Malnutrition in African adults

5.* Effects of hookworm infestation on absorption of foodstuffs

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It was reported in the previous paper (Holmes & Darke, 1959) that, although the absorption of energy and nitrogen from the intestine in various groups of subjects was less than would be expected by generally accepted standards, it was not affected by the presence of small hookworm loads. The majority of the subjects observed initially had hookworm eggs in their stools, but no difference in their absorption of energy or N before and after worming was apparent. On the other hand, only on two occasions were more than 200 worms counted in the stools collected after the vermifuge and none of the subjects was anaemic. Since in Kampala loads of 1000–3000 worms are common, and subjects who harbour them are usually severely anaemic, it was thought worth while to investigate such subjects.

EXPERIMENTAL

Subjects

The nine Africans investigated included one child from the metabolic ward in Mwanza. There were ten observations, as one subject was investigated on two separate occasions. All subjects were severely anaemic. Their stools contained many hookworm eggs, and invariably gave strongly positive tests for occult blood. Relevant clinical details are given in Table 1. In the three patients admitted with early congestive heart failure, there was no organic heart disease. Signs of failure and haemic murmurs disappeared completely when the anaemia was corrected. The six observations on the control group of five subjects include four on patients after they had been wormed but were still anaemic, and two on patients who were anaemic, one of whom had none and the other only very occasional hookworm eggs in the stool.

On admission several of the patients were too ill for any absorption tests to be carried out. All were treated with ferrous sulphate by mouth and intramuscular injections of iron, and three were transfused with a pint of blood before investigations could be done. All but one of the patients had been fed on the hospital diet for 7–10 days before the first absorption test was begun.

Diet

The standard hospital diet was used throughout. It was just adequate in meeting the accepted protein requirement i.e. 1 g protein/kg body-weight/24 h, and consisted of the following meals: at 6.30 a.m., maize porridge made with water and a little milk;

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Table 1. *Clinical information about African patients (A) with hookworm infestation and (B) after worming or without hookworm infestation*

Name	Age if known (years)	Weight (kg)	Haemoglobin (Sahli) (%)	Hookworm load	Occult blood	Clinical signs
			(A) Patients with hookworm infestation			
Asansio	Adult	66·9	30	2142	Positive	Pallor, generalized oedema, koilonychia
Yosef	Adult	52·9	33	1158	Positive	Pallor, systolic murmur, one tapeworm on worming
Yakobo	12	20·0	39	1592	Positive	On admission Hb 10%, congestive heart failure
Andrea	26	46·0	36	2796	Positive	Gross oedema, early congestive heart failure, one tapeworm on worming
Bukombe	Adult	53·5	31	786	Positive	Oedema of legs and sacrum, pallor
Matabalo	Adult	51·9	36	Not wormed	Positive	Had been admitted 7 months previously and treated for anaemia and wormed. On readmission, oedematous, Hb 21 %, and stool loaded with hookworm ova
Kalole	Adult	44·6	46	2839	Positive	Pallor, mild oedema, Hb 20% on admission, one tapeworm on worming
Musa	Adult	46·0	31	950	Positive	Hb 13% on admission, grossly oedematous, early congestive heart failure, one small tapeworm on worming
Wilson	6	15·0	33	416	Positive	Pallor, mild oedema
			(B) Patients after worming or without hookworm infestation			
Asansio	Adult	53·0	41	—	Negative	Oedema-free, after worming
Yakobo	12	22·8	50	—	Negative	Oedema-free, after worming
Andrea	26	47·4	59	—	Negative	Oedema-free, after worming
Kalaveri	Adult	47·7	30	—	Positive	Suspected bleeding peptic ulcer, only occasional hookworm ova in stool
Stefano	22	51·0	70	—	Negative	Stool negative for hookworm ova

at 10.0 a.m., bread and tea; at 12.00 noon, cooked bananas, beans and groundnut soup; at 3.00 p.m., maize porridge made with water and a little milk; at 7.00 p.m., rice, soup, meat (three times a week), sweet potatoes, beans (four times a week).

Methods

The methods of collection, drying, and analysis of food and stools were as described by Holmes & Darke (1959). Tetrachlorethylene followed by magnesium sulphate was used as a vermifuge and all stools passed during 36 h after this treatment were collected. A few ml of 40% (w/v) formaldehyde solution were added, which rendered the stools relatively inoffensive and served to arrest bacterial action and the destruction of the worms. The stool was then passed through a household sieve of suitable mesh, and the faecal lumps were broken up by gentle rubbing with a wooden spatula. The worms were picked out when seen, and more and more usually became visible as the process was continued. The number of worms diminished progressively as each successive stool was examined. Four patients each produced a small tapeworm as well as their hookworms.

At least 7 days elapsed before the post-worming absorption was determined. The dried food and stools were brought back to the Institute at Mwanza for analysis.

The weights of the subjects, their hookworm loads and certain clinical information are given in Table 1.

RESULTS

Table 2 shows that, although there was a wide scatter, the mean daily dry stool weight for the hookworm patients was greater than that for the controls. The energy value/g dried stool was not significantly different in the two groups. There was a difference in the N content of the stools, that for the hookworm patients being greater than that for the controls.

Table 2. *Mean values with their standard errors for daily weight and energy and nitrogen contents of dried stools of patients with hookworm infestation, and of controls*

Group	No. of observations	Weight (g)	Energy content* (kcal/g)	N content (mg/g)
Anaemic patients with hookworm infestation	10	50·0 ± 3·5	5·04 ± 0·10	61·8 ± 2·7
Anaemic patients free from or with small hookworm infestation	6	38·1 ± 4·1	4·90 ± 0·18	54·6 ± 1·7

* By bomb calorimeter.

