IMPACT OF PARASITIC INFECTIONS AND DIETARY INTAKE ON CHILD GROWTH IN THE SCHISTOSOMIASIS-ENDEMIC DONGTING LAKE REGION, CHINA

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Abstract. The simultaneous impacts of parasitic infections and dietary intake on growth patterns were investigated for 427 children aged 10–13 years in the schistosomiasis-endemic Dongting Lake region of China. Height, weight, mid-upper arm circumference, and skinfold thicknesses (triceps, biceps, and subscapular) were measured, and eggs of Schistosoma japonicum, Ascaris lumbricoides, Trichuris trichiura, and Fasciolopsis buski in the collected stool samples of each subject were detected by Kato-Katz thick smear technique. Long-term dietary intake of each subject was assessed with a semiquantitative food frequency questionnaire. The results demonstrate that the study children were retarded in growth compared with the standards of Chinese rural children; among them, the girls were more frequently infected for S. japonicum and had lower intakes of protein and energy. Reduced height, weight, and mid-upper arm circumference were noted in children infected with S. japonicum, most severely in the girls with the least energy and protein intakes. Multiple stepwise regression analysis indicated that growth retardation was significantly and substantially associated with S. japonicum infection and lack of protein-energy intakes. For child health programs, regular schistosomiasis screening and treatment in schoolchildren needs to be complemented by health and nutrition education for both children and parents. Also, special attention should be paid to educating parents about the needs of girls.

INTRODUCTION

Nutritional deficiency and infectious diseases play significant roles in retardation of growth. Many studies show that such environmental stresses affect preadolescents more than older persons. Previous studies focused on nutrition or parasitic infections, but not both. Here we report growth patterns of schoolchildren in the schistosomiasis-endemic Dongting Lake area of Hunan Province, China, and relate growth to both parasitic infections and intakes of energy and nutrients.

In China’s Yangtze valley, schistosomiasis due to Schistosoma japonicum remains a serious infectious disease despite long-term efforts for snail control, chemotherapy, sanitation, and health education. More than 100 million people are at risk of this infection in Hunan, Hubei, Jiangxi, Anhui, Jiangsu, Sichuan, and Yunnan provinces. The worst areas are around Dongting and Poyang Lakes and the associated marshlands south of the middle reaches of the Yangtze River. The prevalence of S. japonicum is particularly high in children and adolescents due to their frequent contact with infested water and their underdeveloped resistance to reinfection, and the infection retards child growth. Other parasites, especially soil-transmitted helminths (Ascaris lumbricoides, Trichuris trichiura) and food-borne trematodes (Fasciolopsis buski), are also prevalent among schoolchildren in many schistosomiasis-endemic areas in China because of warm, moist weather, poor sanitary behavior, and the habit of eating raw water plants.

Most schistosomiasis-endemic areas in China are rural and economically less developed; consequently, the inhabitants have inadequate nutrient intakes and growth faltering, manifested by short stature and light body weight. The Third Chinese National Nutrition Survey in 1992 revealed that child intakes of energy, protein, and fat were lower in rural areas than in urban areas, accounting for the regional difference in growth, represented by height and weight. Thus, children in the schistosomiasis-endemic areas are threatened by both parasitic infections and undernutrition.

MATERIALS AND METHODS

Study area and population. The five villages selected in this study are situated in Guangxing town in Hunan Province, facing Dongting Lake in the south and the Yangtze River in the east, and all of them are similar for environmental conditions and socioeconomic status. For instance, the amount of annual per person income scarcely varies from village to village, averaging about 1,000 Chinese yuan (equivalent to US$120). Houses are scattered along the embankments linked to the lake or river, and canals carry water from the lake to the residential zone and the surrounding agricultural fields. The villagers have many opportunities to contact schistosomiasis-infested water or marshland when fishing, traveling by boat, herding, harvesting grass, or swimming in the summer.

