficacy for albendazole was estimated in terms of CR and FECRR and assessed to be 52.2% and 72.6%, respectively. Reduced efficacy may be indicative for emergence of resistance; however, it need to be evaluated further carefully.

✉To whom correspondence may be addressed. E-mail: drshubhagarg@gmail.com

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-Non Commercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

©2024 *Asian Pacific Journal of Tropical Medicine* Produced by Wolters Kluwer-Medknow.

How to cite this article: Garg V, Garg A, Garg S, Jain SK, Dikid T, Jain S, et al. Assessment of albendazole efficacy against *Ascaris lumbricoides* at three sites of Andhra Pradesh, Odisha, and Kerala in India. Asian Pac J Trop Med 2024; 17(7): 310-316.

Article history: Received 4 September 2023 Revision 4 June 2024
Accepted 27 June 2024 Available online 25 July 2024

1. Introduction

Soil-transmitted helminths (STH) is a major public health problem and primarily caused by intestinal parasites namely *Ascaris* (*A.*) *lumbricoides*, *Necator americanus*/*Ankylostoma duodenale* and *Trichuris trichura*. Approximately more than 1.5 billion people are infected and 5.6 billion people are at risk of STH infections worldwide[1].

Considering the impact of STH infections on human health, WHO proposed the administration of periodic preventive chemotherapy (PC) with benzimidazole (BZ) drugs like albendazole (ALB), mebendazole in the population at risk, irrespective of diagnosis and intensity of infection, along with health and hygiene education and registered many success stories[2].

In India, since the year 2015, National Deworming Day is being observed on 10th February and 10th August every year wherein an estimated 110 million children and adolescents were administered PC with a single oral dose of 400 mg of ALB across 25 states/ Union Territories in year 2020 which was halted due to COVID-19 pandemic[3]; however, frequent and widespread use of BZ drugs for PC has raised suspicion of development of resistance against these drugs probably due to selection pressure. Unceasing and noteworthy development of anthelmintic drug resistance has already been reported in STH infecting livestock[4,5]. Hence, the question of anthelminthic resistance among intestinal parasites of humans, is a cause of concern. Reduced efficacy has been reported from various parts of the world across the continents which might be indicative for the emergence of the anthelminthic drug resistance in human STH[6,7]. However, available data need to be interpreted with caution. In case of proven signs of emergence of resistance, we may have to relook into our strategies to control these parasites.

In view of the above, the present study was planned to assess the efficacy of single oral dose (ALB) (administered as PC) against human STH at three sites, one each of Andhra Pradesh (AP), Odisha (OD), and Kerala (KL) in India to generate data pertaining to Indian context. However, at baseline survey, STH infections other than *A. lumbricoides* was not found hence ALB efficacy was estimated only against *Ascaris* infection.

2. Subjects and methods

2.1. Selection of study sites

For selection of study sites, an attempt was made to include sites based on different sociocultural-geographical characteristics, high helminthic prevalence and the operational feasibility of conducting the study. Accordingly, Wayanad (WD) district of KL (mountainous terrains), East Godavari (EG) district (coastal area endemic to filaria) and Sundergarh (SG) district (tribal area) were selected to carry out the present study.

2.2. Sample size estimation

Considering 30%-40% prevalence of *A. lumbricoides* infection (unpublished data from our 2016 STH survey) and 80% compliance rate, sample size was calculated using following formula to obtain at least 50 STH positive stool samples at baseline

$$\text{No. of children to be screened} = \frac{\text{No. of infected children}}{\text{Compliance rate} \times \text{Prevalence}}$$

Hence, 150-250 school children were included in the baseline survey at each study site[8] (Figure 1).

2.3. Target population

Since prevalence of STH infections is highest in school aging children globally, survey was designed to assess therapeutic efficacy of single oral dose of 400 mg of ALB against *A. lumbricoides* in school aging children aged 9-12 years[8]. Children from 14 schools [5 schools from Rajamahendravaram (RM) city, EG, AP, 5 schools from WD City, WD, KL and 4 schools from SG city, SG, OD] were included in the study which was carried out between August and September 2016.

At the beginning of baseline survey, a team from our organisation visited schools and explained about the objective of the survey and sampling method to the teachers and school children and also gave necessary instructions to the children to collect the next day morning stool sample. Written informed consent was taken from the parents of school children. School children meeting the inclusion and exclusion criteria and with written informed consent from parents were included in the baseline survey. The details of the study design are placed at Figure 1.

