Intestinal parasitic infections in Black scholars in northern KwaZulu

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Summary
Faecal specimens were collected from a total of 7 569 scholars at 45 different localities in northern KwaZulu and screened for the presence of intestinal helminth and protozoan parasites. The soil-transmitted nematodes Ascasis lumbricoides, Trichuris trichiura and hookworm sp. were extremely common, with prevalences in certain localities ranking among the highest to be recorded in South Africa. Entamoeba coli was by far the commonest (60%) of the protozoa; all the other species had prevalences of less than 10%. The distribution, age-specific prevalence and the influence of the variables — sex, area and age — on the occurrence of the various intestinal parasites are described.

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A cross-sectional study on schistosomiasis in the northernmost part of Natal was recently completed. Since it was necessary to examine stools for the presence of Schistosoma mansoni ova, the faecal material collected could also be used for the identification and recording of helminth ova and protozoan cysts.

The only published record of the intestinal parasites occurring in the population of the area is that of Appleton and Bruton, who presented prevalence data in respect of 4 helminths (Trichuris, Ascaris, Taenia and hookworm) occurring at 6 of the schools. In this paper we present, for the area as a whole, data on the occurrence of the various intestinal parasites.

Subjects and methods
The area
Northern KwaZulu (Fig. 1A), comprising the Ngwavuma and Umbombo districts of Natal, borders on Mozambique in the north and Swaziland in the west. In the south it extends roughly below 100 m above sea level; it is only on the extreme western side where the altitude (on the Lebombo mountain range) exceeds 100 m. The area can be divided into 4 subdivisions, viz. the Lebombo mountains (> 300 m), the Lebombo foothill area (100-300 m), the Pongolo flood-plain with its numerous perennial pans of varying sizes caused by overflow from the river, and the eastern lowlands. The latter comprises a dry central area, marshall further east and two lake regions along the coastal belt.

Subjects
We have concentrated on the Black scholars in the area; their ages vary between 5 and 25 years, but since there were few subjects younger than 7 and older than 18 years these were included in the 5-7 and 18-25-year age groups respectively for the statistical analyses.

Stool specimens were obtained from scholars at 45 different localities (indicated in Fig. 1A) in the area; a total of 7 569 was examined for parasites. On the day of examination plastic histology containers large enough to take entire stool specimens were issued to the scholars, usually between 09h00 and 10h00. The advantage of early stool collection was that it did not interfere with the collecting of urine, which took place between 12h00 and 14h00 on the same day.

No laboratory facilities were available and specimens had to be fixed in 10% formalin and brought to the laboratory in Durban, where they were examined by the formol-ether concentration technique; this is preferred to the zinc-sulphate technique, which does not show up the schistosome ova satisfactorily, a result borne out by Van Niekerk et al. Results were coded for statistical analyses in which the biomedical computer programme of Dixon was used.

Results
Overall prevalence
All the parasites found, as well as their prevalences, are listed in Table 1. Entamoeba coli was by far the most common protozoan; in fact, the prevalence of 60% is one of the highest ever recorded in South Africa. We could find no evidence to support the observation by Goldsmid et al. in Zimbabwe that there are two strains (one large and one small) of E. coli. The other protozoan were rather uncommon, with prevalences ranging between 1% and 7%. This included the sporozoan Isospora which, with one exception (I. bellii), was identified as I. hominis. The small number of unidentified trophozoites seen were thought to be those of either E. histolytica or E. coli. S. haematobium is the most common trematode in the area, with a 54% overall prevalence; it is not surprising, therefore, that ova of this parasite were frequently detected. In contrast, the two other schistosomes, S. mansoni and S. mattheei, were rather poorly represented. Fasciola hepatica ova were present in only 22 of the 7 569 subjects examined.

The soil-transmitted nematodes, A. lumbricoides, T. trichiura and hookworm sp., were extremely well represented. A small number of fresh stools could be examined by means of the Harada-Mori coproculture technique, which revealed Necator americanus to be the predominant species. Trichostrongylus sp., the normal hosts of which are probably domestic animals and...
ruminants, were found on a few occasions. Enterobius vermicularis ova and larvae of Strongyloides sp. were rather uncommon.

Tapeworms were rare and Hymenolepis diminuta the least common of all the intestinal parasites identified.