The rate of enrollment in primary school in these villages was 99%. All 445 students (227 boys and 218 girls) of grades 5 and 6, aged 10–13 years, a group known to be at high infection risk based on previous research, participated in this study in October 2001. The purpose and the contents of the study were explained by classroom teachers to the students and their parents, and signed informed consent was obtained from all the parents. The study was reviewed and approved by the Ethical Committee of Xiangya Medical College, Central South University (Changsha, Hunan, People’s Republic of China).

Anthropometry. Anthropometric measurements were conducted for body weight, height, mid-upper arm circumference, and skinfold thickness, following the standard methods. Body weight with minimum clothing was recorded to the nearest 0.1 kg, using a portable digital scale (model 1597; Tanita, Tokyo Japan). For height, the child stood erect against a stadiometer affixed to a wall for measurement to the nearest 0.1 cm. Mid-upper arm circumference (MUAC) was measured with a flexible tape and recorded to 0.1 cm. Skinfold thicknesses at triceps, biceps, and subscapular sites on the left side of the body were measured with the Holtain caliper (Holtan, Brierian, United Kingdom) to the nearest 0.2 mm.
and the sum of the 3 measurements were used for analysis. All measurements were done twice by one of the authors (H.Z.) blinded to parasitic infection status, and the average values were used for analysis. Body mass index (BMI: [weight (kg)/
[height (m)]\(^2\)) and arm muscle area (AMA: [MUAC – (triceps skinfold \(\times \pi\))]\(^2\)/(4 \times \pi)) were calculated. To standardize
the anthropometric variables, the Z scores of height-for-age (HAZ) and weight-for-age (WAZ) were computed using the
NCHS reference data,\(^13\) and those of BMI-for-age (BMIZ) and MUAC-for-age (MUACZ) were computed using the
NHANES data.\(^14\)

Parasitological examination. A stool sample was collected from each subject, and 3 × 42-mg smears were prepared using
the Kato-Katz thick smear technique for parasitological examination.\(^15\) Quantitative counts of eggs of S. japonicum and
examinations for presence or absence of eggs of A. lumbricoides, T. trichiura, and F. buski were conducted by one of the
authors (Y. H.) with assistance of experienced technicians in the laboratory of the Hunan Institute of Parasitic Diseases.

It is noted that the subjects who were diagnosed positive for S. japonicum infection were treated with a 2-day split oral
dose of praziquantel, 60 mg/kg of body weight.\(^16\) Those children found positive for F. buski infection were treated with a
single dose of 25 mg/kg praziquantel.\(^17\) All students were given treatment with a single dose of 400 mg albendazole.\(^16\)

Dietary intake. Dietary habit, or long-term dietary intake, for each subject was evaluated with a self-administered semi-
quantitative food frequency questionnaire (FFQ). The FFQ method has been developed as a valid and reproducible
means for long-term dietary intake, particularly suitable to children.\(^18,19\) In the current study, our FFQ was designed to
fill-in usual frequencies of consuming 80 local food items and their portion sizes per consumption; the FFQ was developed
and modified for this after pretest among same-age students in another nearby school. The questionnaire sheets were
distributed to the students in the five study schools by the classroom teachers, who gave detailed explanation. The question-
naire sheets answered by each student with help of his or her parents were checked, one by one, by our research team in
the school on the following day.

Applying the Chinese Food Composition Tables\(^20\) to each student’s consumption frequency of all foods and their portion
sizes reported, total intakes of energy and major nutrients per day were calculated; that is, \(\Sigma\) (frequency \(\times\) portion
size \(\times\) nutrient content). Total energy intake (TEI) adjusted by weight (called TEI/weight, kJ/kg per day), contributions
of protein and fat to TEI (called %protein and %fat, respectively) were used to assess each subject’s long-term energy
and major nutrient intakes. Body size has a significant effect on individual energy needs, so TEI/weight were used to
evaluate individual energy intake.\(^1\) In this study, TEI/weight was used for analysis; the indicators of %protein and %fat are
effective in FFQ-based studies because of their stability regard-less of under- or over-reporting of foods consumed\(^22\) and
are suited for evaluation of nutritional status in developing countries.\(^21\)

