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Efficacy of mebendazole and levamisole alone or in combination against intestinal nematode infections after repeated targeted mebendazole treatment in Zanzibar

M. Albonico,1 Q. Bickle,2 M. Ramsan,3 A. Montresor,4 L. Savioli,4 & M. Taylor2

Objective To evaluate the efficacy of and resistance to mebendazole (500 mg) and levamisole (40 or 80 mg), alone or in combination, for the treatment of Ascaris lumbricoides, Trichuris trichiura and hookworm infections on Pemba Island — an area exposed to periodic school-based mebendazole treatment since 1994.

Methods A randomized, placebo-controlled trial was carried out in 914 children enrolled from the first and fifth grades of primary schools. Stool samples collected at baseline and 21 days after treatment were examined by the Kato–Katz technique to assess the prevalence and intensity of helminth infection.

Findings Efficacies of mebendazole and levamisole as single treatments against intestinal nematode infections were comparable with those in previous trials, but mebendazole treatment of hookworm infections gave significantly lower cure (7.6%) and egg reduction (52.1%) rates than reported in a study undertaken before the beginning of periodic chemotherapy (cure rate, 22.4%; egg reduction rate, 82.4%). Combined treatment with mebendazole and levamisole had a significantly higher efficacy against hookworm infections (cure rate, 26.1%; egg reduction rate, 88.7%) than either drug given alone. No difference in mebendazole efficacy was found in children who had been treated repeatedly compared with those who had not been treated previously.

Conclusion The overall efficacy of mebendazole against hookworm infections after periodic chemotherapy is reduced. The efficacy of benzimidazoles in chemotherapy-based control programmes should be monitored closely. Combined treatment with mebendazole and levamisole may be useful as a tool to delay the development of benzimidazole resistance.

Keywords Ascaris/larvae/chemistry; Trichuris/larvae/chemistry; Ascaris lumbricoides/chemistry; Mebendazole/chemistry; Levamisole/chemistry; Placebos; Drug resistance; Randomized controlled trials; Comparative study; United Republic of Tanzania (source: MeSH, NLM).

Introduction Public health programmes to control morbidity associated with soil-transmitted helminth infections depend mainly on the delivery of anthelmintic drugs to primary-school children (I).

Voir page 350 le résumé en français. En la página 350 figura un resumen en español.

يمكن الإطلاع على المأخوذ بالعربية على الصفحة 351

In theory, four single-dose drugs are available (albendazole, levamisole, mebendazole, and pyrantel); in practice, however, most control programmes only use the benzimidazoles (albendazole and mebendazole) because they are given as a single-dose tablet and children do not need to be weighed (2).
Aside from reducing the load of worms, benzimidazole treatment also improves the nutritional status and cognitive development of children infected with *Ascaris lumbricoides*, *Trichuris trichiura*, and hookworms and reduces hookworm-associated anaemia in children and in women of childbearing age (3–9). A number of studies have shown the short- and long-term benefits of periodic treatment with a single dose of 500 mg mebendazole in endemic areas (8, 10, 11).

Mebendazole also is used in helmint control programmes with good results, although it is less effective than mebendazole against *T. trichiura* and *Necator americanus* infections. Comparative trials of both drugs, alone or in combination, are few, however, and none have compared single-dose administration of 500 mg mebendazole and 40 or 80 mg levamisole (12–16).

At present, concern exists about the possible emergence of drug resistance to the anthelmintic compounds used to control intestinal nematodes in humans, particularly given the well-documented and widespread problem of anthelmintic resistance in livestock as a consequence of frequent periodic mass treatments (17). The efficacy of combined treatments that use anthelmintics with differing modes of action (e.g. mebendazole plus levamisole) need to be assessed, both to explore possible additive or synergistic effects and to identify a combination that could delay the occurrence of anthelmintic drug resistance to each class of drug (18).

Comparison of the efficacy of mebendazole in the treatment of *A. lumbricoides*, *T. trichiura*, and hookworm infection in an area where the school-age population has been exposed to the drug for the last five years with data collected before the beginning of the control programme and with other efficacy data collected elsewhere can give valuable information on possible changes in drug susceptibility of worms.