2.4. Parasitological examination

The WHO recommended semi-quantitative single slide Kato-Katz (KK) thick smear technique was used to determine the presence and number of STH eggs per gram (EPG) of faeces in a single stool specimen taken pre and post ALB treatment[9]. We found stool samples were infected with only *A. lumbricoides*. *A. lumbricoides* eggs counted in single KK slide were multiplied by 24 to obtain EPG. Calculation of efficacy was done on the basis of Egg Reduction Rate among SAC who were found positive in baseline survey and submitted the second stool sample in follow-up survey[8]. For quality control purpose, 10% randomly selected slides were reviewed by an expert microscopist following the egg count conducted by trained laboratory technician. None of the samples were preserved. In case of discrepancies, the slides were read again and discussed till a consensus was reached.

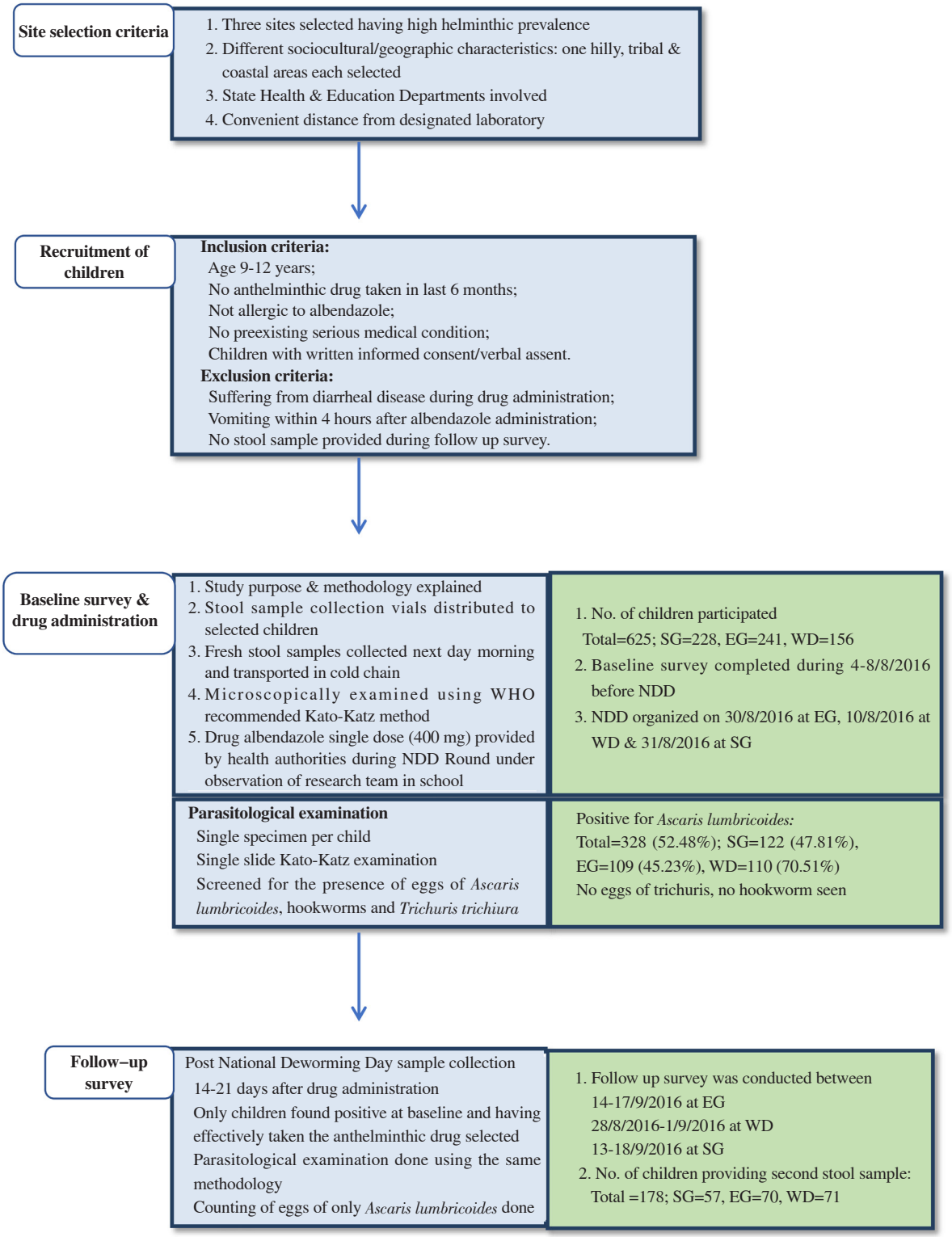

Figure 1. Albendazole efficacy study design. SG: Sundergarh, EG: East Godavari, WD: Wayanad; NND: National Deworming Day.