Data analysis. Differences in anthropometric indicators were analyzed by groups according to parasitic infections,
using ANOVA with Tukey HSD multiple comparisons. In-
tensity of S. japonicum was originally categorized as follows:
light, 1–100 eggs/g of feces (epg); moderate, 101–400 epg; and
heavy, > 400 epg. But due to the small number of heavily and
moderately infected individuals, all subjects were regrouped
into “infected” or “uninfected” for analysis. To examine the
effects of parasites on growth, the subjects were thus divided
into three groups: Group 1 included children not infected with
any of the four parasites; Group 2, children infected with
one or more of the three nonnchistosome parasites; and
Group 3, children infected with S. japonicum and any or none
of the other three parasites. TEI/weight, %protein, and %fat
were also compared among the three groups by ANOVA
with Tukey HSD multiple comparisons. Stepwise multivariate
regression analysis was performed to analyze the impact of
parasitic infections, energy, and nutrient intakes on growth.
HAZ, WAZ, MUACZ, and BMIZ were dependent variables
in the models. The independent variables included sex, posi-
tive/negative for the four parasites (dummy variables), and
TEI/weight, %protein, and %fat, all of which were admitted
into the model at \(P < 0.10\) level. All statistical analyses were
performed using the SPSS 10.0 (Statistical Package for the
Social Science, SPSS Inc., Tokyo, Japan, 1999). The significa-
cantly different level was set at \(P < 0.05\) for both.

RESULTS
For all of the 445 subjects, anthropometric measurements
and FFQ data were obtained, while stool samples for testing
parasitic infections were collected from 427 subjects (96.0%).
The data from these 427 subjects, 217 boys and 210 girls, were
analyzed.

Anthropometric measurements. Growth status in terms of
height, weight, BMI, MUAC, arm muscle area, and the sum
of skinfold thicknesses by age and sex are seen in Table 1. On
average, our sampled children were smaller on all these mea-
sures than those included in a China National Survey 10 years
before, suggesting that our study population is relatively
worse off nutritionally than most other Chinese children.
There were high and significant correlations between MUAC
and arm muscle area (Pearson’s \(r = 0.94, P < 0.001\)) and
between BMI and skinfold thickness (Pearson’s \(r = 0.66, P <
0.001\), so that the subsequent analyses used weight, height,
MUAC, and BMI as the direct anthropometric indicators of
growth. Figure 1 shows that, by international age-sex–specific
standards, WAZ and BMIZ were significantly lower in fe-
nal sexes than in males (\(P < 0.05\) for both).

Frequency of parasitic infections. The frequencies of para-
sitic infections by sex and age are shown in Table 2. Preva-
ience of S. japonicum was twice as high in girls (12.4%) as in
boys (6.5%) (\(\chi^2 = 4.42, P < 0.05\), and among the girls the 12-
to 13-year age group was significantly more infected than
their younger female counterparts (19% versus < 9%).
Among infected children, heavily and moderately infected
subjects (> 100 epg) were not significantly different between
boys (7%) and girls (27%) (\(P = 0.14\). The prevalence of A.
lumbricoides (> 33%) and T. trichiura (> 19%) infections did
not differ much by sex, but the latter was significantly higher
among girls aged 12–13 years (27.4%) than among the other
girls (< 18%). Fasciolopsis buski infections were uncommon
(3.6% for both sexes pooled).

Energy and nutrient intakes. Table 3 gives the results of
energy and nutrient intakes by sex and age, in which there
were two major observations. First, mean of TEI/weight was
significantly larger in boys than in girls, especially for the 12-
to 13-year age group (\(P < 0.001\)). Second, %protein was sig-
nificantly larger in boys than in girls (\(P < 0.01\) for both).
Interrelations among parasitic infections, dietary intake, and growth indicators. Table 4 reveals that HAZ, WAZ, and MUACZ were significantly lower in children infected with *S. japonicum* (Group 3) than in the other two groups (children not infected with any of the four parasites, and children infected with one or more of the three nonschistosome parasites) for girls, but Z scores did not differ significantly among the three groups for boys. Among the group of children infected with *S. japonicum*, males were significantly closer to normal than females for both HAZ and WAZ (*P* < 0.05 for both).