**Distribution**

*T. trichiura* was most common in the northern part of the eastern lowlands, where the prevalence in all localities was above 70% (Fig. 1 B). In the 3 northernmost localities (29, 30 and 31) between 90% and 100% of the subjects were infected with this nematode. Localities with low prevalences were those to the west of the Pongola river on the Lebombo mountains and foothills.

In the case of hookworm (Fig. 2 A), all sites with high prevalences (> 50% infected) were in the Pongola flood-plain and eastern lowlands; there were 2 localities, Mfakubheka (29) and Makhaniestdrift (21), where the infection rate exceeded 90%. Prevalences in all localities on the Lebombo mountains and foothills were below 30%.

The prevalence of *A. lumbricoides* infection (Fig. 2 B) in all localities on the Lebombo mountains was more than 30%, whereas on the Lebombo foothills and the western side of the Pongola river the prevalence in all sites was less than 30%. The highest prevalences, however, were found in the northern part of the eastern lowlands, where 9 localities had infection rates of more than 75%.
There were no marked differences in prevalence between the four areas with regard to *E. coli*. All sites had prevalences greater than 30%, the lowest being in the northern marshy area and Sibaya localities of the eastern lowlands where between 38% and 53% of the subjects examined were found to be infested.

It is interesting to note that all the other protozoan species have their minimum prevalences in the eastern lowlands (Table II). *E. histolytica*, *E. hartmanni* and *Endolimax nana* were the most common of the amoebae in the Pongola flood-plain area, whereas *Iodamoeba butchili* occurred mainly on the Lebombo
the foothills. Of the flagellates, Giardia lamblia was most common on the Pongola flood-plain and Chilomastix mesnili on the foothills. Isospora was found mainly on the Lebombo mountains.

Taenia sp. and E. vermicularis were most prevalent on the Lebombo mountains, whereas the dwarf tapeworm, H. nana, occurred almost exclusively on the foothills of this mountain range (Table II).

**Age prevalence**

Fig. 3 shows the relationship between the percentage of subjects infected and age in respect of the 4 most common parasites found in the area. The age-prevalence pattern for each of these parasites was remarkably similar for each of the 4 areas. T. trichiura (Fig. 3 A) and A. lumbricoides (Fig. 3 C) prevalence decreased somewhat with age in all 4 areas whereas E. coli prevalence (Fig. 3 D) increased with age. Hookworm prevalence (Fig. 3 B), on the other hand, did not change with age.

The small number of subjects in each age group makes it impossible to draw any definite conclusions regarding the age prevalence of the remaining parasites. G. lamblia is the exception; it showed a very distinct pattern and decrease in prevalence with age, which is in agreement with a similar observation by Goldsmid et al. in Zimbabwe.

**Influence of age, area and sex on prevalence**

Four-way contingency tables were constructed. For each parasite each child was classified according to the 4 variables: parasite (positive or negative), sex (male or female), area (the 4 subdivisions) and age. To investigate the dependence of a particular parasite on the 3 independent variables (sex, area, age), a linear model was fitted to the logarithm of the odds of a parasite being present. The results are summarized in Table I. For the purpose of the analyses the different parasites were divided, according to prevalences it was necessary to reduce the number of categories. To obviate the use of too many zero cells. Obviously no analyses were done on the rare parasites (prevalence < 3%).

