Public Health Nutrition: 4(6), 1211–1219 DOI: 10.1079/PHN2001180

Epidemiology of helminth infections: implications for parasite control programmes, a South African perspective

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Submitted 21 September 2000: Accepted 8 May 2001

Abstract

Objectives: To determine the epidemiology of helminthic infections and the efficacy of parasite treatment among rural South African primary school children in the province of KwaZulu-Natal. To assess the South African government's parasite control policy.

Methods: The study recruited 268 school children, aged 8 to 10, and randomly allocated them into treatment and placebo groups (treatment consisted of a single dose of albendazole (400 mg) and praziquantel (40 mg/kg)). Anthropometric measurements and the prevalence and intensity of helminth infections were taken at baseline (prior to treatment) and 16 weeks post treatment. Two weeks after treatment prevalence and intensity were again measured for an approximate 50% sub-sample of the children to investigate efficacy of treatment. An analysis of the South African government's policies concerning parasite control is assessed in the light of these epidemiological findings.

Results: Low levels of both stunting and wasting were observed throughout the study (approximately 10% and 1%, respectively), but did not vary significantly across either treatment group or time period ($P > 0.50$). At baseline the observed prevalences for the three main helminths found in this study among the treated children were *Ascaris lumbricoides* 29.5%, *Trichuris trichiura* 51.9% and *Schistosoma haematobium* 22.3%. These prevalences declined significantly to 4.7% ($P < 0.0005$), 38.0% ($P < 0.03$) and 3.3% ($P < 0.0002$), respectively, 16 weeks post treatment. The majority of infections observed at baseline were of light intensity, namely *A. lumbricoides* (50%), *T. trichiura* (80%) and *S. haematobium* (100%), and following treatment these levels were reduced significantly ($P < 0.0001$, $P < 0.05$ and $P < 0.005$, respectively). The levels of both prevalence and intensity in the untreated group remained constant. The cure rates over the first two weeks of the study were found to be 94.4% for *A. lumbricoides,* 40% for *T. trichiura* and 72.2% for *S. haematobium*.

Conclusion: The benefits of targeted, school-based treatment in reducing the prevalence and intensity of infection supports the South African government's focus of using school-based interventions as part of an integrated parasite control programme. These strategies and programmes are consistent with recommendations of the World Health Organization (WHO) and The United Nations Children's Fund (UNICEF).

Keywords
Parasite control
Ascaris lumbricoides
Trichuris trichiura
Schistosoma haematobium
Albendazole
Praziquantel
Intervention
Rural school children
Policy

This study was set in KwaZulu-Natal, the third poorest province in South Africa with a population of over 8.5 million[1], with high prevalence of HIV/AIDS[2]. The majority of the population live in the rural areas where lack of adequate sanitation and safe water supplies compound the poor socio-economic circumstances[1,3], and place communities at increased risk of helminth infections[4].

While intestinal nematodes and schistosomiasis are recognised as public health problems in the developing world[5], their epidemiology is known to vary throughout the world. This requires the development of context-specific parasite control strategies and programmes. The World Health Organization (WHO) has recommended three strategies for the control of helminthic infections,

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Table 1 Conceptual framework

Epidemiological factors	Application and interpretation	Programme implementation
Prevalence	Establish magnitude of problem	Enable targeting: universal, selective, targeted
Intensity	Burden of disease Individual/community level	Define high-risk groups for treatment
Treatment efficacy	Define appropriate treatment regimens	Frequency of treatment
Re-infection rates	Efficacy, suitable choice of drugs, single or multiple doses	Training of appropriate personnel, teacher and/or health workers in parasite control and micronutrient programmes
Multiple infections		
Defining cohorts and distribution:	Distribution patterns of disease burden	Targeting
Age – pre-school/school aged	Multi-factorial causality	Comprehensive multiple or selective interventions
Geographic – urban, rural, altitude		School- or community-based programme or both
Socio-economic/development status		Monitoring and evaluation

namely universal, targeted and selective treatment[6]. For the development of effective South African control programmes and strategies, and implementation of a national parasite control programme, detailed information is required with respect to the epidemiology of helminth infections, namely the prevalence, intensity, cure rates and re-infection rates, in order to control parasite transmission. In South Africa the prevalence and intensity of helminth infections nationally is unknown[7,8], and little is known about cure and re-infection rates. However, local studies in South Africa have found a high prevalence of intestinal nematode infections in the provinces of the Western Cape[8], Mpumalanga[9] and KwaZulu-Natal[10]; while schistosomiasis is endemic in approximately one-quarter of South Africa[7]. It is well-documented that children are the most vulnerable group, and in recent years cost-effective treatment options for helminth infections have become available to address the burden of disease amongst children, since it has been recognised that large numbers of children can be reached through school-based programmes[6].

