

Efficacy of albendazole against *Giardia* and hookworm in a remote Aboriginal community in the north of Western Australia

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Abstract

The parasitological, clinical efficacy and tolerability of albendazole in the treatment for both giardiasis and hookworm infection in a remote Aboriginal population was investigated. Albendazole at a dose rate of 400 mg daily for 5 days was highly effective in reducing hookworm egg numbers and both *Giardia* antigen and cysts. The 36.6% prevalence of *Giardia* prior to treatment fell to 12% between days 6 and 9, 15% for days 10–17 and rose to 28% between days 18 and 30. Tolerability and clinical efficacy were excellent. The effect of albendazole on hookworm was longer lasting than that on *Giardia*, reducing percent infection from over 76–2% on days 6–9 and zero by day 18–30 despite conditions highly conducive to rapid re-infection. We conclude that albendazole is highly efficacious against both parasites when used as described but that long term community benefit may require additional education programmes to avoid re-infection with *Giardia* although treatment strategies would seem appropriate for hookworm. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

Enteric parasites, particularly hookworm and *Giardia*, are important causes of morbidity in Aboriginal communities in Australia (Hopkins et al., 1997a), and their presence is of particular concern in children by contributing to poor weight gain and failure to thrive (Roberts et al., 1988). The existence of hookworm infections in Australia has been recognised for some time, but to date there is little quantitative information on the pattern of infection in affected communities. For example, in relation to host sex or age or to other variables (such as crowding, occupation etc.) which might influence susceptibility to and risk of infection (Prociv and Luke, 1995a). African studies also indicate that poor growth, physical activity, fitness and probably cognitive function are linked to these infections and it is known that at least some of these effects can be reversed by effective anthelmintic therapy (Stephenson et al., 1993a).

Hookworm infection (*A. duodenale*) requires treatment since parasites live for several years and may lower haemoglobin levels, even if infection is light, particularly in undernourished patients (Botero, 1986; Hopkins et al., 1997a). Against hookworm, pyrantel, mebendazole and albendazole are used but there are disturbing reports of lack of efficacy with both pyrantel and mebendazole (Mani et al., 1993; De Clercq et al., 1997). Current treatment for *Giardia* infestation in humans involves the use of nitroimidazoles. Although effective, metronidazole treatment is frequently accompanied by severe nausea, and while tinidazole is less toxic, its taste can induce vomiting and poor patient compliance, especially in children. There is therefore a justification to develop further treatments, preferably with a different mode of action to current medication for *Giardia* infection.

Albendazole has the broadest spectrum of activity of the benzimidazoles released to date (including *Giardia*) and has been widely used in human clinical medicine as a safe anthelmintic with high activity against larval and adult stages of nematodes and cestodes (Hall and Anwar, 1991; Reynoldson et al., 1992; Horton, 1997). Further advantages in addition to its vermifugal property, are its larvicidal and ovicidal activity (Maisonneuve et al., 1985).

Against hookworm, a single oral dose of 400 mg has been shown to be highly effective against *A. duodenale* and *Necator americanus* although there have been some reports of lower efficacy which appear to result from differences in intensity of infection and geographical strain of parasite (Botero, 1986). While there have been reports of efficacy below 70% against 'hookworm' (Ramalingham et al., 1983) other studies have shown cure rates of 100% against both *A. duodenale* and *N. americanus* (Pene et al., 1982; Rossignol and Coulaud, 1983).

Reports from China (Zhong et al., 1986; Cheng-i, 1988) and later, Iran (Al-Waili, 1987; Al-Waili et al., 1988; Al-Waili, 1990) of an incidental effect of mebendazole

against pure *Giardia* infections suggested a useful clinical effect although this has been disputed by other workers (Gascon et al., 1989). These findings resulted in a formal in vitro study of the activity of albendazole against *Giardia* (Meloni et al., 1990). A marked inhibitory effect with minimum inhibitory concentration (MIC) and minimum lethal concentration (MLC) values lower than tinidazole and metronidazole was demonstrated. Efficacy was confirmed in rodent species in vivo Reynoldson et al. (1991). Hall and Anwar (1991) showed, in a small clinical study of mixed infections of parasites in Bangladesh, that albendazole is effective against *Giardia* and, more recently, Hall and Nahar (1993) have shown a dose related clearance of *Giardia* infection with albendazole.

Thus our aim was to focus on a community which has had a history of infection with many enteric parasites including, in particular, hookworm and *Giardia*. In order to optimise future control programmes for these infections in this community, we characterised parasite prevalence and intensity, and assessed the parasitic and clinical efficacy of albendazole against the human intestinal parasites *G. duodenalis* and *A. duodenale*.

2. Materials and methods

The trial commenced in May in a coastal Aboriginal community in Western Australia within the tropics where the average rainfall is 1190 mm and the mean number of rain days is 84, most of which occur between November and March.