In Table 3 the daily energy and N intakes and the percentage absorption of energy and N of the two groups of patients are compared. Here 'absorption' is measured as the difference between the energy value and N content of the food and the energy value and N content of the stools, expressed as a percentage of energy and N intake. (This value is sometimes referred to as 'apparent digestibility'.) It will be seen that with hookworm loads of the magnitude observed there was a significantly diminished absorption of both energy and N. It will be noted that the intake of N was less in the control group, which will tend, for reasons discussed by Holmes & Darke (1959), to

reduce rather than enhance the differences in absorption. Table 3 also shows that these differences were due to worm infestation and not to the associated anaemia, since gross anaemia was still present when the control determinations were carried out, although the hookworms had been removed.

Table 3. *Energy and nitrogen absorption of African patients (A) with hookworm infestation and (B) after worming or without hookworm infestation*

	Energy			Nitrogen		
Name	In diet* (kcal/24 h)	In stool* (kcal/24 h)	Absorption (%)	In diet (g/24 h)	In stool (g/24 h)	Absorption (%)
(A) Patients with hookworm infestation						
Asansio	2189	209	90·5	10·5	2·3	78·4
Yosef	2362	289	87·8	10·9	3·8	67·3
Yosef	2182	399	81·7	8·6	5·1	41·1
Yakobo	1659	209	87·4	7·2	2·3	68·2
Andrea	2010	227	88·7	8·3	2·8	66·7
Bukombe	1908	268	86·0	7·9	3·6	55·0
Matabalo	2271	243	89·3	9·8	3·6	63·4
Kalole	1960	298	84·8	8·2	2·9	64·4
Musa	1674	200	88·1	7·6	2·9	62·3
Wilson	800	188	76·5	5·2	2·2	58·4
Mean	1902	253	86·1	8·4	3·1	62·5
S.E. of mean	—	—	1·3	—	—	3·1
(B) Patients after worming or without hookworm infestation						
Asansio	2304	145	93·7	8·5	1·6	81·6
Asansio	2113	219	89·6	9·1	2·5	72·9
Yakobo	1265	120	90·5	5·2	1·5	70·8
Andrea	1939	234	87·9	7·9	2·6	67·7
Kalaveri	1850	223	87·9	7·7	2·1	72·7
Stefano	1830	172	90·6	8·1	2·1	74·0
Mean	1884	186	90·0	7·7	2·1	73·3
S.E. of mean	—	—	0·9	—	—	1·9

Difference between means (B − A) with its S.E.

Percentage absorption of energy	3·9 ± 1·6
Percentage absorption of nitrogen	10·8 ± 3·6

* By bomb calorimeter.

DISCUSSION

It was shown in the previous paper (Holmes & Darke, 1959) that, although the absorption of energy and N by most of the groups studied was less than would be expected by generally accepted standards, it was not affected by light hookworm loads, such as were borne by a number of the subjects.

It is here shown that absorption, particularly of N, is diminished by heavier worm loads. It seems reasonable to assume with the subject Wilson that 416 worms constitute a heavy load for a child of 6 years, weighing only 15 kg.

Accurate dietary histories could not be obtained from these subjects. It is worth noting, however, that they were all immigrants to Buganda. Previous experience has shown that such people, who as a whole form a floating population of poorly paid labourers, tend to consume a diet poor in protein and containing very little or no animal protein. Most of the African population around Kampala is exposed to repeated hookworm infestation, but it is among the immigrants, rather than among the

more prosperous Baganda, that heavy hookworm loads with gross anaemia are usually encountered.

It has been pointed out by Holmes & Darke (1959) that there is good evidence from other work that ascarid infestation in man results in the production of antisubstances to proteolytic enzymes in the intestine (Weinland, 1903; Hamill, 1906; Harned & Nash, 1932; Collier, 1941) and that *Haemonchus contortus* also produces antisubstances to proteolytic enzymes in the sheep (Stewart, 1932), though, as far as is known, the question as to whether or not hookworms behave similarly in man has never been investigated. It is reasonable to suppose that the antisubstances to proteolytic enzymes secreted by the worm serve to protect it from the host's proteolytic enzymes. There is also evidence that a diet deficient in protein lowers the secretion of digestive enzymes, and so reduces absorption. On these grounds, the following sequence of events may perhaps occur in a population whose members are exposed to repeated hookworm infestation. Such members of the population as suffer from a deficiency of dietary protein, and who may therefore already have some deficiency of digestive enzymes, have their enzymes still further diminished by anti-enzymes secreted by the worms, so that protein absorption falls still further. Though the worms do not reproduce in the gut, it may well be that worms arriving in the alimentary canal as a result of a fresh infestation find it easier to establish themselves as a result of the host's enzyme deficiency, so that the load of worms is progressively increased and the host's powers of absorption progressively lowered.

There is also the possibility that protein deficiency lowers the host's powers of resistance to invasion by the infective larvae, though there is at present little concrete evidence for or against this view. The experience of some of us in Africa has been that it is rare to find heavy hookworm loads with severe anaemia in persons whose diet is not, or has not recently been, grossly deficient in protein. An hypothesis such as that just outlined would explain this observation.

SUMMARY

1. The absorption of energy and nitrogen from the intestine by nine African patients heavily infested with hookworms has been measured.

2. It was shown that these heavy infestations reduce the absorption of N from the intestine. The effect on the absorption of energy is less.

3. The implications of these findings are discussed.

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