The primary purpose of this trial was to evaluate the efficacy of single-dose mebendazole in an area where this drug has been used widely for periodic chemotherapy targeted at schoolchildren. A secondary objective was to assess and compare the efficacy of mebendazole with that of levamisole given as one or two 40-mg tablets and the efficacy of the two drugs given in combination.

**Materials and methods**

**Study area and study population**

The study was carried out on Pemba Island, the smaller of the two islands of Zanzibar, United Republic of Tanzania. Important features of the island have been described in detail elsewhere (19, 20). Intestinal helmint infections affect most of the population and cause a heavy burden of disease in children and in women of childbearing age (21). The National Helmint Control Programme was initiated in Zanzibar in June 1994, and since then, mebendazole 500 mg has been given to schoolchildren as a single dose every 4–6 months (21).

The study was conducted in August 1999 among children enrolled in the first grade (Standard 1) and fifth grade (Standard 5) of 10 public schools on Pemba Island. The schools were chosen randomly from the 72 schools on the island. Children at Standard 1 had not yet been treated with mebendazole in school, whereas children at Standard 5 had been exposed to 15 rounds of mebendazole treatment.

Children were excluded from the trial if they did not have parental or guardian permission to participate, did not provide a stool sample, had significant comorbidities (e.g. severe diarrhoea, severe anaemia, or high fever), or had recently transferred to the school from an area outside Zanzibar.

**Study design**

The study was a randomized, placebo-controlled trial. Before children were enrolled in the study, parents or guardians of children in the selected schools were given a comprehensive explanation of the risk and benefits of the trial, and verbal consent was sought.

Children enrolled in the study were assigned randomly to one of four treatment groups to receive 500 mg mebendazole (Janssen, Belgium), 40 or 80 mg levamisole (Zeneca, UK), 500 mg mebendazole plus 40 or 80 mg levamisole, or placebo. Placebo pills resembled mebendazole in colour, size, taste, and shape.

On the day before the scheduled treatment date, children eligible to participate in the trial were given a container in which to bring a fresh stool sample the next day. On the day of treatment, the stools were collected and the children’s weights were recorded. Randomization was blocked on weight, and a computer-generated programme was used to create two randomized treatment lists: one for children who weighed 15–20 kg, who were to receive one tablet of 40 mg levamisole, and another for children who weighed 21–60 kg, who were to receive two tablets (80 mg). One tablet of mebendazole 500 mg and one of placebo was given irrespective of body weight. Treatments given were placed in sealed, opaque envelopes and were coded with a number. Children were identified by these numbers only throughout the study.

Twenty-one days after treatment, all children were revisited to collect a further stool sample. Any child who failed to bring a stool sample was followed for up to 24 days. Parents and children were instructed to report to the teacher and refer to the nearest health centre with any severe adverse effects that occurred in the week after treatment. After completion of the study, children in the placebo group and children positive after the follow-up survey were treated with mebendazole 500 mg.

The study was approved by the Zanzibar Health Research Council, and by the ethical committees of WHO and the London School of Hygiene and Tropical Medicine.

**Parasitology**

After both surveys, egg counts in stool samples were assessed within six hours of the sample being produced at the Public Health Laboratory Ivo de Carneri. All laboratory investigations were blinded, so the technicians who examined the slides were unaware of the treatment the patients received. Stools were analysed using the Kato–Katz technique according to WHO guidelines (22). The slides were examined within one hour of preparation to avoid overclarification of hookworm eggs. Comparison of egg counts before and after treatment allowed calculation of the cure rate and the egg reduction rate. A random sample of 10% of the smears prepared for the Kato–Katz technique was read by two different technicians to evaluate the accuracy of the diagnosis and the precision of the egg counts. Slides were re-examined if the quality control showed a >10% difference in egg counts.