2.1. Study protocol

The study was carried out as an open non-comparative trial. The population of approximately 300 people was known to have endemic hookworm infection and giardiasis. Residents aged 2 years and more who were infected with either *Giardia* or hookworm, or both, were treated and patients of both sexes were admitted to the study after their, or parental, informed consent was obtained. Female patients of child bearing age underwent a pregnancy test and a negative result was required before admission to the study. Exclusion prior to the study included: patients receiving or who had received anthelmintics during the 10 days prior to commencing the study; patients with acute illness, with or without fever; patients with significant proteinuria or history of blood dyscrasias; pregnant women and those of child-bearing potential (unless adequate contraception was in use) defined as use of intrauterine devices and oral contraceptives but excluding condoms, spermicides, pessaries and similar methods) because of the possible effects on the foetus; mothers who were breast feeding; patients with known hypersensitivity to either albendazole or mebendazole; patients for whom any of the treatments used in the study were contraindicated. As many members of the population as possible were assessed prior to treatment to determine the prevalence of both *Giardia* and hookworm infection in the community. Prior permission was granted by the community leaders and the study was carried out under the auspices of the Australian CTN (Clinical

Trial Notification) scheme, submitted to an ethical review committee (Murdoch University IEC) and written unconditional approval obtained from both IEC and the community leaders before commencement.

Immediately prior to entering the study, each patient underwent a complete physical examination and two stool samples were collected at an interval of several days for laboratory analysis to confirm infection with *G. duodenalis* and/or hookworm (*A. duodenale*). Albendazole ('Zentel', SmithKline Beecham) 2% suspension containing 200 mg albendazole/10ml for oral administration or 200 mg tablets for oral administration were administered according to the following dose schedule: children under 5 years of age, single 400 mg dose (20 ml suspension) of albendazole daily for 5 days; adults and children over 5 years of age, 400 mg (two 200 mg tablets) of albendazole daily for 5 days. Patients were withdrawn from the efficacy analysis if they had not taken at least 80% (four doses) of the medication within 7 days but these patients were followed up wherever possible to assess safety and tolerability at visits specified. Similarly, patients were withdrawn if adverse events required discontinuation of therapy, when deterioration of condition required alternative therapy.

Stools were collected between days 2 and 5 during treatment to estimate the rate at which the parasites were cleared. Symptoms (diarrhoea, abdominal pain, nausea, vomiting, anorexia, weakness) were recorded pre-treatment and daily for the first 6 days after treatment initiation and scored as mild, moderate or severe. Stools were collected again between days 6–9, 10–17 and 18–30 after initiation of treatment for assessment of clearance of the parasites. A follow up study was conducted at 5, 11, 34 and 41 months after the initial treatment. Symptoms were assessed as described above.

2.2. Laboratory methods

Both *Giardia* cysts and hookworm eggs were identified in fresh faecal material (less than 24 h old) by a zinc sulphate flotation method and direct faecal microscopic examination. A quantitative Kato-Katz egg count was carried out if direct microscopy was positive (Katz et al., 1972) according to the WHO guidelines and kits supplied by WHO were used for this test. The intensity of infection was calculated as eggs/g of faeces (EPG) and then adjusted for stool consistency and age, using WHO guidelines (World Health Organisation, 1961) and hookworm eggs were identified (some random positive samples were cultured to identify hookworm species). Correction for the age group <4 years varied very slightly from WHO guidelines in that the EPG was divided by 1.33 instead of the recommended 2 to make the age corrections more linear. An ELISA test ('CELISA', Cellabs, Brookvale, NSW, Australia) was used for assessment of *Giardia* antigen in faeces. In previous work with the CELISA we have demonstrated a diagnostic sensitivity of 100% and a specificity of 91% with human stool samples in the field (Hopkins et al., 1992). ELISA results are used for analysis throughout.

2.3. Statistical analysis

The results are presented as prevalence and as adjusted EPG data (mean \pm SEM). The EPG data were analysed by GLIM (A statistical system for generalised linear interactive modelling; GLIM 4, PC version, Royal Statistical Society 1993) as described previously using a model with negative binomial errors and an identity link function (Crawley, 1993; Behnke et al., 1994). We entered EPG values for the individuals whose stools were examined by the Kato-Katz method (295) and zero values for all remaining individuals whose stools did not yield hookworm eggs by the salt flotation method. Host sex and age were entered as factors in the analysis. The latter comprised eight age cohorts with the following ranges: ≤ 4 , 5–9, 10–14, 15–19, 20–29, 30–39, 40–49, ≥ 50 . Relationships between variables were examined by the Spearman Rank Order Correlations Test (R_s). Contingency tests were carried out for all four most common parasites for prevalence by sex; age group; before versus after treatment; by household; co-occurrence of parasites using the 'StatView 4.02' computer package. Corrected values for eggs/g (from Kato Katz scores) were also compared using standard non-parametric tests. Prevalences were transformed using arcsin square root before the use of ANOVA for the geographic distribution analysis.

