Ascaris egg profiles in human faeces: biological and epidemiological implications

W. PENG[1,3]*, X. ZHOU[2] *and* R. B. GASSER[3]

[1] *Jiangxi Medical Science Research Institute, 461 Bayi Road, Nanchang 330006, P. R. China*
[2] *Department of Parasitology, Jiangxi Medical College, 603 Bayi Road, Nanchang 330006, P. R. China*
[3] *Department of Veterinary Science, The University of Melbourne, 250 Princes Highway, Werribee, Victoria 3030, Australia*

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SUMMARY

Since 2 morphological forms (fertilized and unfertilized) of egg can be produced by *Ascaris*, infected humans can release in their faeces fertilized eggs only (FEO), unfertilized eggs only (UEO) or both fertilized and unfertilized eggs (FUE) (designated herein as the 3 different egg profiles). Epidemiologically, fertilized eggs are of significance as they enable effective transmission of the parasite. This study, for the first time, characterizes the *Ascaris* egg profiles in human faeces in an endemic region of China, explores possible host- and parasite-factors related to these profiles, and discusses the biological and epidemiological implications of the findings. The 3 egg profiles were recorded throughout the study period of 2 years, and the overall percentages of people with FEO, FUE and UEO profiles were ~41–47%, 32–42% and 17–21%, respectively. The overall number of unfertilized eggs for the entire population accounted for ~6–9% of all eggs excreted. The different *Ascaris* egg profiles showed no correlation to host gender, but they did relate to age and worm burden of the host and to the sex ratio and developmental status of the parasite. While an annual universal anthelmintic treatment resulted in some fluctuation in the values of individual egg profiles, the general features of these profiles remained similar throughout the study period. The findings of this study should have significant implications for understanding transmission patterns of *Ascaris* and for the implementation of control measures against ascariasis in endemic regions.

Key words: *Ascaris*, fertilized eggs, unfertilized eggs, epidemiology, China.

INTRODUCTION

The infection of humans with *Ascaris* is of major public health importance in many parts of the world (WHO, 1987; Peng, Zhou & Crompton, 1998; O'Lorcain & Holland, 2000; Crompton, 2001). *Ascaris* is the largest intestinal nematode of humans and has a direct life cycle. Adult female worms produce unembryonated eggs which pass *via* human faeces into the environment. Within these eggs develop the first, second and/or third stage larvae (Crompton, 1989; Geenen *et al*. 1999) under conditions of adequate moisture, oxygen and shade (Crompton, 1994). Humans usually contract infection *via* the faecal-oral route by ingesting eggs containing infective second/third stage larvae (Crompton, 1989; O'Lorcain & Holland, 2000), but there is also some risk of exposure by inhalation and subsequent swallowing, because infective eggs have been shown to occur in the air and dust in geographical areas endemic for ascariasis (WHO, 1967; Bidinger, Crompton & Arnold, 1981; Wong, Bundy & Golden, 1991; Kroeger *et al*. 1992).

Two morphological forms of egg can be produced by *Ascaris*, namely fertilized eggs and unfertilized eggs (Crompton, 1989). Microscopically, the fertilized eggs are usually elliptical in shape, varying in size from ~50–70 × 40–50 μm. Most fertilized eggs contain a zygote and are enclosed by a thick egg-shell consisting of 4 layers (i.e. the irregular outer coat produced by the parent female worm and the other 3 layers excreted by the embryo itself), although the outer coat may be absent from some fertilized eggs (Wharton, 1980). Unfertilized eggs are longer and narrower than the fertilized eggs, measuring ~60–100 × 40–60 μm (Crompton, 1989).

Humans with ascariasis can shed in their faeces fertilized eggs only, unfertilized eggs only or both fertilized and unfertilized eggs (Makiya *et al*. 1988; Seo, 1990; Fallah *et al*. 2002). From an epidemiological perspective, fertilized eggs are of significance for the effective transmission of *Ascaris* whereas unfertilized eggs are not. Thus, information on the different egg profiles in human populations may provide insights into the biology of *Ascaris*, elucidate particular transmission patterns for ascariasis and provide information relevant to the control of ascariasis. Although there is wealth of literature concerning the epidemiology of ascariasis in humans (e.g. Forrester & Scott, 1990; Asaolu, Holland & Crompton, 1991; Ferreira, Ferreira & Nogueira,

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* Corresponding author: Jiangxi Medical Science Research Institute, 461 Bayi Road, Nanchang 330006, P. R. China. Tel: +86 791 6361261. Fax: +86 791 6361187. E-mail: pwdjxmu@hotmail.com