There are two major observations in Table 5, which shows energy and nutrient intakes among three groups. First, in girls, %protein and %fat were lower in children infected with *S. japonicum* (Group 3) than in the other two groups (*P* < 0.01 for both). Second, in the schistosome-infected Group 3, TEI/weight was larger in infected males than in infected females (*P* < 0.05), and %protein and %fat were also higher in infected males than in infected females (*P* < 0.01 for both). In other words, girls infected with *S. japonicum* had the least energy and nutrient intakes even after adjusting for their smaller body size.

Multivariate stepwise regression analysis indicated that *S. japonicum* infection was a significant explanatory factor for models of HAZ, WAZ, and MUACZ, and %protein was a significant explanatory factor for all four growth models (Table 6). It is noteworthy that *S. japonicum* infection accounted for 26% of the stunting after adjusting for the positive influence of protein intake (14% of outcome variation) and the negative influence of *F. buski* infection (9%). For wasting (WAZ, MUACZ, and BMIZ), *S. japonicum* infection was less important (accounting for 9–19% of outcome variation) and %protein intake relatively more important (accounting for 19–25% of variation), with %fat intake accounting for 8–10% of variation. Other factors (TEI/weight, intestinal nematodes) were not significant (*P* > 0.10) and so were not included in any models.

**Table 1**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>N</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI (kg/m)</th>
<th>MUAC (cm)</th>
<th>Arm muscle area (cm²)</th>
<th>Skinfold (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>131.7 (5.0)</td>
<td>27.7 (3.8)</td>
<td>16.1 (1.7)</td>
<td>17.6 (1.9)</td>
<td>18.8 (3.4)</td>
<td>17.3 (5.2)</td>
</tr>
<tr>
<td>11</td>
<td>107</td>
<td>136.8 (4.9)</td>
<td>30.2 (4.2)</td>
<td>16.1 (1.6)</td>
<td>18.4 (1.7)</td>
<td>20.8 (3.6)</td>
<td>17.3 (4.8)</td>
</tr>
<tr>
<td>12–13</td>
<td>60</td>
<td>142.0 (5.7)</td>
<td>33.3 (5.2)</td>
<td>16.5 (1.9)</td>
<td>19.1 (2.1)</td>
<td>22.2 (4.7)</td>
<td>17.6 (6.2)</td>
</tr>
<tr>
<td>Total</td>
<td>217</td>
<td>137.1 (6.4)</td>
<td>30.5 (4.8)</td>
<td>16.2 (1.7)</td>
<td>18.4 (1.9)</td>
<td>20.9 (4.1)</td>
<td>17.4 (5.3)</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>34</td>
<td>133.2 (6.9)</td>
<td>27.3 (5.0)</td>
<td>15.5 (1.7)</td>
<td>17.3 (2.1)</td>
<td>17.5 (3.7)</td>
<td>19.7 (5.9)</td>
</tr>
<tr>
<td>11</td>
<td>92</td>
<td>138.2 (6.2)</td>
<td>30.9 (4.4)</td>
<td>16.1 (1.5)</td>
<td>18.5 (1.6)</td>
<td>20.3 (3.6)</td>
<td>19.7 (4.2)</td>
</tr>
<tr>
<td>12–13</td>
<td>84</td>
<td>143.4 (5.4)</td>
<td>35.9 (4.4)</td>
<td>16.4 (1.4)</td>
<td>19.2 (1.5)</td>
<td>22.0 (3.5)</td>
<td>20.1 (3.9)</td>
</tr>
<tr>
<td>Total</td>
<td>210</td>
<td>139.5 (7.0)</td>
<td>31.5 (5.0)</td>
<td>16.1 (1.5)</td>
<td>18.6 (1.8)</td>
<td>20.5 (3.9)</td>
<td>19.9 (4.4)</td>
</tr>
</tbody>
</table>

BMI, body mass index; MUAC, mid-upper-arm circumference.