3. Results

Of 295 people assessed, 203 met the criteria and gave subsequent samples but sampling was not complete and as the study progressed the numbers of people assessed on each occasion was a subset of the initial cohort. In all cases (except at 41 months, a random sample of the whole population) samples were from only those who satisfied our inclusion criteria and had been treated.

3.1. Pre-treatment prevalence

3.1.1. *G. duodenalis*

The prevalence of *Giardia* infection in the population was 36.6% ($n = 295$) (Fig. 1). Prevalence was maximal in the 5–9 year group (65% infection), and declined with age to below 8% in the over 40 year group (Fig. 1). There were no significant differences in prevalence between males and females.

3.1.2. Hookworm

Hookworm prevalence was more uniform, ranging from 76% in the 20–29 year group to 85% in the 5–9 year group (Fig. 1). The overall prevalence of hookworm in the population was 80% (236 of 295 people tested).

3.1.3. Other enteric parasites

Hymenolepis nana was a common parasite identified in this study (30%). The highest prevalence was in age groups 5–9 years (57%), 10–14 years (60%) and

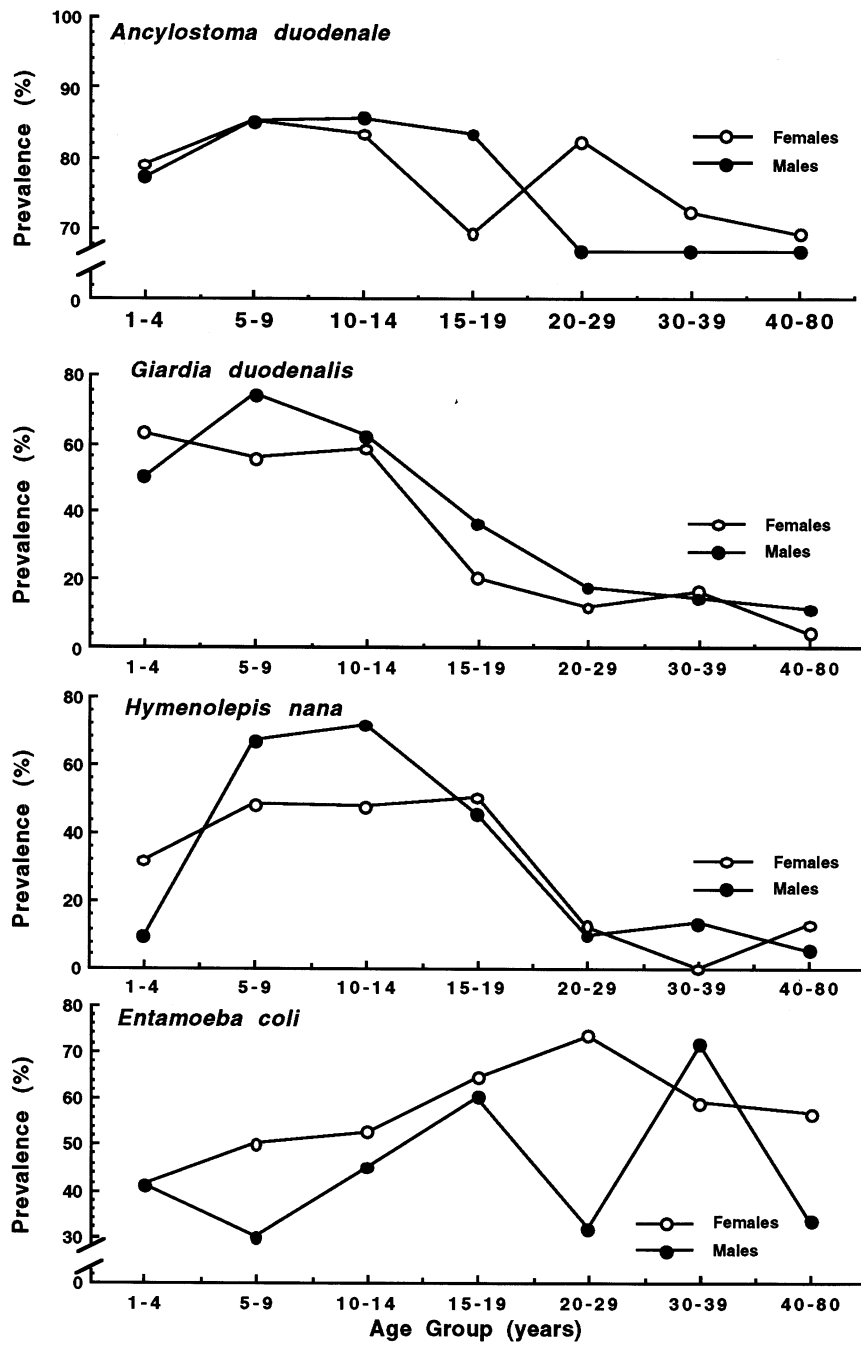


Fig. 1. Prevalence of hookworm (*A. duodenale*), *G. duodenalis*, *H. nana* and *E. coli* in the population. All members of the community were assessed for parasite infection.