To describe the egg count distribution in the study population before and after treatment, intensity of infection was classified as “light”, “moderate”, or “heavy” on the basis of faecal egg counts. As no heavy infections with *A. lumbricoides* were present at baseline when analysed according to WHO cutoff points, categories for *A. lumbricoides* intensity of moderate and heavy infection were revised to include a meaningful number of children for comparison (Table 1). Categories for intensity of *T. trichiura* and hookworm infection are according to WHO guidelines (Table 1) (23).
Statistical analysis
Data were entered and analysed with EpiInfo software. Cure rates were calculated as the percentage of children with egg counts >0 before treatment who had negative egg counts after treatment. The percentage reduction in prevalence was calculated as \( \left( \frac{N^+}{n} - \frac{N_{21}^-}{n} \right) / \frac{N^+}{n} \), where \( N^+ \) = the number of positive children at baseline, \( N_{21}^- \) = the number of positive children 21 days after treatment, and \( n \) = the total number of children with samples from both day 0 and day 21. Both cure rates and percentage reductions in prevalence were calculated. As the sensitivity of the Kato–Katz method could be influenced by the intensity of infection, however, reductions in prevalence were comparable only when pre-treatment intensities of infection were similar.

The percentage reduction in eggs induced by treatment was estimated as \( 100[1 - \exp(-D)] \% \), where \( D = \Sigma \left( \frac{\log(E_{21}) - \log(E_0)}{n} \right) / \log(2) \). Geometric mean egg counts were estimated as \( \exp[\Sigma \log(e+1)] / n \), where \( e \) = the count (eggs per gram) for a particular individual and \( n \) = the total number of samples. Geometric means were compared with analyses of variance by ANOVA if Bartlett’s test of homogeneity indicated homogeneity of variances and by the Kruskal–Wallis test if Bartlett’s test was significant at the 5% level.

Results
Analysis of baseline data
Of 1137 children examined at the baseline, 904 (79.5%) returned stool samples at follow-up. Loss at follow-up was high compared with that in other surveys in Zanzibar. The proportion of children with hookworm infections at baseline was 73.2% (486 children), and 54.9% of children harbouring double or triple infections, respectively. Table 3 gives the prevalence and intensity of hookworms at baseline and 21 days after treatment in the four treatment groups.

Overall drug efficacy
Follow-up egg counts, cure rates, reductions in prevalence and egg reduction rates for the three nematode infections were statistically significantly better with all of the drug regimens compared with those at baseline, except for cure rates for hookworm infections with mebendazole and for \( T. trichiura \) infections with levamisole (although in both cases the mean egg counts were reduced substantially). Compared with placebo, all drug treatments produced significantly higher cure rates and egg reduction rates and lower prevalences at follow-up, except for the egg reduction rate for levamisole in \( T. trichiura \) infections (Table 3).

Both drugs had very high efficacy (98.5% and 99.1% egg reduction rates for levamisole and mebendazole, respectively) against \( A. lumbricoides \). Mebendazole alone and in combination with levamisole had better efficacy than levamisole alone for \( T. trichiura \) infection (81% and 85% vs 41.5% egg reduction rates, \( P<0.001 \)). Levamisole treatment produced a marginally significant reduction in prevalence of hookworm infection, which was greater than the reduction seen with mebendazole (8.9% vs 3.6%, \( P<0.05 \)); the combination had better efficacy in reducing prevalence than either drug alone (23.6%, \( P<0.001 \)). The egg reduction rate for hookworm infection was 88.7% for the combined treatment, but significantly less for either drug alone (61.3% for levamisole and 52.1% for mebendazole, \( P<0.001 \)).

Table 1. Egg counts (eggs per gram) used to describe intensity of infection

<table>
<thead>
<tr>
<th>Causative pathogen</th>
<th>Intensity of infection (egg count per gram)</th>
<th>Light</th>
<th>Moderate</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A. lumbricoides )</td>
<td>( 1–4999 )</td>
<td>( 5000–9999 )</td>
<td>( \geq 10 000 )</td>
<td></td>
</tr>
<tr>
<td>( T. trichiura )</td>
<td>( 1–999 )</td>
<td>( 1000–9999 )</td>
<td>( \geq 10 000 )</td>
<td></td>
</tr>
<tr>
<td>Hookworm</td>
<td>( 1–1999 )</td>
<td>( 2000–3999 )</td>
<td>( \geq 4000 )</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 shows the distribution of intensities of infections, expressed as eggs per gram faeces, before and after treatment for \( A. lumbricoides \), \( T. trichiura \), and hookworm infections. Higher efficacy of treatment is indicated by an increase in negative and light infections and a decrease in moderate and heavy infections 21 days after treatment. Stratified analysis by intensity was performed on the cure rates and egg reduction rates for each species of helminth. For any treatment, lower cure rates were achieved in children with heavy infections compared with light infections: \( A. lumbricoides \) 93.3% vs 97.0% (\( P=0.07 \)), \( T. trichiura \) 83.3% vs 19.3% (\( P=0.1 \)), and hookworm 8.4% vs 16.3% (\( P<0.05 \)). On the other hand, higher egg reduction rates were achieved in children with heavy compared with light infections for \( T. trichiura \) (93.8% vs 81.4%, \( P<0.05 \)) and hookworm (91.3% vs 73.2%, \( P<0.01 \)). Efficacy of treatment was not influenced by whether \( A. lumbricoides \), \( T. trichiura \), or hookworm infections presented as single or multiple infections. Although adverse effects were not investigated actively, no adverse events were reported after any single or combined treatment in the week following the administration of anthelmintics.