*Data of the Third Chinese National Survey in 1992 are from Ge and others.*

**Table 2**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>N</th>
<th>Schistosoma japonicum (%)</th>
<th>Ascaris lumbricoides (%)</th>
<th>Trichuris trichiura (%)</th>
<th>Fasciolopsis buski (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>4.0</td>
<td>28.0</td>
<td>14.0</td>
<td>6.0</td>
</tr>
<tr>
<td>11</td>
<td>107</td>
<td>5.6</td>
<td>42.1</td>
<td>23.4</td>
<td>3.7</td>
</tr>
<tr>
<td>12–13</td>
<td>60</td>
<td>10.0</td>
<td>36.7</td>
<td>23.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>217</td>
<td>6.5</td>
<td>37.3</td>
<td>21.2</td>
<td>3.2</td>
</tr>
<tr>
<td>P</td>
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<tr>
<td>*</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>34</td>
<td>8.8</td>
<td>29.4</td>
<td>17.6</td>
<td>8.8</td>
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<td>92</td>
<td>7.6</td>
<td>28.3</td>
<td>13.0</td>
<td>2.2</td>
</tr>
<tr>
<td>12–13</td>
<td>84</td>
<td>19.0</td>
<td>40.5</td>
<td>27.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Total</td>
<td>210</td>
<td>12.4*</td>
<td>33.3</td>
<td>19.5</td>
<td>4.3</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*</td>
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</tr>
</tbody>
</table>

*Significantly different frequency of parasitic infections between males and females (P < 0.05).
Mean and standard deviation of total energy and major nutrient intakes in the study children

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Males</th>
<th></th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>7.6 (1.5)</td>
<td>253.1 (50.2)</td>
<td>7.3 (1.3)</td>
</tr>
<tr>
<td>11</td>
<td>7.5 (1.4)</td>
<td>252.6 (48.1)</td>
<td>7.5 (1.3)</td>
</tr>
<tr>
<td>12–13</td>
<td>7.8 (1.2)*</td>
<td>244.7 (37.9)**</td>
<td>7.3 (1.4)*</td>
</tr>
<tr>
<td>Total</td>
<td>7.6 (1.4)</td>
<td>250.5 (46.0)***</td>
<td>12.0 (2.4)**</td>
</tr>
</tbody>
</table>

TEI, total energy intake; TEI/weight, total energy intake adjusted by weight. %protein, %fat, contributions of protein/fat to energy.

*Significantly different between males and females. **P < 0.01. ***P < 0.001.

Table 3

Parasitic infections. Schistosoma japonicum, together with common intestinal nematode parasites such as A. lumbricoides and T. trichiura, remain prevalent among schoolchildren in the Dongting Lake region of China. This study revealed that the prevalence of S. japonicum was highest among 12- to 13-year-old children in grade 6, 19% in girls and 10% in boys, while the prevalences of A. lumbricoides and T. trichiura were also the highest in this age group. We have previously found in other Dongting Lake areas that infection rates of S. japonicum were higher in grades 5–6 children than in grades 3–4 children, so it is apparent that older primary schoolchildren are at higher risk in S. japonicum infection.

This study also demonstrated a higher prevalence of S. japonicum in girls than in boys. This sex difference probably reflects differences in contact with infested water. For example, girls, older ones in particular, often do domestic work, such as collection of grass in marshland for animal feeding and harvest of wild vegetables along water embankments, though swimming and other recreational activities in infested water in the summer may be more frequent in boys than in girls. Frequency of potentially dangerous water contact is a highly significant risk factor of S. japonicum infection.

Although adverse influences of A. lumbricoides and T. trichiura infections on child growth have been revealed in some populations of developing countries, these infections did not significantly affect our subjects. This may reflect the effects of school-based mass treatment of deworming, which has been conducted once a year in the study area. In fact, we found most infections with A. lumbricoides or T. trichiura were of light intensity at levels that may be too low to have a significant influence on child growth.