With this focus, the South African Government, like many other middle-income and developing countries, initiated a national Primary School Nutrition Programme (PSNP) that included parasite control and targeted school children[11]. The development of this programme since 1994 and its relationship to parasite control are assessed in the light of international strategies to promote child development through helminth control programmes. The purpose of this study was to establish the epidemiology of helminthic infections amongst rural school children in KwaZulu-Natal. A deeper understanding of the epidemiology will contribute to the assessment of parasite control programmes. Specific objectives were to determine the prevalence and intensity of intestinal nematode infections – namely *Ascaris lumbricoides, Trichuris trichiura* and hookworm – and the schistosomes – *Schistosoma mansoni* and *Schistosoma haematobium*. Other objectives included determining the efficacy of treatment using single-dose albendazole (400 mg) for intestinal nematode infections and praziquantel (40 mg/kg) for schistosomiasis, determining the re-infection rate after treatment, and making recommendations to guide parasite control programmes.

The approaches recommended by WHO and the United Nations Children's Fund (UNICEF) for developing parasite control programmes served as the basis for developing a conceptual framework (Table 1) which linked the epidemiological profiles of helminth infections with the policy and programme elements to provide a perspective for other developing countries.

Method

This intervention study measured prevalence and intensity of helminth infection at T1 (baseline, prior to treatment), T2 (two weeks after treatment for an approximate 50% sub-sample of the population) and T3 (16 weeks post treatment). Serial measurements were undertaken amongst rural primary school children over the study period. The intervention consisted of a single dose of albendazole (400 mg) for intestinal helminths and praziquantel (40 mg/kg) for schistosomiasis, or placebo, given after taking the baseline measurements. All children with helminthic infections at the end of the study were treated.

Eleven schools were randomly selected from all primary schools in the Ugu North Health District in rural southern KwaZulu-Natal (Fig. 1). Ugu North was chosen as being representative of rural areas in this province with underdeveloped social services and communities with low socio-economic status. On the basis of previous work on helminth infections on black KwaZulu-Natal school pupils[9,12], it was calculated that a sample size of 95 per study arm would be adequate to detect at least a 20% decline in levels of *T. trichiura* (recognised as one of the

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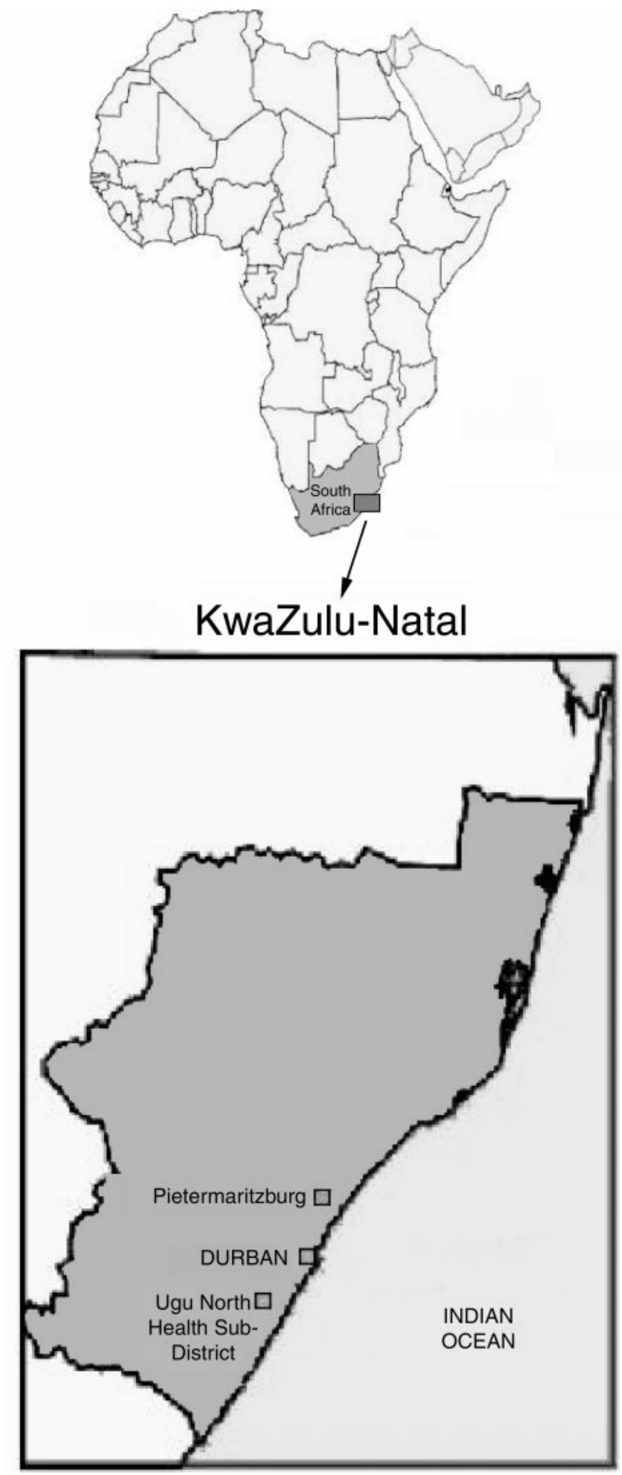