Drug efficacy in Standard 1 and Standard 5 children
Overall, 446 children were in Standard 1 classes and had a mean (SD) age of 9.5 (1.5) years, and 458 children were in Standard surveys (Table 3). Their mean (SD; range) age was 11.5 (2.4; 7–18) years, and 45% were boys. The four groups were homogeneous at baseline for age and helminth infections, but differed in the proportion of males to females (Table 2). The prevalence of any helminth infection was 99.7%, with 38.3% and 54.9% of children harbouring double and triple infections, respectively. Table 3 gives the prevalence and intensity of \( A. lumbricoides \), \( T. trichiura \), and hookworms at baseline and 21 days after treatment in the four treatment groups.
5 classes and had a mean (SD) age of 13.4 (1.3) years. Boys accounted for 49.8% and 40.4% of children from Standard 1 and Standard 5 classes, respectively. Tables 4 and 5 give the prevalences and intensities of *A. lumbricoides*, *T. trichiura*, and hookworm infections at baseline and 21 days after treatment in the four treatment groups in Standard 1 and Standard 5 children, respectively. The baseline mean intensities of infection for all three species of helminths were significantly higher in the Standard 1 children than in the Standard 5 children (P<0.001). In addition, Standard 1 children at baseline had higher prevalences of moderate and heavy infection for each helminth than Standard 5 children — (*A. lumbricoides*: moderate 14.1% vs 9.2%, heavy 18.8% vs 9.0%; *T. trichiura*: moderate 45.3% vs 22.3%, heavy 2.5% vs 0.2%; and hookworm: moderate 12.1% vs 6.3%, heavy 11.4% vs 5.0%).

In both Standard 1 and Standard 5 children, but particularly in Standard 1 children, mebendazole and its combination with levamisole were more effective than levamisole in *T. trichiura* infection (the efficacy of levamisole did not differ significantly from that of placebo).

### Table 2. Characteristics of the study sample at baseline

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Treatment</th>
<th>Total (n = 285)</th>
<th>Lost at follow-up (n = 49)</th>
<th>Total (n = 277)</th>
<th>Lost at follow-up (n = 67)</th>
<th>Total (n = 286)</th>
<th>Lost at follow-up (n = 70)</th>
<th>Total (n = 289)</th>
<th>Lost at follow-up (n = 47)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td></td>
<td>11.5 (2.3)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.3 (2.1)</td>
<td>11.7 (2.5)</td>
<td>12.1 (2.3)</td>
<td>11.7 (2.4)</td>
<td>12.2 (2.5)</td>
<td>11.6 (2.5)</td>
<td>12.1 (2.3)</td>
</tr>
<tr>
<td>Sex (% boys)</td>
<td></td>
<td>48.4</td>
<td>53.1</td>
<td>54.2</td>
<td>56.7</td>
<td>43.0</td>
<td>55.7</td>
<td>42.6</td>
<td>51.1</td>
</tr>
<tr>
<td>Ascaris</td>
<td></td>
<td>61.4</td>
<td>69.4</td>
<td>60.3</td>
<td>62.7</td>
<td>62.9</td>
<td>65.7</td>
<td>58.1</td>
<td>63.8</td>
</tr>
<tr>
<td>Geometric mean (epg)&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td>134</td>
<td>232</td>
<td>99</td>
<td>117</td>
<td>129</td>
<td>149</td>
<td>100</td>
<td>122</td>
</tr>
<tr>
<td>Trichuris</td>
<td></td>
<td>90.9</td>
<td>91.8</td>
<td>94.6</td>
<td>97.0</td>
<td>93.7</td>
<td>95.7</td>
<td>93.8</td>
<td>93.6</td>
</tr>
<tr>
<td>Geometric mean (epg)</td>
<td></td>
<td>304</td>
<td>315</td>
<td>365</td>
<td>384</td>
<td>371</td>
<td>421</td>
<td>458</td>
<td>346</td>
</tr>
<tr>
<td>Hookworm</td>
<td></td>
<td>95.1</td>
<td>95.9</td>
<td>96.0</td>
<td>95.5</td>
<td>95.1</td>
<td>98.6</td>
<td>95.2</td>
<td>89.4</td>
</tr>
<tr>
<td>Geometric mean (epg)</td>
<td></td>
<td>429</td>
<td>352</td>
<td>454</td>
<td>392</td>
<td>401</td>
<td>504</td>
<td>475</td>
<td>316</td>
</tr>
</tbody>
</table>