2.5. Data analysis

Data was compiled and analysed using Microsoft Excel and SPSS 22. Therapeutic efficacy of single oral 400 mg dose of ALB was evaluated by estimating cure rate (CR) that is proportion of children who were found positive for *A. lumbricoides* eggs at baseline survey and became negative after 14-21 days post treatment follow-up (no excretion of eggs in the stool) and faecal egg count reduction rate (FECRR) using the following formula: FECRR(%)=100% × [1-(arithmetic mean FEC at follow-up/arithmetic mean FEC at baseline)] (% reduction in EPG in post treatment samples). Based on FECRR estimates, efficacy was classified into 'satisfactory (FECRR ≥ 95%)', 'doubtful (85%≤FECRR<95%)' and 'reduced (FECRR <85%)' as per WHO criteria for a single Kato Katz.

2.6. Ethical clearance

Ethical clearance was obtained from Institutional Ethical committee, National Centre for Disease Control (NCDC), Ministry of Health and family Welfare (MoH & FW), New Delhi, India. Prior to the start of the study, written informed consent was obtained from the parents or legal guardians and verbal assent from the participating children.

3. Results

3.1. Pre and post treatment prevalence of A. lumbricoides Infection

Out of 625 recruited children in all three surveys, 328 children (52.5%) were found positive for *A. lumbricoides* infection in the baseline survey. All of them were given single dose of 400 mg ALB orally. At post-treatment follow-up, out of 178 samples analysed, 85 children (47.8%) were found positive for *A. lumbricoides* infection[8].

3.2. Cure rate (CR)

Out of 178 post treatment follow-up samples across the three sites, 93 were found to be negative for *A. lumbricoides* eggs. Overall, estimated CR (95% *CI*) was 52.2% (59.6%-44.9%). Among the three study sites, CR was highest in EG [78.6% (88.2%-69.0%)] followed by SG [52.6% (65.6%-39.7%)] and WD [15.7% (25.7%-5.7%)] (P<0.05, *Chi* square test).

Age wise CR was most pronounced for 9 years old children [64.9% (77.3%-52.5%)] and least for 10 years old [43.5% (55.2%-31.8%)] (P>0.05, *Chi*-square test). Females had higher CR [63.3% (73.9%-52.7%)] than males [43.4% (53.2%-33.7%)] (P<0.05, *Chi*–square test). Across all three survey sites, pre-treatment infection intensity was represented by Faecal Egg Count (FEC)/EPG of stool sample. Pre-treatment EPG showed inverse relationship with CR. Children who had pre-treatment EPG≤150 showed higher CR [72.1% (82.0%-62.3%] than the children with >150 pre-treatment EPG (P<0.001, *Chi* square test) (Table 1).

3.3. Faecal egg count (FEC)

Pre-treatment FEC across all three survey sites ranged from 24 to 31 680 EPG [median 192, Inter Quartile Range (IQR) 72-552], which was found to be low to moderate intensity of *A. lumbricoides* infection as per WHO criteria[10]. Post treatment FEC ranged from 0 to 6 000 EPG (median 0, IQR 0-102), represents significant

Table 1. Albendazole efficacy for *Ascaris lumbricoides* in terms of cure rate & faecal egg count reduction rate across different geographical areas, age, sex and pre-treatment FEC.