It has been shown outside Asia that both Schistosoma haematobium and Schistosoma mansoni inhibit child growth. Similar results have been obtained in Asia. Among 8- to 19-year-old subjects in the Philippines, the infection of S. japonicum reduced height, weight, arm muscle area, and skinfold in females and the latter two anthropometric indicators in males. Results were similar for 4- to 19-year-old subjects studied in Jiangxi Province, China. Our results are consistent with these studies and showed a clear pattern of a negative S. japonicum effect on growth for both boys and girls for all outcomes, reaching statistical significance for girls, the worst-affected sex. It is notable that in our study the intensity of infection was much lower than in earlier Chinese studies in Jiangxi province (where 38.3% of infected subjects excreted > 100 epg), showing that even with quite low schistosomiasis worm burdens now prevailing in Hunan schistosomiasis can still detectably retard growth.

Some studies conducted in schistosomiasis-endemic areas have indicated that S. japonicum had stronger effects on growth retardation than A. lumbricoides and T. trichiura. We also have found this. Also, as with these earlier studies, a sex difference in the adverse effect of S. japonicum infection

Table 4

Mean and standard deviation of growth indicators by sex and parasite-based groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>HAZ</th>
<th>WAZ</th>
<th>MUACZ</th>
<th>BMIZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>104</td>
<td>0.88 (0.76)</td>
<td>0.85 (0.76)</td>
<td>-1.32 (0.47)</td>
<td>-0.55 (0.87)</td>
</tr>
<tr>
<td>Group 2</td>
<td>99</td>
<td>0.98 (0.73)</td>
<td>0.94 (0.82)</td>
<td>-1.31 (0.56)</td>
<td>-0.52 (1.06)</td>
</tr>
<tr>
<td>Group 3</td>
<td>14</td>
<td>1.05 (0.86)*</td>
<td>1.21 (0.53)*</td>
<td>-1.51 (0.69)</td>
<td>-0.78 (0.81)</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>0.07</td>
<td>0.26</td>
<td>0.41</td>
<td>0.63</td>
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<td>Females</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>112</td>
<td>0.83 (0.78)</td>
<td>0.89 (0.75)</td>
<td>-1.36 (0.50)</td>
<td>-0.77 (0.73)</td>
</tr>
<tr>
<td>Group 2</td>
<td>72</td>
<td>0.89 (0.88)</td>
<td>0.90 (0.75)</td>
<td>-1.19 (0.57)</td>
<td>-0.60 (0.78)</td>
</tr>
<tr>
<td>Group 3</td>
<td>26</td>
<td>0.80 (0.88)*</td>
<td>1.06 (0.46)*</td>
<td>-1.50 (0.31)</td>
<td>-0.94 (0.50)</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.02</td>
<td>0.09</td>
</tr>
</tbody>
</table>

*Significantly different between males and females (P < 0.05).

Group 1: children not infected with any of the four parasites; Group 2: children infected with one or more of the three nonschistosome parasites; Group 3: children infected with S. japonicum and any or none of the other three parasites. HAZ, Z score of height-for-age; WAZ, Z score of weight-for-age; MUACZ, Z score of mid-upper arm circumference-for-age; BMIZ, Z score of body mass index-for-age.

DISCUSSION

Parasitic infections. Schistosoma japonicum, together with common intestinal nematode parasites such as A. lumbricoides and T. trichiura, remain prevalent among schoolchildren in the Dongting Lake region of China. This study revealed that the prevalence of S. japonicum was highest among 12- to 13-year-old children in grade 6, 19% in girls and 10% in boys, while the prevalences of A. lumbricoides and T. trichiura were also the highest in this age group. We have previously found in other Dongting Lake areas that infection rates of S. japonicum were higher in grades 5–6 children than in grades 3–4 children, so it is apparent that older primary schoolchildren are at higher risk in S. japonicum infection.