Fig. 1 Map showing location of the study area

commonest helminths to be found in KwaZulu-Natal) at 5% statistical significance with 80% power. A 30% study dropout rate was also allowed for, which increased the sample size estimate to 125 per study arm. From the selected schools, grade 3 pupils aged between 8 and 10 years were randomly selected for inclusion into the study; 268 pupils provided stool samples before treatment and 16 weeks post treatment, and were enrolled into the study. Of the 268 pupils recruited, 129 (48%) were randomly allocated into the treated group, and 139 (52%) to the untreated group. To analyse the efficacy of treatment a random sample of 124 stool samples was obtained two weeks post treatment (i.e. a 46.3% sub-sample). Of these, 66 (53.2%) were from the treated group and 58 (46.8%) the untreated group.

The schools selected were Dududu, Dumisa, Himmelberg, Hlutankungu, Kwamaquza, Nomandla, Soul, St Michael, Tholimfundo, Vukaphi and Zamafuthi, situated at a longitude range of 30.19–30.69° and a latitude range of 30.19–30.86°. An assessment of the schools' environment (reported elsewhere) indicated that all the schools (except one) had inadequate sanitation and access to clean water, and that most pupils came from a rural home environment with similarly inadequate access to clean water and sanitation.

Anthropometric measurements

All children participating in the study were weighed without sweaters (using a Masskot electronic scale) and their barefoot height measured with a stadiometer. Weight-for-age *Z*-scores and height-for-age *Z*-scores were computed. The reference population used in calculating these indices was that given by the National Center for Health Statistics (NCHS)[13]. Values less than two standard deviations (SD) below the median for weight-for-age are taken as a measure of wasting, while those below the median for height-for-age are taken as a measure of stunting.

Analysis of stool and urine samples

Stool and urine samples were collected from all pupils prior to treatment (i.e. at baseline/pre treatment T1), from the sub-sample two weeks after treatment (T2), and then 16 weeks after treatment (T3), to determine the prevalence and intensity of helminth and schistosomiasis infections.

The stool samples were fixed in 10% formalin. For the stool analysis, two aliquots were measured from the homogenised stool sample (using a Stomacher Lab Blender Model 80 – BA 7020) and analysed separately[14,15]. The stool investigation determined the prevalence of infection of *A. lumbricoides*, *T. trichiura*, hookworm, and *S. mansoni*. An aliquot of the urine samples was analysed for *S. haematobium* using a helminth filter and simply quantified as light, moderate or heavy[16]. The intensity of the other helminths was quantified at the Medical Research Council laboratory, Durban, as follows:

1. *A. lumbricoides*
   Light, $<$20 eggs per coverslip;
   Moderate, 20–75 eggs per coverslip;
   Heavy, $>$75 eggs per coverslip.

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2. *T. trichiura*
   Light, <20 eggs per coverslip;
   Moderate, 20–50 eggs per coverslip;
   Heavy, >50 eggs per coverslip.
3. Hookworm
   Light, <10 eggs per coverslip;
   Moderate, 10–20 eggs per coverslip;
   Heavy, >20 eggs per coverslip.
4. *S. mansoni*
   Light, <20 eggs per coverslip;
   Moderate, 20–50 eggs per coverslip;
   Heavy, >50 eggs per coverslip.