<sup>a</sup> Values in parentheses are standard deviations.

<sup>b</sup> epg = eggs per gram.

### Table 3. Results before and 21 days after treatment with mebendazole, levamisole, mebendazole + levamisole, and placebo

<table>
<thead>
<tr>
<th>Causative pathogen</th>
<th>Drug</th>
<th>Prevalence&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Egg count (epg)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Cure rate</th>
<th>Reduction in prevalence</th>
<th>P-value&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Egg reduction rate</th>
<th>P-value&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascaris</td>
<td>Mebendazole</td>
<td>236</td>
<td>59.7</td>
<td>3.0</td>
<td>114</td>
<td>0.2</td>
<td>96.5</td>
<td>95.0</td>
</tr>
<tr>
<td>Levamisole</td>
<td></td>
<td>210</td>
<td>59.5</td>
<td>5.7</td>
<td>94</td>
<td>0.4</td>
<td>91.2</td>
<td>90.4&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mebendazole + levamisole</td>
<td></td>
<td>216</td>
<td>62.0</td>
<td>1.4</td>
<td>131</td>
<td>0.1</td>
<td>98.7</td>
<td>97.5</td>
</tr>
<tr>
<td>Placebo</td>
<td></td>
<td>242</td>
<td>57.0</td>
<td>51.2</td>
<td>96</td>
<td>63</td>
<td>22.5</td>
<td>10.2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>904</td>
<td>59.5</td>
<td>106</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichuris</td>
<td>Mebendazole</td>
<td>236</td>
<td>90.7</td>
<td>75.0</td>
<td>302</td>
<td>57</td>
<td>22.9</td>
<td>17.3&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Levamisole</td>
<td></td>
<td>210</td>
<td>93.8</td>
<td>90.0</td>
<td>359</td>
<td>210</td>
<td>9.6</td>
<td>4.1&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mebendazole + levamisole</td>
<td></td>
<td>216</td>
<td>93.1</td>
<td>74.5</td>
<td>356</td>
<td>53</td>
<td>22.9</td>
<td>20.0</td>
</tr>
<tr>
<td>Placebo</td>
<td></td>
<td>242</td>
<td>93.8</td>
<td>94.2</td>
<td>484</td>
<td>395</td>
<td>4.8</td>
<td>-0.4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>904</td>
<td>92.8</td>
<td>371</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hookworms</td>
<td>Mebendazole</td>
<td>236</td>
<td>94.9</td>
<td>91.5</td>
<td>447</td>
<td>213</td>
<td>7.6</td>
<td>3.6&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td>Levamisole</td>
<td></td>
<td>210</td>
<td>96.2</td>
<td>87.6</td>
<td>476</td>
<td>184</td>
<td>11.9</td>
<td>8.9&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mebendazole + levamisole</td>
<td></td>
<td>216</td>
<td>94.0</td>
<td>71.8</td>
<td>373</td>
<td>41</td>
<td>26.1</td>
<td>23.6</td>
</tr>
<tr>
<td>Placebo</td>
<td></td>
<td>242</td>
<td>96.3</td>
<td>95.9</td>
<td>514</td>
<td>432</td>
<td>3.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>904</td>
<td>95.4</td>
<td>451</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Percentage positive for pathogen.