Criteria	Number of stool samples (*n*)	CR (%) (95% *CI*)	*P* value	Pre-treatment FEC (arithmetic mean)	Post-treatment FEC (arithmetic mean)	FECRR% (95% *CI*)
Location						
Sundergarh	57	52.6 (65.6-39.7)	<0.05	241.7	32.8	86.4 (95.3-77.5)
East Godavari	70	78.6 (88.2-69.0)		183.8	18.9	89.7 (96.8- 82.6)
Wayanad	51	15.7 (25.7-5.7)		2 267.3	701.6	69.0 (81.7-56.4)
Age, years						
9	57	64.9 (77.3-52.5)	>0.05	506.5	198.7	60.8 (73.4-48.1)
10	69	43.5 (55.2-31.8)		1 317.9	289.0	78.1 (87.8- 68.3)
11	52	50.0 (63.6-36.4)		432.0	148.1	65.7 (78.6-52.8)
Sex						
Male	99	43.4 (53.2-33.7)	<0.05	915.6	205.8	77.5 (85.7-69.3)
Female	79	63.3 (73.9-52.7)		653.5	235.4	64.0 (74.6-53.4)
Pre intervention EPG						
EPG≤150	80	72.1 (82.0- 62.3)	<0.001	82.5	21.0	74.6 (84.1- 64.9)
EPG>150	98	36.4 (45.8-26.9)		1 384.4	380.6	72.5 (81.3-63.7)
Total	178	52.2 (59.6-44.9)		799.3	218.9	72.6 (79.2-66.0)

CR=Cure rate, FEC=Faecal egg count, FECRR=Faecal egg count reduction rate, EPG= Eggs per gram. FECRR (%): FECRR is calculated as per WHO recommended formula using arithmetic mean of pre and post treatment FEC, and it is expressed as mean (95% *CI*).

reduction in FEC following treatment (Wilcoxon signed rank test, *Z* value -10.445, *P*<0.001). Sitewise pre-treatment FEC was highest in WD (median 1 272, IQR 432-2 640) followed by SG (median 120, IQR 72-360) and EG (median 120, IQR 72-216) (*P*<0.001, Kruskal-Wallis *H* test) (Figure 2).

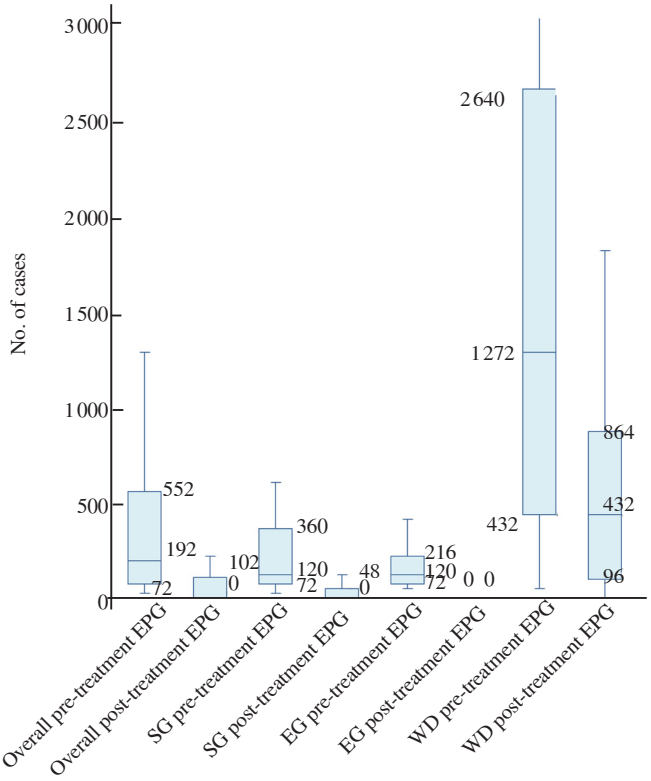

Figure 2. Overall and site wise graphical representation of fecal egg counts (FEC) expressed in eggs per gram (EPG) of stool samples before and after administration of albendazole.

3.4. Fecal Egg Count Reduction rate (FECRR)

FECRR was calculated using WHO recommended group-based formula where arithmetic mean of pre and post treatment FEC of entire group were taken into consideration instead of arithmetic mean of an individual FECRR. Overall, estimated FECRR 95% confidence interval (*CI*) of ALB was 72.6% (79.2%-66.1%), indicative of reduced efficacy. It was highest in EG [89.7% (96.8%-82.6%)], followed by SG [86.4% (95.3%-77.5%)] and WD [69% (81.7%-56.4%)].

Although the age groups were not widely placed, considerable variation was observed in FECRR at different age and gender. However, FECRR was comparable for EPG more/less than 150 (Table 1).