Faecal samples were examined directly via 'wet preps' after homogenising. Actual egg counts were not done because of the cost and other resource constraints.

Assessment of nutrition policy and programmes

A policy analysis was undertaken of the key South African government documents relating to helminthic control, at national and provincial levels[11,17–19]. The relevance of international strategies for the promotion of child development through helminth control programmes for developing countries such as South Africa was examined[6].

Study approval

Ethical approval for the study was obtained from the Ethics Committee of the University of Natal, and the KwaZulu-Natal Departments of Health, and Education & Culture. Written informed consent was obtained from the relevant tribal authorities, and parents; while verbal consent was provided by the pupils.

Data analysis

EPI INFO version 6.04 was used for data entry; analysis was undertaken in SPSS version 8.0. Statistical significance was taken at $P < 0.05$.

Results

The results include a general description of the school children recruited (in terms of their age, gender and anthropometric measurements) and the epidemiology of helminth infections, the efficacy of treatment and the observed helminth re-infection rates. The relationship between the epidemiological factors, and their interpretation for policies and programmes of developing countries relating to nutrition and parasite control, are reviewed.

The study recruited 103 boys (45 in the treated and 58 in the untreated group) and 165 girls (84 in the treated and 81 in the untreated group); the mean age of boys was 109.2 (SD 6.9) months and for girls 107.8 (SD 6.4) months. There was no significant difference in age across gender and treatment group ($P > 0.10$) at baseline nor for anthropometric indices (height, weight, height-for-age and weight-for-age) with respect to gender ($P > 0.10$).

Table 2 Anthropometric parameters for the two treatments groups, pre treatment (T1) and 16 weeks post treatment (T3)

TREATED GROUP

	Height (cm)			Weight (kg)		
Time point	*n*	Mean	SD	*n*	Mean	SD
T1	129	127.8	6.9	127	27.1	3.6
T3	124	129.4	6.8	124	28.5	4.0
	Height-for-age <−2 SD			Weight-for-age <−2 SD		
	n	(%)		*n*	(%)	
T1	8	(6.2)		1	(0.8)	
T3	12	(9.7)		1	(0.8)	

UNTREATED GROUP

	Height (cm)			Weight (kg)		
Time point	*n*	Mean	SD	*n*	Mean	SD
T1	137	127.3	5.0	136	26.8	3.5
T3	126	129.1	5.4	126	28.0	3.6
	Height-for-age <−2 SD			Weight-for-age <−2 SD		
	n	(%)		*n*	(%)	
T1	13	(9.5)		1	(0.7)	
T3	14	(11.1)		1	(0.8)	

From the two main study time points (T1 and T3), there was no statistically significant difference in anthropometric indicators with respect to both gender and treatment groups ($P > 0.10$) (Table 2). In this study stunting ranged from 6.2% to 11.1% in the children examined, but did not vary significantly across group or time period ($P > 0.50$); wasting appeared constant at approximately 0.8% throughout ($P > 0.80$). When considering the prevalence and intensity of helminth infections by age and gender, no significant differences were observed for any of the parasite groups under study with respect to gender ($P > 0.40$); hence no further analysis in respect of age and gender is presented in this paper.

At baseline/pre treatment (T1) over 50% of the children were infected with *T. trichiura* (Table 3 presents this information per treatment group). Less than 30% were infected with *A. lumbricoides* and very few children (approximately 3%) were infected with hookworm. *S. haematobium* was the most common of the schistosome infections with approximately one-fifth of the children infected; less than 1% were infected with *S. mansoni*. Treatment with albendazole resulted in a significant decrease in prevalence 16 weeks later (T3) for *T. trichiura* and *A. lumbricoides* infections ($P < 0.03$ and $P < 0.0005$, respectively, Table 3). There was an indication that hookworm infection declined in the treated group ($P = 0.06$, but based on very small numbers). There was, however, a significant decrease in schistosome infections after treatment with praziquantel (*S. haematobium*, $P < 0.0002$).