15–19 years (48%), Fig. 1. *Entamoeba coli* was also identified in 50% of people assessed with the prevalence in groups 1–4 years (41%), 5–9 years (39%), 10–14 years (49%), 15–19 (62%), 20–29 (57%), 30–39 (65%), 40–80 (46%), Fig. 1. *Strongyloides* was only rarely observed in this community (8/298, < 3%). There was significant positive co-occurrence between *H nana* and *Giardia* ($\chi^2 = 18.5$, $df = 1$, $P < 0.0001$) and hookworm ($\chi^2 = 7.2$, $df = 1$, $P < 0.01$).

3.2. Hookworm infection pre-treatment

3.2.1. Distribution of infection and prevalence overall

The adjusted EPGs conformed to a negative binomial distribution with a k value of 0.063. The frequency distribution is illustrated in Fig. 2, which shows that the categories corresponding to 100–499 and 1000–4999 EPG had the highest numbers of individuals. 12 subjects had > 5000 EPGs and the highest count was over 71000 in a 17-year-old female. Overall, the mean intensity of infection was 1106 ± 256 EPG ($n = 295$). Of the 295 subjects for whom sex and age were recorded, 141 were males and 154 females.

3.2.2. Age-prevalence and age intensity

Summary statistics are illustrated in Figs. 1 and 2. The mean intensity of infection rose from a low among the 4 year old children to a peak among the 5–9 year old group and then drifted downwards. There was a highly significant effect of age on EPGs (Table 1), attributable partly to the lower mean EPGs among the = 4, 30–39 and 40–49 cohorts compared with the 5–9 years cohort.

3.2.3. Effect of sex

The prevalence of infection was very similar in both sexes (Fig. 1), dipping after the 30–39 age cohorts. There was no main effect of host sex on EPGs despite the high mean EPG for female (all age cohorts combined) relative to male subjects (males = 753 ± 119 , females 1422 ± 476). The high mean count among females arose because two female subjects, both aged 17, had EPGs of 71000 and 15000 respectively, the highest two infections. When these two counts were omitted the mean EPG for females was 876 ± 116 (Fig. 2b).

There was a significant interaction between age and sex (Table 1) and this is primarily attributable to the difference in EPGs between the sexes among subjects in the 30–39 and 40–49 years cohorts (Fig. 2b), in which EPGs declined more steeply with age among male compared with female subjects.

3.2.4. Pre-treatment geographic distribution of hookworm

The 295 subjects in the study resided in 33 households. Between one and 24 subjects/household were sampled. There were significant correlations between prevalence of *Giardia* infection and the total number of people in a house and the number of children below 14 years of age in a house (ANOVA with arcsin square root transformation; $F = 4.98$, $P < 0.001$; $F = 6.64$, $P < 0.001$ respectively).

Similar results were obtained for hookworm. We analysed the effect of household size by a 1-way ANOVA with negative binomial errors, and this gave scaled deviance $\chi_{32}^2 = 107.167$, $P < 0.001$. Therefore there were highly significant differences in the intensity of infection between households. It is clear from the analysis