<sup>b</sup> Mean egg count expressed as geometric mean.

<sup>c</sup> P-value from day 21 to day 0.

<sup>d</sup> Values in parentheses are 95% confidence intervals.

<sup>e</sup> Compared with mebendazole plus levamisole P<0.05.

<sup>f</sup> NS, not significant.

<sup>g</sup> Compared with levamisole P<0.001.

<sup>h</sup> Compared with mebendazole plus levamisole P<0.001.

<sup>i</sup> Compared with levamisole P<0.05.
Fig. 1. Distribution of *Ascaris lumbricoides*, *Trichuris trichiura* and hookworm egg counts before and after treatment with mebendazole, levamisole, mebendazole + levamisole, and placebo.
children, the effect of mebendazole against hookworm infection was similar to that of placebo, although its reduction of intensity of infection approached statistical significance (egg reduction rate 37%, \( P = 0.06 \), while levamisole was more effective (egg reduction rate 66.3%, \( P<0.001 \)) and the combination was the best treatment (egg reduction rate 92.9%, \( P<0.001 \)). In Standard 5 children, the combination was still the better option (although to a lesser extent than in Standard 1 children) than either drug alone for the treatment of hookworm infection (egg reduction rate 81.9% vs 56.3% for mebendazole, \( P<0.001 \)). Overall, none of cure rate, percentage reduction in prevalence, or egg reduction rate differed significantly between Standard 1 and Standard 5 children for any helminth infection. Furthermore, no evidence was seen of a reduced cure or egg reduction rate for mebendazole relative to levamisole in Standard 5 children.

### Discussion

This study confirms the extremely high prevalence of intestinal nematode infections in Zanzibar despite the periodic chemotherapy control programme that started in 1994. The objective of this programme, however, was reduction in intensity rather than prevalence of infection. In this respect, the significantly lower egg counts at baseline in Standard 5 children who had received 15 rounds of treatment with mebendazole compared with children in Standard 1 classes, who had never been treated, are encouraging. A possible explanation for this finding could be an intrinsic decline in intensity with increasing age. This is not supported by a previous study on untreated children in the same population, however, which showed that between the ages of 9 (Standard 1) and 13 years (Standard 5), the mean intensity of ascariasis in fact increased, the intensity of hookworm infections remained stable, and the intensity of trichuriasis slightly decreased, although to a much lesser extent than between Standard 1 and Standard 5 children in the present study (21). The benefit of periodic chemotherapy is shown further in the significant reduction of moderate and heavy helmint infections — those most associated with morbidity — in Standard 5 children. From the public health perspective, it seems, therefore, that the helmint control programme is effective in reducing intensity, although the low efficacy of treatment of hookworm infections found in this trial is worrying.

High, and similar, levels of efficacy in the treatment of *A. lumbricoides* infection were achieved using mebendazole, levamisole, and their combination. The efficacy of each treatment was equally excellent in light and heavy *A. lumbricoides* infections, with egg reduction rates approaching 100%. This result is consistent with previous efficacy trials and is also similar — for mebendazole — to the results of an efficacy study carried out in Pemba in 1993 before the mebendazole-based control programme was started (14, 24–27).

Drug efficacies in *T. trichiura* infection were also similar to those seen in previous trials, as treatment with mebendazole reduced the prevalence of infection, while levamisole had a much smaller effect (14, 26–29). Reductions in egg counts were significant for mebendazole and for levamisole, although mebendazole and the combined treatment were both significantly better than levamisole alone. When compared with the efficacy trial performed in Pemba before the control programme started, the mebendazole cure rate and egg reduction

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### Table 4. Results before and 21 days after treatment with mebendazole, levamisole, mebendazole + levamisole, and placebo in Standard 1 children