Table 3 Prevalence and intensity of helminth infection ($n = 268$) pre treatment (T1) and 16 weeks post treatment (T3)

		Intensity of infection*					
Helminth species	Time period	Nil *n*	Light *n* (%)	Moderate *n* (%)	Heavy *n* (%)	Prevalence (%)	*P*-value
Ascaris lumbricoides							
Treated	T1	91	19 (14.7)	13 (10.1)	6 (4.7)	29.5	
	T3	123	2 (1.6)	3 (2.3)	1 (0.8)	4.7	<0.0005
Untreated	T1	100	20 (14.4)	14 (10.1)	5 (3.6)	28.1	
	T3	102	21 (15.1)	12 (8.6)	4 (2.9)	26.6	0.89
Trichuris trichiura							
Treated	T1	62	53 (41.1)	13 (10.1)	1 (0.8)	51.9	
	T3	80	44 (34.1)	4 (3.1)	1 (0.8)	38.0	0.03
Untreated	T1	64	60 (43.2)	15 (10.8)	–	54.0	
	T3	65	65 (46.8)	7 (5.0)	2 (1.4)	53.2	1.00
Hookworm spp.							
Treated	T1	124	3 (2.3)	1 (0.8)	–	3.1	
	T3	129	–	–	–	–	0.06
Untreated	T1	133	4 (2.9)	–	–	2.9	
	T3	135	3 (2.2)	1 (0.7)	–	2.9	1.00
Schistosoma haematobium							
Treated	T1	87	25 (22.3)	–	–	22.3	
	T3	89	3 (3.3)	–	–	3.3	0.0002
Untreated	T1	89	25 (21.9)	–	–	21.9	
	T3	72	21 (21.9)	3 (3.1)	–	25.0	0.72
Schistosoma mansoni							
Treated	T1	128	–	1 (0.8)		0.8	
	T3	127	–	–	–	–	1.00
Untreated	T1	138	1 (0.7)	–	–	0.7	
	T3	133	–	1 (0.7)	–	0.7	1.00

* Intensity of infection is defined as number of children in the light, moderate and heavy groups.

Although *T. trichiura* was the most prevalent helminth infection, the majority of infections were of light intensity; approximately 80% being classified as light over both treatment groups at T1, 19% as moderate and approximately 1% as high (Table 3). For *A. lumbricoides* the pattern at T1 was approximately 50% classified as light, 35% moderate and 15% high. At T1 all of the children with *S. haematobium* had light infections. When considering the change in intensity of infection to T3 for the treated group, significant declines were observed in intensity (high–moderate, moderate–light, etc.) for *T. trichiura*, *A. lumbricoides* and *S. haematobium* ($P < 0.05$, $P < 0.0001$ and $P < 0.005$, respectively). For the untreated group no clear declines were observed ($P > 0.15$ in all cases). For hookworm and *S. mansoni* the numbers were too small to make any conclusive statement.

A sub-sample of 124 children is considered in Table 4 at three study time points, namely pre treatment (T1), two weeks post treatment (T2) and 16 weeks post treatment (T3). The effects of treatment per helminth species on prevalence and intensity for this sub-sample over the intervention period (T1 to T3) remains as reported for the main sample given in Table 3. However, the decline for *T. trichiura* becomes non-significant ($P = 0.03$, Table 3; $P = 0.16$, Table 4). When considering the change in helminth prevalence from T1 to T2 similar results to the time period T1 to T3 are observed; however, with the decline in *T. trichiura* again obtaining statistical significance ($P = 0.02$). Treatment with albendazole for *A. lumbricoides* proved very effective, with a 94.4% cure rate from T1 to T2. For hookworm infections, although two-thirds of the children were cured, this was based on very small numbers; for *T. trichiura* infections a cure rate of 40% was obtained. Treatment of schistosomal infections with praziquantel resulted in a cure rate of just below 75% for the children infected with urinary schistosomiasis and a complete cure for the single child moderately infected with *S. mansoni*.

When considering re-infection rates across the different helminth species by treatment group – where re-infection is defined as those who were helminth positive at T1, negative at T2 and positive again at T3, there were no significant differences for the rates of re-infection after successful treatment for *A. lumbricoides*, *T. trichiura*, hookworm spp., *S. haematobium* and *S. mansoni*. This may well arise from the fact that very small numbers of individuals were in the sub-set of data defined for re-infection (less than 20 in all cases for any of the species and treatment groups). The study measured the efficacy of treatment in this rural area and the rate of re-infection 16 weeks after treatment. This study ended in November, which coincided with the end of the school year, and precluded any follow-up work.