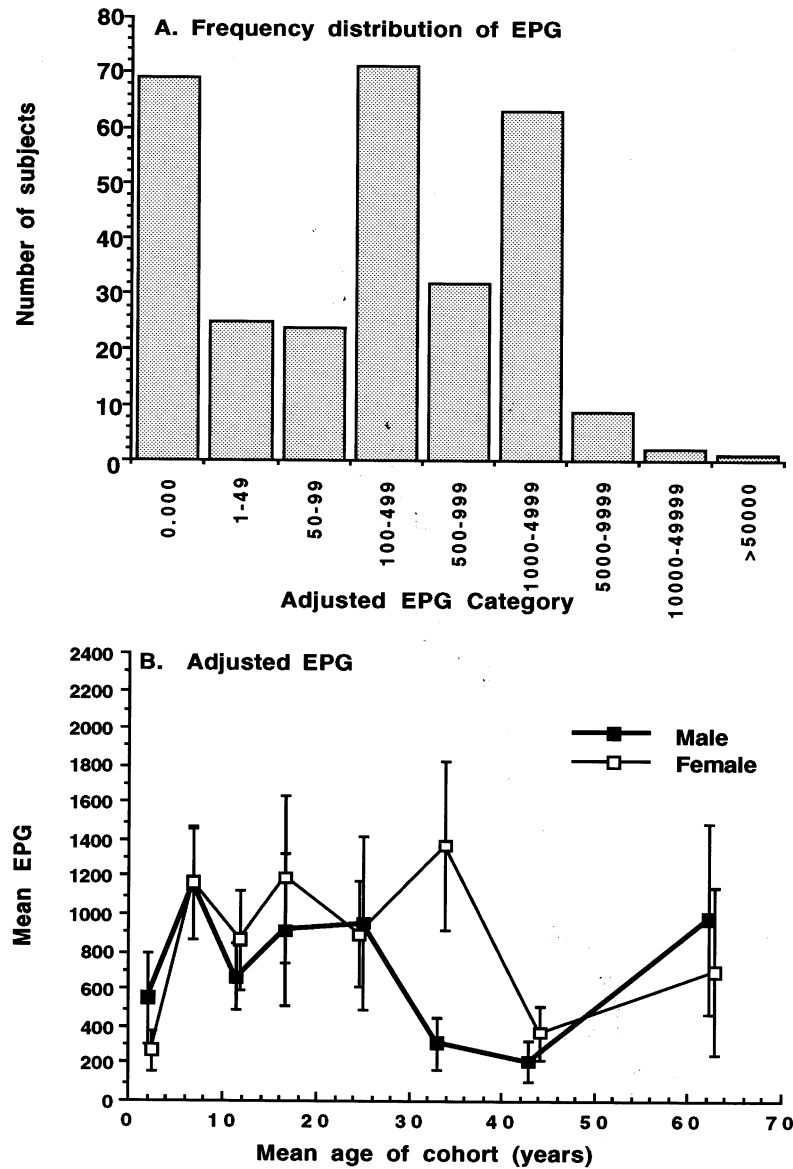


Fig. 2. Frequency distribution of adjusted *A. duodenale* faecal egg counts (EPG) in the community. Categories correspond to limits of EPG as shown on the horizontal axis and are non-linear. B: Sex distribution of worm burden by age for 295 participants prior to treatment.

Table 1

Statistical analysis of the factors affecting the intensity of infections with *A. duodenale*, both gender and age as factors, through a 2-way ANOVA with negative binomial errors

Source of variation	Change in scale deviance ^a	Scale parameter	Degrees of freedom	Scaled deviance ^b	<i>P</i>
Sex	3009	2335	1	1.289	NS
Age	58 377	2497	7	23.379	<0.005
Sex × age interaction	49 139	2353	7	20.884	<0.01

^a Change in deviance following the removal of the combination specified in 'source of variation' column from the full factorial model. We begin by removing the age and sex interaction from the model and then remove the main effects one at a time, replacing them before proceeding to the next effect, in the order from the base of the table towards the top.

^b Scaled deviance is a measure of the contribution of the factor specified under the column labelled 'source of variation' to explaining the variation in the data. It is calculated by fitting an analysis of variance with negative binomial errors through GLIM and is distributed as χ^2 . For the full factorial model the scale parameter was 2236. For full details see Behnke et al. (1994).

that there were some clusters of infection, such that certain houses were identified where the intensity of infection was very high and others in which intensity was low. Similarly there was much variation in prevalence between households and clear evidence of aggregation, particularly close to areas such as the store and school.

For hookworm we also examined the relationship between the average intensity of infection of subjects and the number of persons resident in each household. There was a significant positive relationship identified ($R_s = 0.404$, $n = 33$, $P = 0.02$). However, the number of children varied between households and therefore it was necessary to control for age-related differences in egg counts. Likewise the interaction between age and sex had to be taken into account. We therefore standardised individual EPGs by age and sex (re-expressed the data for each subject as the number of SD from the mean of that particular single sex age cohort) and then averaged these values by household. The relationship between the standardised EPGs and the number of residents remained significant ($R_s = 0.375$, $n = 33$, $P = 0.031$).

3.3. Hookworm species

Identification of hookworm larvae as *A. duodenale* was made following faecal culture in charcoal using standard techniques (Beaver et al., 1984). In addition, a single adult worm was recovered in faeces after drug treatment and was identified as *A. duodenale* based on the structure of teeth in the buccal capsule. Specimens have been deposited in the Museum of Western Australia, Perth, under registration numbers WAM 1-97 (larvae) and WAM 2-97 (adult).

3.4. Albendazole treatment effects

Since the conditions for inclusion in the analysis were that the patients must take at least 80% of the doses and provide at least one stool sample before and after treatment the numbers in this analysis (a total of 203 representing all included subjects) were fewer than in the sections above in which pretreatment parasite burdens were characterised. Tolerability of albendazole was good with 89% of recipients grading the drug as excellent, 1% as good, 1% as moderately good. Another 9% gave no response. Adverse experiences were recorded in five patients (1.9% of those treated). Mild abdominal pain was recorded in two patients, mild or moderate diarrhoea in two patients, moderate fever in one patient and weakness in one patient. Prevalence of both parasites was greatly reduced by treatment (Table 2).