This study also demonstrated a higher prevalence of S. japonicum in girls than in boys. This sex difference probably reflects differences in contact with infested water. For example, girls, older ones in particular, often do domestic work, such as collection of grass in marshland for animal feeding and harvest of wild vegetables along water embankments, though swimming and other recreational activities in infested water in the summer may be more frequent in boys than in girls. Frequency of potentially dangerous water contact is a highly significant risk factor of S. japonicum infection.

Although adverse influences of A. lumbricoides and T. trichiura infections on child growth have been revealed in some populations of developing countries, these infections did not significantly affect our subjects. This may reflect the effects of school-based mass treatment of deworming, which has been conducted once a year in the study area. In fact, we found most infections with A. lumbricoides or T. trichiura were of light intensity at levels that may be too low to have a significant influence on child growth.

It has been shown outside Asia that both Schistosoma haematobium and Schistosoma mansoni inhibit child growth. Similar results have been obtained in Asia. Among 8- to 19-year-old subjects in the Philippines, the infection of S. japonicum reduced height, weight, arm muscle area, and skinfold in females and the latter two anthropometric indicators in males. Results were similar for 4- to 19-year-old subjects studied in Jiangxi Province, China. Our results are consistent with these studies and showed a clear pattern of a negative S. japonicum effect on growth for both boys and girls for all outcomes, reaching statistical significance for girls, the worst-affected sex. It is notable that in our study the intensity of infection was much lower than in earlier Chinese studies in Jiangxi province (where 38.3% of infected subjects excreted > 100 epg), showing that even with quite low schistosomiasis worm burdens now prevailing in Hunan schistosomiasis can still detectably retard growth.

Some studies conducted in schistosomiasis-endemic areas have indicated that S. japonicum had stronger effects on growth retardation than A. lumbricoides and T. trichiura. We also have found this. Also, as with these earlier studies, a sex difference in the adverse effect of S. japonicum infection

Table 5

Mean and standard deviation of energy and nutrient intake indicators by sex and parasite-based groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>TEI/weight (kJ/kg per day)</th>
<th>%protein (%)</th>
<th>%fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>107</td>
<td>257.0 (40.3)***</td>
<td>11.8 (2.4)</td>
<td>10.9 (3.7)</td>
</tr>
<tr>
<td>Group 2</td>
<td>96</td>
<td>246.1 (52.1)*</td>
<td>12.3 (2.5)</td>
<td>11.1 (3.6)</td>
</tr>
<tr>
<td>Group 3</td>
<td>14</td>
<td>234.4 (31.8)*</td>
<td>11.9 (1.7)**</td>
<td>11.1 (3.5)**</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>0.09</td>
<td>0.30</td>
<td>0.89</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>112</td>
<td>239.7 (35.1)**</td>
<td>11.3 (2.1)</td>
<td>10.6 (3.7)</td>
</tr>
<tr>
<td>Group 2</td>
<td>72</td>
<td>250.4 (37.4)*</td>
<td>12.0 (2.4)</td>
<td>11.1 (3.6)</td>
</tr>
<tr>
<td>Group 3</td>
<td>26</td>
<td>227.8 (25.3)*</td>
<td>10.1 (1.6)**</td>
<td>8.2 (2.6)**</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>0.07</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

*Significantly different between males and females (P < 0.05, P < 0.01, and P < 0.001, respectively.

Groups: N: number of subjects; TEI/weight, total energy intake adjusted by weight; %protein, %fat, contributions of protein/fat to energy.
on growth was apparent in our study with girls more affected than boys. McGarvey and others speculated that the sex difference may arise because food intakes were better for boys than girls, perhaps due to cultural factors. We investigated this aspect by our study of dietary intakes (see below).

**Dietary intake and growth pattern.** Means of body height and weight of our subjects in each age group were slightly lower than those of children studied in China’s national survey of 1992. For this comparison, we must first consider secular trends as living conditions in China improved in the 1990s due to the economic reforms, with continuous overall improvement in the growth of children. It is thus reasonable to conclude that the subject children are falling behind in height and weight compared with Chinese children as a whole. According to the Chinese Recommended Daily Allowance (RDA), the average daily energy intake in our study subjects is 83.3% of RDA and average daily protein intake is 75.4% of RDA. Thus, our data suggest that the subjects in this study are malnourished.