Negative correlation was observed between pre-treatment FEC and FECRR [(Spearman's rho=-0.35 (95% *CI* -0.48 -0.21), *t* value -4.9, *P* value < 0.001)].

4. Discussion

To the best of our knowledge, the present study is the first efficacy study of ALB against *A. lumbricoides* conducted in India across three distinct geographical areas. We estimated CR and FECRR for a single oral dose of ALB for *A. lumbricoides* infection. Overall CR was 52.2% while FECRR was 72.6% which might indicate reduced efficacy at our study sites as per WHO benchmarks[8]. The findings of the study correspond to study conducted by Krucken *et al.* in 12 schools in the Huye district of Rwanda where they had 75.4% FECRR[7]. However, the results aren't in line with the observations of studies which indicated that single dose ALB is the most effective treatment against *A. lumbricoides* infections and has efficacy >95%[11–14].

CR was lesser than FECRR across the different sites, age, sex and pre-treatment FEC which is in agreement with other studies[11,12]. The reason might be that drug into consideration would have not completely cured the infection (determined by no excretion of eggs in the stool) but reduced the relative intensity of infection measured by reduced excretion of eggs in the stool following treatment.

WHO has endorsed FECRR calculated by arithmetic mean of pre- and post-treatment FEC of the group as most robust and recommended parameter for assessing drug efficacy in the field, over CR or geometric mean or Arithmetic mean of reduction of FEC of an individual. CR is very sensitive criteria, highly affected by sample size, pre-treatment FEC and diagnostic modality. It may be overestimated, if study sample size is insufficient or underestimated if an overtly sensitive diagnostic technique is used for the detection of parasite eggs. Underestimated results may be found in the situations where intensity of infection (FEC) was high before the intervention (pre-treatment FEC)[15].

Initial intensity of infection or pre- treatment FEC appeared to have influence on FECRR too, though FECRR is unaffected by other variables. In our study, the sample size was sufficient as per the WHO benchmarks. More than 50 subjects could be finally analysed with paired stool samples at each of the three trial sites. KK was the diagnostic modality used which has shown no significant difference in FECRR when compared with Mac master egg counting method in earlier studies[16]. Out of three sites, we found least efficacy (CR & FECRR) in WD (15.7% & 69% respectively) where pre-treatment FEC arithmetic mean was highest (2 267.3) among all three sites. Bennett *et al* reviewed individual studies which have exhibited a reduction in CR & FECRR with high intensities of STH infections[14]. For *A. lumbricoides*, Levecke *et al.* demonstrated that the FECRR after treatment with ALB remained unchanged across mean FEC at pre-intervention, but that the FECRR after MEB treatment declined on average by 0.4% for each 1 000 EPG incremental increase in mean FEC at pre-intervention[12]. In present study also, we observed low negative correlation between pre-

treatment FEC and FECRR; however, bigger scale studies with sampling primarily from the areas with high intensity infection are warranted to validate these findings.

In addition to above, geographical conditions like hilly area, temperature and humidity compatible for the longer survival of parasite eggs in the soil and involvement of the local population in the high-risk professions like tea picking *etc.* might also be contributing factors for continuous transmission of infective stages of parasites in WD and would have resulted in reduced efficacy of ALB treatment at that site[17-20].

CR and FECRR were the most pronounced in EG (78.6% and 89.7%, respectively). Other factors like awareness about water, sanitisation & hygiene (WASH) interventions in the local population or regular ALB administration through national lymphatic filariasis control program might have contributed to the results. SG where tribal predominant population inhabits, is neighbouring filarial endemic districts of Odisha. Efficacy results should be evaluated carefully at these sites considering other native factors at play.

Bennett & Guyatt *et al* has evaluated that ALB showed lower efficacy in Asian countries compared with other regions of the world (Africa, central & south America)[14]. The possible explanation for this apparent geographic variation includes treatment history, genetic differences in the STH species, the quality of the drug administered and host related factors[11,15].