3.4.1. *Giardia*

Following treatment with albendazole, infection with *Giardia* in the population fell markedly to 11% during treatment (days 2–5), was 12% immediately after treatment (days 6–9), rose to 15% by days 10–17, returned to 28% by days 18–30 and was 27% at 5 months following treatment (Fig. 3). Eleven months after treatment *Giardia* prevalence was only 8%. At 34 months after the 5-day treatment regime, *Giardia* prevalence was 40% in the population (Table 2) and at 41 months was 22%. When prevalence was assessed on an age-related basis, the reduction in

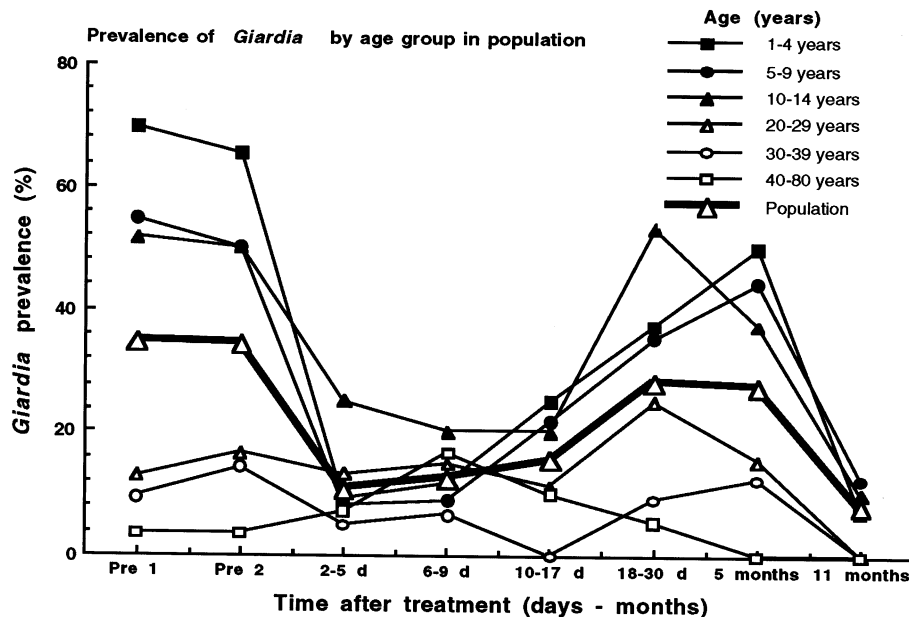


Fig. 3. Reduction in prevalence of *Giardia* in age groups and the population over time after a five day course of treatment with albendazole.

Table 2
Prevalence of *Giardia* and hookworm in the population prior to, and following 5 days treatment with 400 mg albendazole

	Pre (all)	Pre (trial)	2–5d	6–9d	10–17d	18–30d	5 mo	11 mo	34 mo	41 mo
Hookworm (%)	80	82	14	2	1	0	12	10	31	41
N	295	202	198	179	165	152	95	98	108	54
Female/male	154/141	111/91	107/91	98/81	89/76	82/70	56/39	53/45	58/50	24/30
<i>Giardia</i> (%)	36	43	11	12	16	28	27	8	40	22
N	295	202	187	154	134	114	88	101	108	54
Female/male	157/138	111/91	106/81	86/68	77/57	67/47	51/37	54/47	58/50	24/30

Percent prevalence of hookworm and *Giardia* in the population prior to treatment (Pre-all) and in that subset included in the efficacy analysis (Pre-trial) prior to and up to 41 months following 5 days treatment with 400 mg albendazole (columns 3–10). For hookworm and *Giardia* analysis and subsequent follow-up 202 people met the protocol criteria. N represents the number of people included in the study initially (Pre-all) and in subsets of that group assessed at various times thereafter.

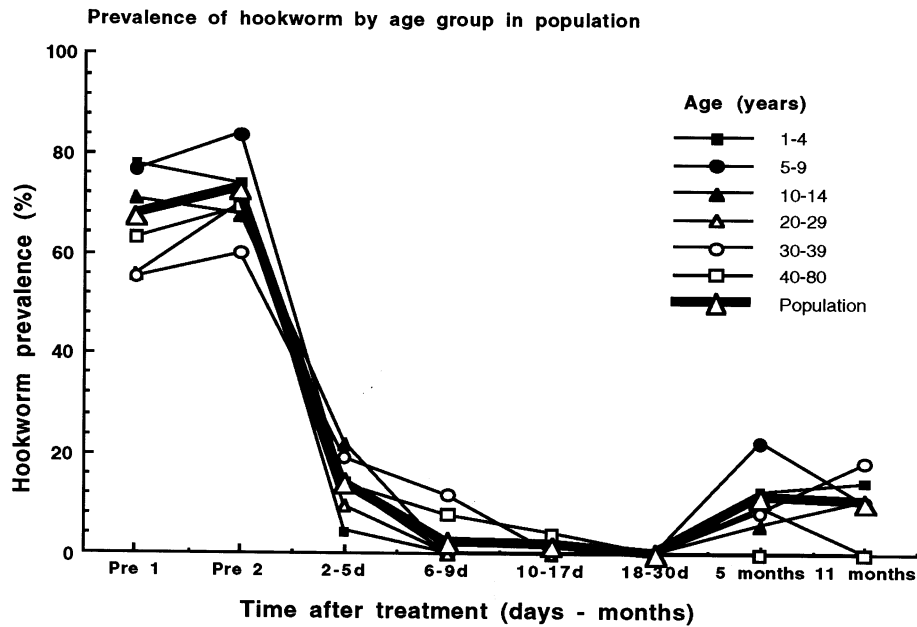


Fig. 4. Reduction in prevalence of hookworm in age groups and the population over time after a five day course of treatment with albendazole.