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Drug</th>
<th>Prevalence(^a)</th>
<th>Egg count (epg)(^b)</th>
<th>Cure rate</th>
<th>Reduction in prevalence</th>
<th>(P)-value(^c)</th>
<th>Egg reduction rate</th>
<th>(P)-value(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascaris</td>
<td>Mebendazole</td>
<td>120 67.5 5.8 264 0.4 93.8 91.4(^d)</td>
<td>&lt;0.001 99.5 (98.8–99.7)(^e)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levamisole</td>
<td>98 70.4 4.1 254 0.4 94.2 94.2(^f)</td>
<td>&lt;0.001 99.5 (98.8–99.8)(^g)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mebendazole + levamisole</td>
<td>108 67.6 0.1 248 0.1 100.0 99.9</td>
<td>&lt;0.001 99.6 (99.1–99.8)(^h)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Placebo</td>
<td>120 65.0 61.7 192 152 17.9 5.1</td>
<td>NS(^i) 20.9 (–44.1–56.6)</td>
<td>NS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>446 67.5 237</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichuris</td>
<td>Mebendazole</td>
<td>120 95.0 76.7 534 69 22.8 19.3(^j)</td>
<td>&lt;0.001 86.9 (78.0–92.2)(^k)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levamisole</td>
<td>98 95.9 95.9 643 416 4.2</td>
<td>NS 35.2 (–3.7–59.5)</td>
<td>NS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mebendazole + levamisole</td>
<td>108 97.0 82.4 776 94 17.1 15.1</td>
<td>&lt;0.001 87.9 (80.6–92.4)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Placebo</td>
<td>120 95.0 95.8 726 590 4.4</td>
<td>NS 18.8 (–18.8–44.5)</td>
<td>NS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>446 95.7 661</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hookworms</td>
<td>Mebendazole</td>
<td>120 94.1 95.0 483 304 4.4</td>
<td>–1.0</td>
<td>NS 37.0 (6.0–57.8) (\times) 0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levamisole</td>
<td>98 99.0 90.8 827 107 9.2</td>
<td>8.3(^m)</td>
<td>&lt;0.01 66.3 (48.7–7.8) (\times) 0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mebendazole + levamisole</td>
<td>108 96.3 71.3 604 42 26.0</td>
<td>&lt;0.001 92.9 (88.7–95.6)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Placebo</td>
<td>120 96.7 98.3 674 619 0.9</td>
<td>–1.7</td>
<td>NS 8.1 (–29.0–34.6)</td>
<td>NS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>446 96.4 628.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

\(^a\) Percentage positive for pathogen.

\(^b\) Mean egg count expressed as geometric mean.

\(^c\) \(P\)-value from day 21 to day 0.

\(^d\) Compared with mebendazole plus levamisole \(P<0.05\).

\(^e\) Values in parentheses are 95% confidence intervals.

\(^f\) Compared with mebendazole plus levamisole \(P<0.05\).

\(^g\) NS, not significant.

\(^h\) Compared with levamisole \(P<0.001\).

\(^i\) Compared with levamisole \(P<0.05\).
rates were not significantly different (24). The poor efficacy of levamisole against *T. trichiura* has already been reported, although Ismail et al. showed an egg reduction rate of 73% (2, 14). The finding that egg reduction rates were significantly higher in both *T. trichiura* and hookworm “heavy” infections compared with “light” infections is consistent with trials with albendazole (29, 30).

Striking features of this study were the low cure (7.6%) and egg reduction (52.1%) rates when mebendazole was used against hookworms. Mebendazole efficacy was lower when compared with that in published studies and, more specifically, compared with that in the trial carried out in Pemba before exposure to periodic treatment, in which mebendazole had a cure rate of 22.4% and an egg reduction rate of 82.4% (14, 24–27). Furthermore, in a recent trial comparable with our trial in the neighbouring island of Mafia, in which there is no school-based deworming programme and use of benzimidazoles has been very limited, mebendazole efficacies were similar (cure rate 31.3%; egg reduction rate 78.1%) to the pre-treatment values on Pemba and very much higher than the current efficacy in Pemba (31).