Similar to our study, Krucken *et al.* when estimated reduced efficacy in Rwanda, investigated a total of 144 *Ascaris* samples for the occurrence of single nucleotide polymorphism (SNP) in the codon 167, 198 and 200 from all four β-tubulin isotypes[7]. No putative SNP responsible for resistance was detected in the study which raise the understanding that variation in drug efficacy is not always a surrogate indicator that suggest the emergence of genetically resistant worms, but rather, depends on the frequency of transmission, initial intensity of infection, consumed drug quality and many biological factors related to host and parasite like stool consistency, dietary fibre content *etc.*

Diet, any clinical condition like gastrointestinal disorder, malnutrition or immunodeficiency, drugs like anti-inflammatory drugs, antibiotics also have effect on pharmacokinetic and dynamics of anthelminthic drug. Extensive pharmacology studies on BZ drugs especially more commonly used ALB drug in children should be designed in this context.

Variation in efficacy across the host age and sex may also be explained by above confounding factors albeit, individual's personal hygiene, life style, sanitation and wash habits are not less important. In present study, there was 9 occasions when post treatment FEC was higher than pre-treatment FEC of *A. lumbricoides* following chemotherapy as observed in other studies[11,12,21]. This may be best explained by findings of the Kopp *et al* where considerable proportion of the pre adult worm population survived despite adequate PC, resulted in density dependent fecundity consequently impacting FEC and FECRR[21].

Although, above confounding factors appear to be valid and have been examined *in vivo* in the field but confirmation data by *in vitro* assays, performed in the laboratory are still lacking; however, should be taken at priority as advocated by other studies too[11,12,15].

In this study, high attrition rate (54.3%) was observed in follow up survey and positivity for STH other than *A. lumbricoides* was not found, hence we could not assess efficacy of ALB on other STH infections. Also, effect of the biological factors related to host and parasite could not be fully evaluated in our study which may be considered as the limitations of our study, however, in conclusion, our study confirms overall reduction in FEC although with varying ALB efficacy for *A. lumbricoides* infection in three different geographic locations in India. These finding need to be assessed in the context of ongoing Mass Drug Administration for Filaria control program. There is need for further studies which evaluate confounding factors responsible for such findings extensively and reach a conclusion possibly by *in vivo* as well as *in vitro* methods. Overall, cohesive approach including periodic and regular treatment with optimal drug regimens, careful evaluation of early warning signs of emerging drug resistance and improvement in basic sanitation and health education are the key elements for the successful operation of STH control programme in India.

Conflict of interest statement

The authors declare no potential conflicts of interest.

Funding

The authors received no extramural funding for the study.

Authors' contributions

VG conceptualised the manuscript. VG and A Garg visited schools and helped in sample collection and data acquisition. Data compilation, analysis and interpretation and manuscript draft were prepared by SG. VG and A Garg edited a draft and revised it critically for important intellectual content. SKJ monitored and facilitated the field process as departmental head. TD reviewed statistical analysis and manuscript as a whole. JM reviewed manuscript. AM provided guidance and clarity on WHO criteria whenever there was confusion in interpretation. A Goel supervised and supported overall work as organisation head. All authors gave their consent and approval to the final manuscript version to be sent for the publication.

References

[1] World Health Organisation. *Soil-transmitted helminth infections*. [Online]. Available from: https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections. [Accessed on 21 November 2022].

[2] World Health Organization. *Investing to overcome the global impact of neglected tropical diseases: Third WHO report on neglected diseases 2015*. Geneva: World Health Organization; 2015. [Online]. Available from: https://apps.who.int/iris/handle/10665/152781. [Accessed on 21 November 2022].

[3] Ministry of Heath & Family Welfare (MoHFW). *Evidence-based Impact of National Deworming Day in India*. [Online]. Available from: https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=1666053. [Accessed on 29 December 2022].

[4] Bosco A, Kiebler J, Amadesi A, Varady M, Hinney B, Ianniello D, et al. The threat of reduced efficacy of anthelmintics against gastrointestinal nematodes in sheep from an area considered anthelmintic resistance-free. *Parasit Vectors* 2020; **13**(1): 457.

[5] Peña-Espinoza M. Drug resistance in parasitic helminths of veterinary importance in Chile: Status review and research needs. *Austral J Vet Sci* 2018; **50**: 65-76.

[6] Vercruysse J, Albonico M, Behnke JM, Kotze AC, Prichard RK, McCarthy JS, et al. Is anthelmintic resistance a concern for the control of human soil-transmitted helminths? *Int J Parasitol Drugs Drug Resist* 2011; **1**(1): 14-27.