Giardia prevalence was similar between age groups with prevalence reduced below 10% in the groups with the greatest prevalence (1–4 and 5–9 years) by days 6–9 whereas those above this age took until days 10–17 or 18–30 to clear the infection (Fig. 3). There were no significant differences between males and females in reduction of parasite prevalence or in rate of reinfection.

If only those patients positive for *Giardia* prior to treatment were assessed, prevalence fell to 13% by days 2–5 but rose rapidly to 20% by days 6–9, 31% by days 10–17, 43% by days 18–30, 57% by 5 months, 13% at 11 months.

3.4.2. Hookworm

Hookworm appeared to be more sensitive to albendazole than *Giardia*, and was eliminated from all age groups. The population prevalence fell to 14% by days 2–5, 2% by days 6–9, 1% by days 10 to 17 and 0% by days 18–30 (Table 2). Prevalence was 12 and 10% at 5 and 11 months respectively (Fig. 4). At 34 months after treatment hookworm prevalence was 30.6% and at 41 months was 41%.

As with *Giardia*, when prevalence was assessed on an age-related basis, the reduction in hookworm prevalence was similar among age groups with prevalence reduced to 0 (or close to 0) in people up to 29 years by days 6–9 whereas those above this age took until days 18–30 to clear the infection (Fig. 4).

Intensity of hookworm infection averaged 921 ± 125 (SEM) eggs/g (EPG) prior to treatment and fell to 47 EPG by days 2–5, 3.5 EPG by days 6–9, 8.3 EPG by

With respect to *Giardia*, there was no evidence of any aggregated geographic distribution although there was a correlation between *Giardia* infection and both total numbers of inhabitants in a house and numbers of children below the age of 14. This is not unexpected since it illustrates the faecal-oral nature of the transmission of *Giardia* which is likely to be enhanced in houses with large numbers of inhabitants and/or children. This is further illustrated by the distribution of *H. nana* and *E. coli* which have similar age related prevalence and mode of transmission. Our present results have also shown that the same individuals rapidly become reinfected with *Giardia* and this may suggest a lack of immunity following previous exposure. However, our previous studies have shown that a number of strains of *Giardia* are present in this community and it remains to be determined whether individuals are becoming reinfected with antigenically different strains (Meloni et al., 1995; Hopkins et al., 1997b).

In many parts of the world albendazole is one of the drugs of choice in the treatment of hookworm infections along with pyrantel pamoate and mebendazole. Albendazole has the advantage that single dose treatments are effective against many species of nematodes although higher doses are necessary to treat *Strongyloides* (Coulaud et al., 1982) and multiple doses necessary for *Giardia* (Hall and Nahar, 1993). Pamba et al. (1989) have also shown that albendazole is effective against hookworm, *Ascaris*, *Trichuris* and *Hymenolepis* and they advocate the use of a drug such as albendazole which is effective in treating polyparasitism to improve nutritional status.

Our results with albendazole against *Giardia* agree well with previous studies by Hall and Nahar (1993) in which five doses of 400 mg produced a 95% reduction in *Giardia* prevalence. Similarly, the reduction of hookworm obtained with albendazole in this community agrees well with previous work although it must be remembered that five doses were used in this trial in order to treat giardiasis. However, subsequent treatment with a single 400 mg dose of a small sub-group of the population positive for hookworm produced elimination of eggs in faeces (Reynoldson et al., 1997). Albonico et al. (1994) demonstrated a reduction of 56.8% in prevalence and 97.7% in intensity of 'hookworm' infection with a single 400 mg dose of albendazole although Raccurt et al. (1990) showed a much higher cure rate (87%, *N. americanus*) with a single 400 mg dose. The clearance time for hookworm in the present study is similar to that demonstrated by Bradley et al. (1992) for *N. americanus*. In that study expulsion was complete over 6 days and over 95% of worms were expelled within 4 days.

The data presented here confirm the usefulness of albendazole with respect to multi-parasite infections since both helminth and protozoan infections were markedly reduced. Further, hookworm prevalence and intensity of infection remained low for a considerable time, indicating that mass therapy, if it were to be carried out here, would be required no more frequently than once a year. This frequency of mass therapy has also been advocated by Anderson (1986) and demonstrated experimentally by others. Once or twice yearly treatment is appropriate for hookworm, *Trichuris* and *Ascaris* and timing may depend on the local epidemiology and species present (Stephenson et al., 1993b). In contrast, reinfection

with *Giardia* occurs much more rapidly (within several weeks) and suggests that alternative strategies must be developed for this parasite. The faecal-oral nature of the transmission of *Giardia* makes health and hygiene education imperative in attempts to control this parasite.