A number of potential confounding factors were ruled out by the fact that both trials were carried out in schoolchildren by the same staff and used the same methods and drug (mebendazole 500 mg from Janssen). It is notable that the cure rates and egg reduction rates for *Ascaris* and *Trichuris* were comparable between the two trials. Interestingly, levamisole also showed a lower efficacy against hookworms in the present study than in previous studies (32–34). A possible explanation is that levamisole has been reported to be more effective against *A. duodenale* than *N. americanus*, but the latter pathogen is the most prevalent species in Pemba (20). If mebendazole also was less effective against *N. americanus*, repeated use of mebendazole in Pemba could have created an increased *Necator/Ancylostoma* ratio, which would have resulted in an overall lower efficacy against hookworms. Data from recent studies suggest that the *Necator/Ancylostoma* ratio is indeed higher now than it was before periodic anthelminthic treatment (Albonico, unpublished data, 2000) (20).

An alternative explanation for the apparent reduced efficacy of mebendazole compared with historical controls is the selection of drug resistance by the repeated treatment regimen. If a proportion of drug-resistant worms was present in the worm population in Pemba, we would have expected resistant worms to have accumulated in children after multiple rounds of treatment and reinfection and to have represented a higher proportion of worms than that found in Standard 1 children. In this case, a lower drug efficacy would have been expected in the Standard 5 children. In fact, the efficacy of mebendazole in Standard 5 children who had received multiple (15) doses of mebendazole was not lower than in Standard 1 children who had never been treated; this suggests that a mebendazole-resistant population of worms had not accumulated in the repeatedly treated Standard 5 children. Nevertheless, the possibility that drug resistance is emerging in Pemba cannot be excluded. In Mali, failure of mebendazole in the treatment of human hookworm infections has been reported (35). In that case, however, the population had not been exposed to periodic treatment with mebendazole, although mebendazole had been available in that community for some years; pre-exposure efficacy data were not available for comparison and the sample of children studied was rather small. These factors suggest a need for caution when interpreting these results. A subsequent drug efficacy study in Mali (36) showed reasonably good efficacy of mebendazole and even better results from albendazole, which show a lack of significant resistance in human hookworms to benzimidazoles in that area. Poor efficacy of pyrantel against hookworms has
The efficacy of the combined administration of mebendazole 500 mg and levamisole 40 or 80 mg was evaluated for the first time in this study and showed higher efficacy than either drug alone against hookworm infections. This is a promising result, because the combined administration of two different anthelmintic drugs could be used as the treatment of choice in this context. In addition, the adoption of combination therapy with drugs with distinct modes of action when used at early stages has been shown to delay the onset of anthelmintic drug resistance (18).

Although this study clearly shows that the efficacy of mebendazole in the treatment of hookworm infections in Pemba Island schoolchildren is lower than in previous studies, demonstration of anthelmintic resistance is still lacking. A need exists, therefore, for alternative methods by which to address this question, such as the in vitro egg hatch assay — a technique widely used in veterinary medicine (38) and recently adapted to human hookworms (39). This would require comparisons with strains of hookworms that had not been exposed to treatment. The early detection of drug resistance is of the utmost importance, because the in vivo and in vitro tests currently available in the veterinary field detect resistance when the proportion of worms carrying the drug resistance allele in a population already has reached >25% (40). The development of methods for the early detection of benzimidazole resistance in human nematodes would be of great value, therefore, and the polymerase chain reaction methods developed by veterinary scientists need to be evaluated for their applicability in human nematodes (41).

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Conflicts of interest: none declared.
infecciones por anquilostoma logró unas tasas de curación (7,6%) y de reducción del número de huevos (52,1%) significativamente inferiores a las notificadas en un estudio emprendido antes del comienzo de la antibiototerapia periódica (tasa de curación, 22,4%; tasa de reducción del número de huevos, 82,4%). El tratamiento combinado con mebendazol y levamisol tuvo una eficacia significativamente mayor contra las infecciones por anquilostoma (tasa de curación, 26,1%; tasa de reducción del número de huevos, 88,7%) que cualquiera de los medicamentos por separado. No se observó ninguna diferencia en cuanto a la eficacia del mebendazol entre los niños tratados repetidamente y los que no habían sido tratados anteriormente.

**Conclusión** La eficacia global del mebendazol contra la anquilostomiasis se ve reducida después de la antibiototerapia periódica. Debería vigilarse estrechamente la eficacia de los benzimidasoles en los programas de control basados en la antibiototerapia. El tratamiento combinado con mebendazol y levamisol podría ser una valiosa arma para retrasar la aparición de resistencia a los benzimidasoles.

**Referencias**