**TABLE II. PREVALENCE (%) OF INTESTINAL PARASITIC INFECTIONS IN THE 4 AREAS OF NORTHERN KWAZULU**

<table>
<thead>
<tr>
<th>Parasite</th>
<th>Lebombo mountains</th>
<th>Lebombo foothills</th>
<th>Pongola flood-plain</th>
<th>Eastern lowlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. histolytica</td>
<td>4.9%</td>
<td>3.8%</td>
<td>5.6%</td>
<td>3.8%</td>
</tr>
<tr>
<td>E. coli</td>
<td>60.9%</td>
<td>65.0%</td>
<td>73.6%</td>
<td>54.9%</td>
</tr>
<tr>
<td>E. hartmanni</td>
<td>3.9%</td>
<td>5.5%</td>
<td>7.6%</td>
<td>3.1%</td>
</tr>
<tr>
<td>E. nana</td>
<td>8.6%</td>
<td>7.9%</td>
<td>8.9%</td>
<td>5.4%</td>
</tr>
<tr>
<td>I. butchelli</td>
<td>4.6%</td>
<td>7.4%</td>
<td>5.9%</td>
<td>2.8%</td>
</tr>
<tr>
<td>G. lamblia</td>
<td>3.9%</td>
<td>3.7%</td>
<td>4.3%</td>
<td>2.8%</td>
</tr>
<tr>
<td>C. mesnili</td>
<td>3.6%</td>
<td>7.2%</td>
<td>7.0%</td>
<td>2.8%</td>
</tr>
<tr>
<td>I. hominis</td>
<td>2.8%</td>
<td>0.9%</td>
<td>0.4%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Hookworm sp.</td>
<td>11.7%</td>
<td>11.7%</td>
<td>52.8%</td>
<td>50.7%</td>
</tr>
<tr>
<td>T. trichiura</td>
<td>30.3%</td>
<td>23.3%</td>
<td>48.7%</td>
<td>74.6%</td>
</tr>
<tr>
<td>A. lumbricoides</td>
<td>50.2%</td>
<td>15.2%</td>
<td>31.2%</td>
<td>66.0%</td>
</tr>
<tr>
<td>E. vermicularis</td>
<td>2.5%</td>
<td>1.2%</td>
<td>0.5%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Strongyloides sp.</td>
<td>0.2%</td>
<td>0.2%</td>
<td>0.8%</td>
<td>0.4%</td>
</tr>
<tr>
<td>H. nana</td>
<td>0.6%</td>
<td>2.1%</td>
<td>0.6%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Taenia sp.</td>
<td>3.9%</td>
<td>2.1%</td>
<td>0.6%</td>
<td>0.5%</td>
</tr>
<tr>
<td>F. hepatica</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.7%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

* Figures in parenthesis denote sample sizes.

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Fig. 3. Age-specific prevalence of T. trichiura (A), hookworm (B), A. lumbricoides (C) and E. coli (D) in each of the 4 main areas in northern KwaZulu.

**TABLE III. PARAMETER VALUES FOR T. TRICHIURA**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>a₁</td>
<td>Lebombo mountains</td>
<td>-0.631</td>
</tr>
<tr>
<td>a₂</td>
<td>Lebombo foothills</td>
<td>-1.079</td>
</tr>
<tr>
<td>a₃</td>
<td>Pongola flood-plain</td>
<td>0.071</td>
</tr>
<tr>
<td>a₄</td>
<td>Eastern lowlands</td>
<td>1.265</td>
</tr>
<tr>
<td>b</td>
<td>Age (linear effect)</td>
<td>0.054</td>
</tr>
<tr>
<td>c</td>
<td>Age (quadratic effect)</td>
<td>-0.011</td>
</tr>
</tbody>
</table>

The fitted curve of the prevalence, p, is of the form

\[
\ln \frac{p}{1-p} = a_0 + a_1 \cdot x + a_2 \cdot x^2 + a_3 \cdot x^3 + a_4 \cdot x^4
\]

where the four values of k refer to the four areas and where x = 1 for the age group 5-7, x = 2 for the age group 8, x = 3 for the age group 9, x = 4 for the age group 10.

\[
1 - p = e^{a_0 + a_1 \cdot x + a_2 \cdot x^2 + a_3 \cdot x^3 + a_4 \cdot x^4}
\]

where the four values of k refer to the four areas and where x = 1 for the age group 5-7, x = 2 for the age group 8, x = 3 for the age group 9, x = 4 for the age group 10.
Analysis of the four-way contingency table for *T. trichiura* shows that the prevalence of this nematode is dependent on age and highly dependent on area, but not on sex; in fact, 5% of the total variation is explained by age and by 87% by area. The parameter values are given in Table III and the curve, fitted according to the approach of Baker and Nelder, is plotted in Fig. 3 A.

Similar analyses were done for hookworm sp., *A. lumbricoides* and *E. coli*. Their observed prevalences, on which curves were fitted as before, are indicated in Fig. 3 B, C and D and the percentage variation explained by each of the significant factors in Table I.

For each of the parasites with a prevalence of between 1% and 3%, the percentage of the total variation of the observed prevalence explained by the models is presented in Table I. Note that *E. histolytica* is the only parasite which is dependent on sex.

**Discussion**

This study was primarily an investigation into schistosomiasis and therefore no special techniques such as the adhesive-tape technique for *Enterobius* and the Enterotests for *G. lambia* were used.