Multinational human trials involving over 1500 people have shown albendazole to be extremely well tolerated, with side effects occurring in only 6% of patients (Rossignol and Coulaud, 1983) most of those being mild transient epigastric pain (2.2%) and diarrhoea (2.0%). Our study confirms this low rate of adverse experience. Similarly, albendazole has been used at high dose rates extensively against hydatid cysts with only minor side effects reported (Horton, 1997). Albendazole, like mebendazole, has been shown to cause embryotoxicity and teratogenicity in some laboratory animals and thus has not been recommended for use in pregnant women (Botero, 1986; Horton, 1993, 1997).

We conclude that the use of albendazole within endemic communities such as this will be beneficial in lowering the prevalence of hookworm to manageable levels and should be without incident provided that precautions such as optimising the frequency of dosing and monitoring the parasite status, particularly hookworm intensity of infection, are observed (Anderson, 1986). Lessons learned from the use of anthelmintics in domestic animal species should also be heeded since resistance development has been rapid in that field. Treatment during the dry season or times of drought should be avoided as this will accelerate the development of resistance (Coles, 1995) and could also be ineffective if hypobiosis does occur (Prociv and Luke, 1995b). However, this may not apply to hookworm in this community since, although there is a recognised dry season, the micro-environment in which the infective stages occur is unlikely to be adversely affected by climatic extremes. This is because conditions conducive to hookworm reinfection prevail; the reticulated, grassy areas close to dwellings likely to serve as the most important source of infection. This conclusion is supported by the fact that the hookworm reinfection rate, within the confines of our sample times, appears to be linear despite the passage of several seasons. In contrast, we do appear to see seasonal fluctuations in the prevalence of *Giardia* (see fall in prevalence between 5 and 11 months, Fig. 3). We do not know whether this seasonal variation will have similar consequences for resistance to those highlighted by Coles (1995) for nematode species and remains to be explained.

In conclusion, we consider that the strategic single dose use of albendazole and appropriate health and education programmes will prove useful in the future control of gastrointestinal parasites in this and other Aboriginal communities in northern Australia.

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days 10–17 and 0 by days 18–30. Intensity remained low at both 5 (23 EPG) and 11 months (25 EPG) and was 246 ± 63 EPG at 34 months despite a prevalence of 31% ($n = 108$). Thus approximately 3 years after treatment, prevalence of infection was still $< 35\%$ of the pre-intervention level and the intensity was 26.7% of that recorded in 1993. However, by 41 months post-treatment 22 of 54 people (41%) were positive for hookworm and the mean intensity was 2651 ± 856 EPG ($n = 20$) compared with a mean intensity for positive residents of 1187 ± 136 EPG prior to treatment. Continuing treatment after the initial dosing was sporadic only.

E. coli was unaffected by albendazole although *H. nana* prevalence was reduced from a mean of 29.2–11.6% at 6–9 days post-treatment (non-significant, ANOVA, $P > 0.05$) and all age groups showed a similar reduction despite a higher initial prevalence in the children below the age of 19.

4. Discussion

The major parasites present in this remote Aboriginal community have been identified and the potential role of one regimen of chemotherapy against the most prevalent species, hookworm and *Giardia*, investigated. The pre-treatment age prevalence and age intensity data are similar to those reported elsewhere for other endemic areas for *N. americanus*, with a clear plateau in the 15–29 year age groups and are the first to be published for *A. duodenale* (Figs. 1 and 2). The decline in 30–49 age cohorts and above is not surprising but the fall in older age groups is expected since a convex age/intensity curve has been observed previously for *N. americanus* (Anderson, 1986). In contrast, Schad et al. (1983) reported a rise in old age and attributed this to older people, with poorer eyesight being less able to judge clean versus contaminated (recently disturbed) defaecation sites.

The lack of a main effect of sex on intensity of hookworm infection is not surprising, considering that in this community neither sex has particular tasks which might predispose them to infection. This is in contrast to other parts of the world where one sex may be more involved than the other in agricultural or other practices which predispose to infection (Haswell-Elkins et al., 1988; De Clercq et al., 1997). The significant interaction between age and sex is however a little more difficult to interpret and shows a relatively earlier fall of egg counts in males, possibly related to the roles of females as carers of the infected children. An alternative explanation might be that there is an immunological difference between males and females or that behavioural factors result in differences in worm burdens between the sexes.

Houses with heavier infections near to the school may indicate large numbers of children congregating in the area and contaminating the environment around the periphery of the school. In addition, the community store is also located close to the school thus making this area a focal point for people to gather. A few high-burden individuals within the community can have a significant effect on the parasite status of the community. Haswell-Elkins et al. (1988) showed a strong aggregation of infected people within a community in India where less than 10% of the population carried over 65% of the hookworms (*N. americanus*).