A comparison of multiple helminth infections was undertaken (Fig. 2). From this, before treatment (T1), 183 (68.2%) children had one or more helminth species. Most children, 170 (63.4%), had one or more nematode infections, with 79 (61.2%) in the treated and 91 (65.5%) in the untreated group. There were 30 (23.3%) children in the treated group and 24 (17.3%) in the untreated group with

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Table 4 Prevalence and intensity of helminth infection, for the sub-sample of children ($n = 124$), pre treatment (T1), two weeks post treatment (T2) and 16 weeks post treatment (T3)

		Intensity of infection*					
Helminth species	Time point	Nil *n*	Light *n* (%)	Moderate *n* (%)	Heavy *n* (%)	Prevalence (%)	*P*-value
Ascaris lumbricoides							
Treated – cure rate 94.4%	T1	48	9 (13.6)	6 (9.1)	3 (4.5)	27.2	
	T2	64	–	1 (1.5)	–	1.5	0.0001
	T3	63	–	2 (3.0)	1 (1.5)	4.5	0.0001
Untreated	T1	43	9 (15.5)	4 (6.9)	2 (3.5)	25.9	
	T2	43	8 (14.0)	5 (8.8)	1 (1.8)	24.6	0.96
	T3	41	10 (17.2)	5 (8.6)	2 (3.5)	29.3	0.83
Trichuris trichiura							
Treated – cure rate 40.0%	T1	31	32 (48.5)	3 (4.5)	–	53.0	
	T2	45	20 (30.3)	1 (1.5)	–	31.8	0.02
	T3	40	24 (36.4)	2 (3.0)	–	39.4	0.16
Untreated	T1	22	28 (48.3)	8 (13.8)	–	62.1	
	T2	25	26 (44.8)	5 (8.6)	2 (3.5)	56.9	0.70
	T3	24	30 (51.7)	3 (5.2)	1 (1.7)	58.6	0.85
Hookworm spp.							
Treated – cure rate 66.7%	T1	63	2 (3.0)	1 (1.5)	–	4.5	
	T2	65	1 (1.5)	–	–	1.5	0.62
	T3	66	–	–	–	–	0.24
Untreated	T1	57	1 (1.7)	–	–	1.7	
	T2	56	1 (1.7)	–	–	1.7	1.00
	T3	57	1 (1.7)	–		1.7	1.00
Schistosoma haematobium							
Treated – cure rate 72.2%	T1	38	18 (32.1)	–	–	32.1	
	T2	53	5 (8.6)	–	–	8.6	0.003
	T3	42	2 (4.5)	–	–	4.5	0.001
Untreated	T1	34	11 (24.4)	–	–	24.4	
	T2	45	11 (19.6)	–	–	19.6	0.54
	T3	44	9 (17.0)	–	–	17.0	0.51
Schistosoma mansoni							
Treated – cure rate 100%	T1	65	–	1 (1.5)	–	1.5	
	T2	66	–	–	–	–	1.00
	T3	65	–	1 (1.5)	–	1.5	1.00
Untreated	T1	57	1 (1.7)	–	–	1.7	
	T2	56	1 (1.7)	–	–	1.81.7	1.00
	T3	53	–	1 (1.8)	–		1.00

* Intensity of infection is defined as number of children in the light, moderate and heavy groups.

two or more nematode infections; only 3 (2.6%) in the untreated group had three nematode infections. There were equal numbers of children in each treatment group who were infected with *S. haematobium* (namely 25), and one child in each group was also infected with *S. mansoni*.

Sixteen weeks after treatment (T3) the overall pattern of multiple infections declined significantly in the treated group, but remained relatively unchanged in the untreated group (Fig. 2). Overall, for all helminth types, the change in infections (T1 to T3) in the treated group