Important findings in energy and nutrient intakes in this study are sex differences, represented by higher TEI/weight and %protein in boys than in girls. The significantly higher %protein in boys in this study suggests sex differences in food intake not only in quantity but also in quality. This could reflect the traditional cultural norm of gender difference in rural China. Such a gender bias in the nutrition of the school-children was also pointed out in the studies for children in rural China. Such growth retardation in the preadolescent period impedes long productivity.2

**Effects of schistosomiasis infection and nutrient intake on growth.** The previous discussion reveals the importance of simultaneously assessing the effects of both S. japonicum infection and nutrient intakes on growth, neither soil-transmitted helminthiasis (Ascaris lumbricoides and Trichuris trichiura), nor food-borne trematodiasis (Fasciolopsis buski) in this study. It is possible that low-intensity S. japonicum infection causes low nutrient intakes or that low nutrient intakes increase susceptibility to S. japonicum infection, but it seems more probable that these two factors are themselves products of the same social causes. This was evident in girls, for those infected with S. japonicum were lower in %protein and %fat intakes than the other two non-schistosome-infected groups and also lower than schistosome-infected boys, reflecting both socioeconomic conditions and cultural norms in the study communities. Girls in economically poor families, usually with a lower education level of parents and larger family size in rural areas, consume less nutritious foods and are engaged in domestic work such as harvesting grass in the marshland where risk of S. japonicum infection is high. This increase of opportunity of S. japonicum infection due to economic causes was also noted by Li and his colleagues.5 Therefore, undernutrition and S. japonicum infection may be related to lower family social economic status.

Regression analysis clarifies more systematically the effects of parasitic infections and major nutrient intakes on growth. Schistosoma japonicum infection played independently significantly and substantial roles on height, weight, and arm circumference and %protein on four growth indicators. Height, weight, arm circumference, and BMI are, respectively, indicators of long-term nutritional status, short-term nutritional status, and the body’s reserves of protein and energy. Thus, both %protein and S. japonicum infection affected short-term and long-term nutritional status or growth patterns in this study. The adverse growth effects of chronic S. japonicum infection probably reflect several mechanisms. For instance, infected children tend to have more episodes of diarrhea and general weakness,13 and associated limitation of protein intake will slow child growth. Interaction of undernutrition and infection will lead to even poorer growth than for either factor acting alone.28 In our study, girls infected with S. japonicum had the least energy and least nutrient intakes, which made infected girls the most retarded in growth.

In summary, S. japonicum infection and intakes of energy and major nutrients, protein in particular, all exerted significant and substantial influences on growth patterns of schoolchildren in a schistosomiasis-endemic area of China. Higher prevalence of S. japonicum infection and smaller contributions of protein to energy intake, which were major factors of growth retardation, were more serious in girls than in boys. Such growth retardation in the preadolescent period impairs development, including motor functions and cognitive or intellectual functions, and reduces growth potential in adolescence unless catch-up growth occurs. The lost growth potential in adolescence may seriously affect adult health and life-long productivity.

One of the study limitations is the reliance on stool collection for parasitological diagnosis, which may misclassify light infections as negative even after three slides per child. However, this potential bias would reduce the chance to detect anthropometric differences by lowering the values of the “uninfected” children. Thus, the current results may be a conservative estimate of the growth effects of S. japonicum. Other limitations of our study include the cross-sectional design and low average intensity of S. japonicum. It would be useful to extend this study to note longitudinal growth effects throughout adolescence. And additional study of nutrient intakes, S. japonicum infection, and growth would be useful in other endemic areas with heavy intensity of S. japonicum infection to confirm our findings in more extreme situations. Furthermore, intensified child health programs, including S. japonicum screening and treatment of school-age children, and health and nutrition education for both schoolchildren and their parents are recommended in schistosomiasis-
endemic areas. Special attention should be paid to the needs of girls, who at present are disadvantaged even more than the boys.

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