[7] Krücken J, Fraundorfer K, Mugisha JC, Ramünke S, Sifft KC, Geus D, et al. Reduced efficacy of albendazole against *Ascaris lumbricoides* in Rwandan schoolchildren. *Int J Parasitol Drugs Drug Resist* 2017; **7**(3): 262-271.

[8] World Health Organization. *Assessing the efficacy of anthelminthic drugs against schistosomiasis and soil-transmitted helminthiases*. Geneva: World Health Organization; 2013. [Online]. Available from: https://www.who.int/publications/i/item/9789241564557. [Accessed on 21 November 2022].

[9] WHO bench AID for Field/Laboratory Procedures. *Bench aids for the diagnosis of intestinal parasites*. 2nd ed. [Online]. Available from: https://www.who.int/publications-detail-redirect/9789241515344. [Accessed on 21 November 2022].

[10] World Health Organization. *Helminth control in school-age children: a guide for managers of control programmes*. Geneva: World Health Organization; 2011. [Online]. Available from: https://apps.who.int/iris/handle/10665/44671. [Accessed on November 21 2022].

[11] Vercruysse J, Behnke JM, Albonico M, Ame SM, Angebault C, Bethony JM, et al. Assessment of the anthelmintic efficacy of albendazole in school children in seven countries where soil-transmitted helminths are endemic. *PLoS Negl Trop Dis* 2011; **5**(3): e948.

[12] Levecke B, Montresor A, Albonico M, Ame SM, Behnke JM, Bethony JM, et al. Assessment of anthelmintic efficacy of mebendazole in school children in six countries where soil-transmitted helminths are endemic. *PLoS Negl Trop Dis* 2014; **8**(10): e3204.

[13] Keiser J, Utzinger J. Efficacy of current drugs against soil-transmitted helminth infections: Systematic review and meta-analysis. *JAMA* 2008; **299**(16): 1937-1948.

[14] Bennett A, Guyatt H. Reducing intestinal nematode infection: Efficacy of albendazole and mebendazole. *Parasitol Today Pers Ed* 2000; **16**(2): 71-74.

[15] Coles GC, Bauer C, Borgsteede FHM, Geerts S, Klei TR, Taylor MA, et al. World Association for the Advancement of Veterinary Parasitology (W.A.A.V.P.) methods for the detection of anthelmintic resistance in nematodes of veterinary importance. *Vet Parasitol* 1992; **44**: 35-44.

[16] Albonico M, Ame SM, Vercruysse J, Levecke B. Comparison of the Kato-Katz thick smear and McMaster egg counting techniques for monitoring drug efficacy against soil-transmitted helminths in schoolchildren on Pemba Island, Tanzania. *Trans R Soc Trop Med Hyg* 2012; **106**(3): 199-201.

[17] Wardell R, Clements ACA, Lal A, Summers D, Llewellyn S, Campbell SJ, et al. An environmental assessment and risk map of *Ascaris lumbricoides* and *Necator americanus* distributions in Manufahi District, Timor-Leste. *PLoS Negl Trop Dis* 2017; **11**(5): e0005565.

[18] Saathoff E, Olsen A, Kvalsvig JD, Appleton CC, Sharp B, Kleinschmidt I. Ecological covariates of *Ascaris lumbricoides* infection in schoolchildren from rural KwaZulu-Natal, South Africa. *Trop Med Int Health* 2005; **10**(5): 412–422.

[19] Mekonnen Z, Getachew M, Bogers J, Vercruysse J, Levecke B. Assessment of seasonality in soil-transmitted helminth infections across 14 schools in Jimma Town, Ethiopia. *Pan Afr Med J* 2019; **32**: 6.

[20] Fenta A, Mesganaw B, Belachew F, Teshale G, Abebaw G, Tesfa E, et al. Prevalence and risks of soil transmitted helminths among Ethiopian school children: A cross-sectional study. *Asian Pac J Trop Med* 2022; **15**(3): 121-127.

[21] Kotze AC, Kopp SR. The potential impact of density dependent fecundity on the use of the faecal egg count reduction test for detecting drug resistance in human hookworms. *PLoS Negl Trop Dis* 2008; **2**(10): e297.

Publisher's note

The Publisher of the *Journal* remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Edited by Lei Y, Zhang Q, Pan Y