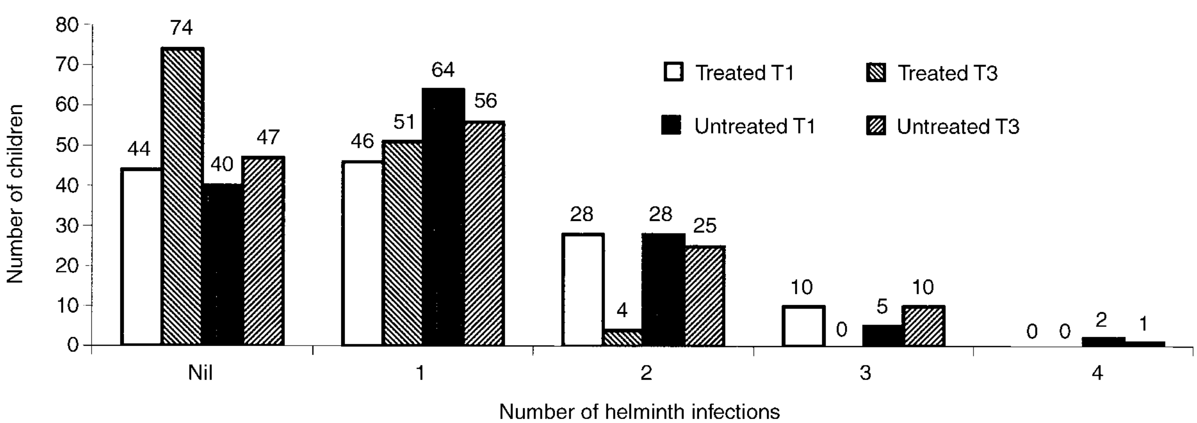

Fig. 2 Prevalence of multiple helminth infections pre and post treatment (T1 and T3)

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was highly significant ($P < 0.0001$) and non-significant in the untreated group ($P = 0.51$). When separating this out for nematodes and schistosomes, the declines seen in the treated group were very significant ($P < 0.0001$ and $P = 0.0002$, respectively) and non-significant for the untreated group ($P = 0.53$ and $P = 0.99$).

The Primary School Nutrition Programme (PSNP) was launched in 1994 to address problems of poverty, malnutrition (protein energy malnutrition and short-term hunger), micronutrient deficiencies (vitamin A, iodine and iron), parasitic infections and improved nutrition education[11]. The aims of the PSNP were to improve children's learning capacity and the quality of schooling by integrating school nutrition into a network of school- and community-based initiatives. The programme was targeted at needs in the rural and informal settlement areas. Based on the association between parasitic infections, impaired cognitive function and education outcome measures, such as absenteeism, under-enrolment and high drop-outs; a deworming programme was recommended where epidemiological evidence suggested high prevalence of infections[11]. Four intervention components were recommended – a basic food supplement, micronutrient supplementation, a parasite control programme and nutrition education[11]. An integrated nutrition strategy, incorporating all the different nutrition programmes and services, was established as part of the Mother, Child and Women's Health Programme at national and provincial levels[17,18]. Although the objectives of the South African Parasite Control Programme were to reduce the transmission of parasite infections through treatment, health education and sanitation and environmental preventive measures[11,17,19], in reality the existing programme has largely focused on treatment of school children.

UNICEF[20] recommends guidelines for developing a national strategy for helminth control, including the use of existing school health services and other systems, and the integration of helminth control into existing (child health) programmes for sustainable child health care and development. The strategy should include a situational analysis to assess the extent of helminthic problems, to identify prevalent species (and hence the drugs to be used in the programme), and the groups at risk[20]. Establishing the need for a parasite control programme depends basically on prevalence data. In turn, this has to recognise that the geographic distribution of infections is localised and uneven, variations occurring among intestinal helminth and schistosomes (which require water sources for transmission), and age-related target groups – such as school children and adults. Likewise universal or targeted mass treatment, as recommended by WHO, is indicated when intensity of infection is low and prevalence exceeds 50%. UNICEF recommends that, for the purpose of monitoring and evaluating programmes, consideration needs to be given to both coverage (interval between treatments and proportion of target group treated) and the effects of treatment on prevalence and intensity of helminths and target groups. Initial epidemiological surveys provide baseline data, from which we can assess changes and measure the impact of the programme. All of these policies and programmes have a strong focus on women and children, with specific reference to nutritional improvement and parasite control. Many of the policy and programmatic elements of the South African programme are consistent with international trends as recommended by UNICEF and WHO[20].

Discussion

The focus of this study has been on determining the helminth species, prevalence and intensity of infections and drug treatment modalities in one area of KwaZulu-Natal province in the context of current parasite control programmes and policies, with a view to improving their relevance and effectiveness. KwaZulu-Natal, with a quarter of the population of South Africa, has climatic, geographic, environmental and socio-economic factors that are uniquely different from those in the rest of the country[1]. KwaZulu-Natal has a long coastal strip alongside the Indian Ocean with a sub-tropical climate and soils conducive to the spread of helminth infections – this differs from other provinces. The population mixture also differs from other provinces. In comparison with the national Human Development Index (HDI) of 0.69, the HDI for KwaZulu-Natal is 0.58[1]. An understanding of the epidemiology of helminthic infections in this region is essential for the effective implementation and monitoring of the Integrated Nutrition Programme (INP) and the Parasite Control Programme (PCP). The appropriate selection of the WHO's strategies of universal, selective or targeted treatment for the control of nematode infections requires both a broader epidemiological perspective of these factors, and the development of parasite control programmes that are sensitive and specific for each region and country and which ensure sustainability.