One of the striking aspects regarding the prevalence of intestinal parasites in northern KwaZulu is the extremely low prevalence of most of the protozoan species. A review of the available literature shows that this is not unusual for South Africa; the prevalence of most protozoan parasites in the majority of localities for which records are available seldom exceeds 10%. There are several reasons for this. In Durban Elsdon-Dew and Freedman noted that the true incidence of a parasite such as *E. histolytica* may be as much as three times that revealed by a single examination, and Goldsmid et al. showed that the number of stools positive for cysts of *E. histolytica* increased with repeated examinations from 15% to 24%. Furthermore, in this laboratory we found that the lower density of the parasite in stool specimens, the more inconsistently it will be present. Another factor which could be responsible for the relatively low prevalence of the intestinal protozoa is our use of the formol-ether technique. Elsdon-Dew and Freedman alleged that the only parasites for which there is not a marked gain by the use of the zinc-sulphate flotation test are ova of *S. mansoni* and larvae of *Strongyloides* sp. The intestinal protozoans are therefore probably more common than the results of this study would suggest, and we assume that the same applies to the helminths, particularly those with low prevalences or low levels of infection.

It is clear that the population of northern KwaZulu carries a heavy load of parasites; not only are the intestinal nematodes extremely common, but the area is also known to be highly endemic for *S. haematobium* and falciaparum malaria. The overall prevalence of hookworm infection is higher than the 27% reported previously and since there are 5 localities with prevalences of more than 70% and a further 11 with more than 50%, northern KwaZulu must be regarded as the area of heaviest hookworm infection in South Africa. *T. trichiura* is extremely common in certain coastal areas of the country, the highest prevalences recorded so far being 96% in Coloureds at Tygerberg, CP, 89% at Guguletu, CP, and 84% in Durban. Our results indicate that several localities, particularly in the northern part of the eastern lowlands, have similarly high rates. In the case of *A. lumbricoides*, the highest prevalences (> 70%, observed in the eastern lowlands) are not unique, such prevalences having been recorded elsewhere, e.g. in Cape Town, Tygerberg and several localities in the vicinity of Durban (unpublished data).

High infection rates with intestinal parasites are well known to indicate a low standard of living and poor sanitation. Although living conditions appear to be very much the same throughout the area, environmental conditions differ considerably in the 4 main areas; this is reflected in significant differences in prevalence (as shown by the results of contingency analyses), particularly of the 3 nematode parasites. For instance, the relatively dry conditions prevailing on the Lebombo mountains and foothills must be responsible for the low hookworm and *T. trichiura* prevalences in these areas.

In schoolchildren at Adams Mission (south of Durban) there was a rather rapid reduction in *A. lumbricoides* and *T. trichiura* prevalence with age. The reduction in age-specific prevalence of these 2 nematodes was considerably less in the scholars in northern KwaZulu, possibly as a result of a greater rate of exposure and reinfection. The fact that hookworm prevalence does not change with age is obviously due to a different mode of transmission. Appropriate environmental conditions for the development of hookworm larvae include shaded, warm, moist soil such as is commonly found on the edge of rivers, streams, pans and other water bodies. Much of the hookworm transmission possibly takes place there. The age-prevalence pattern of *S. haematobium* in the area shows a resemblance to that of hookworm and was considered to be due to the fact that there is no significant reduction in the contact with natural waters in the older age groups.

Little is known regarding the morbidity effects on northern KwaZulu scholars of infestation with the different bowel parasites. Because of the high prevalences of the worm infestations, it seems reasonable to assume that worm loads would be at an equally high level, i.e. that intensity of infection is directly related to prevalence as was found in the case of *S. haematobium*. If this is true, many of the harmful effects, e.g. those described by Adams in respect of *A. lumbricoides*, might be expected to occur and clinicians working in the area as well as health authorities will have to observe the situation carefully.

We are indebted to the KwaZulu Government Service for permission to work in the area, to the Circuit Inspector (Mr Mithothua), the school principals and the scholars for their cooperation, to Mr M. J. Botha of the KwaZulu Health Department and Mr E. J. Jansen of the South African Department of Health for their invaluable assistance in many ways, to Dr T. v. W. Kotze of the MRC Institute for Biostatistics for statistical advice, and to the South African Medical Research Council for permission to publish.

**REFERENCES**