In a meta-analysis of the effects on growth of anthelminthic drugs used for treating children, Dickson *et al.* reported that drug treatment was associated with some positive effects on weight and height[21], but noted that there was significant heterogeneity between the trials' results. Our study did not find any differences in anthropometric measurements between the treatment groups, nor over the intervention period for weight-for-age and height-for-age. However, a small but persistent level of protein energy malnutrition as measured by both stunting (height-for-age) and wasting (weight-for-age) was found throughout the study population (Table 1).

The results of this study confirm that a public health problem exists in rural KwaZulu-Natal that requires a parasite control programme. Previous studies have shown that children of school-going age have the highest prevalence and intensity of most helminth infections, other than hookworm[6]. This study supports these findings, with hookworm and *S. mansoni* both having a very low prevalence.

The relative efficacy of treatment with albendazole differs for the different nematode infections[22]. This study found high cure rates for *A. lumbricoides* and hookworm infections, with lower cure rates for *T. trichiura* infection, as previously reported[22,23]. It is difficult to draw firm conclusions concerning re-infection rates, due to the very low numbers of re-infected children in this population.

Other studies in Africa have confirmed that school-based treatment programmes can be a cost-effective strategy for controlling intensity of helminth infection even where transmission is high[24,25]. Other studies have demonstrated that extra doses of albendazole may improve the efficacy of treatment[26]. Mebendazole has been shown to be equally effective in the treatment of trichuriasis and ascariasis[27,28]. In much of KwaZulu-Natal the prevalence of hookworm infection has been shown to be low, so albendazole – which has proved to be more effective in the treatment of hookworm – may not necessarily be the drug of choice. These findings suggest that either benzimadazole drug could be used for treatment of helminth infection in KwaZulu-Natal, depending on cost and tendering process. Compared with other studies the cure rate for schistosomiasis was low. The reasons for this are not clear and may be due to resistance. However, this was not explored further.

This study has established the specific characteristics of parasites in the Ugu North Health District of Kwa Zulu-Natal, the burden of disease among school children and the efficacy of treatment regimens. The epidemiology of helminth infections described in our study can be of value to health planners and in designing parasite control programmes. For the control of helminth infections and the changing epidemiology of helminthic infections in the different geographical areas in KwaZulu-Natal, continuing surveillance is required. The benefits that resulted from this study also have relevance for the sustainability of control programmes. Control programmes that have elements such as anthelminthic treatment of children[29], nutrition programmes, water and sanitation, and are linked with community-based women and children's health programmes, are more sustainable and more likely to reduce the burden of disease amongst school children.

Such interventions can contribute to the alleviation of the multi-factorial problems of individual and community-level poverty, under-development and morbidity from infections and nutritional deficits.

Conclusion

The public health problems of parasite infections (endemic in many developing countries) identified in this study among primary school children can be addressed by school-based anthelminthic treatment programmes.

The conceptual framework has established the parasite-specific characteristics of the helminth infections (prevalence and intensity), treatment regimens (appropriateness and efficacy) and allowed focused targeting (e.g. school-based multiple drug interventions) in Ugu North, with the aim of contributing to the targeting of current ongoing programmes (e.g. school-based multiple interventions) in KwaZulu-Natal. These findings can also be of benefit to the development of cost-effective national parasite control programmes. We recognise that there are existing ongoing efforts at developing and refining control programmes at provincial and national levels. This paper aims to contribute to this process and is consistent with international recommendations[20].

Acknowledgements

We would like to thank all the members of the research team, including the pupils, teachers and parents, who participated in the study; SmithKline Beecham and Bayer for supplying the drugs. We express our appreciation to the Medical Research Council for laboratory support and the Medical Research Council and Education Foundation for the geo-location of the schools. We also thank the British Council, Durban Office, for assisting with the research collaboration between the Department of Community Health, University of Natal, Durban and the Centre of International Child Health, Institute of Child Health, London.

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