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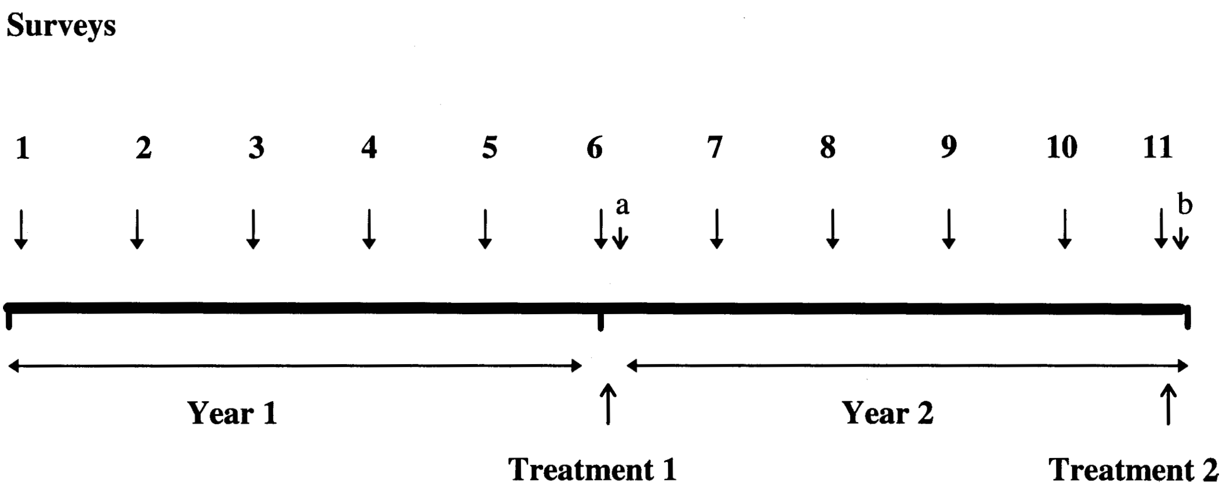

Fig. 1. Design of the longitudinal investigation of human ascariasis in a rural community in Jiangxi, China (a and b indicate drug efficacy test).

1994; Holland *et al.* 1996; Peng *et al.* 1996, 1998; Flores *et al.* 2001), there is a paucity of information regarding faecal egg profiles from infected humans (Seo, 1990; Fallah *et al.* 2002). The aims of the present study were (1) to characterize *Ascaris* egg profiles in the faeces from humans in an endemic area of China, (2) to explore host- and parasite-factors associated with these profiles, and (3) to discuss their possible biological and epidemiological implications.

MATERIALS AND METHODS

Study design

This investigation extended from a previous research project, in which details of the study area and population were described (Peng *et al.* 1996, 1998) (design shown in Fig. 1). In brief, two adjacent villages with a similar human population structure, socio-economic status and cultural habits were selected as the study sites. A 2-year, longitudinal investigation (consisting of 11 cross-sectional surveys with ~2 monthly intervals) of the transmission of ascariasis was carried out, employing the Kato-Katz approach (WHO, 1991) for diagnosis. A universal treatment was given immediately after surveys 6 and 11 using pyrantel pamoate (10 mg/kg, one dosage, Jiangxi Pharmaceuticals) (Fig. 1). Ten days after each treatment, a drug efficacy test (Fig. 1) revealed a cure rate of ~ 94–95% (see Peng & Zhou, 2001).

Parasitological examination and data collection

Throughout the 2-year study period, 333–557 persons were involved (Table 1). Two faecal examinations were performed per person. The numbers of fertilized and unfertilized *Ascaris* eggs per gram (EPG) were determined. Worms expelled from each person within 48 h of each treatment were collected and counted (defined as worm load per person), and individual worms were measured (length, width and weight) and their sex determined (see Peng, Zhou & Cui, 2002). In order to minimize the system error relating to the detection and counting of *Ascaris* eggs on microscopic slides by different examiners, all of the slides from surveys 1, 3, 4, 6–11 and a large proportion of the slides from survey 2 were examined by the same, experienced technician, whereas slides from survey 5 were examined by others. Also, all worms obtained were measured by an experienced person.

Table 1. The number (%) of people with particular *Ascaris* egg profiles in faeces throughout the 2-year study period (cf. Fig. 1)

Survey (*n*)*	FEO†	FUE†	UEO†
Year 1			
1 (557)	170 (47·1)	138 (38·2)	53 (14·7)
2 (548)	125 (36·4)	144 (42·0)	74 (21·6)
3 (516)	166 (44·5)	135 (36·2)	72 (19·3)
4 (414)	114 (37·6)	145 (48·1)	44 (14·5)
5 (403)	105 (43·0)	119 (48·8)	20 (8·2)
6 (466)	119 (35·4)	157 (46·7)	60 (17·9)
Subtotal (2904)	799 (40·8)	838 (42·7)	323 (16·5)
Year 2			
7 (381)	59 (48·4)	34 (27·8)	29 (23·8)
8 (363)	62 (30·5)	105 (51·8)	36 (17·7)
9 (350)	108 (50·9)	70 (33·1)	34 (16·0)
10 (333)	120 (57·4)	41 (19·6)	48 (23·0)
11 (398)	125 (47·9)	76 (29·1)	60 (23·0)
Subtotal (1824)	474 (47·1)	326 (32·3)	207 (20·6)

* Number of people involved in each survey.
† FEO: fertilized eggs only; FUE: fertilized and unfertilized eggs; UEO: unfertilized eggs only.

Analysis of data sets

According to the morphology of *Ascaris* eggs in faeces (Wharton, 1980; Crompton, 1989), 3 faecal egg profiles were recorded. The first profile related to people shedding fertilized eggs only (FEO), the second represented unfertilized eggs only (UEO) and the third both fertilized and unfertilized eggs (FUE). The numbers and percentages of individual profiles were determined for all infected people in the study.

The unfertilized egg rate (UER) per person was defined as a percentage of the total number of unfertilized eggs to the total number of eggs for two faecal examinations, and the overall UER as the percentage of the total number of unfertilized eggs to the total numbers of eggs excreted by a group of persons (e.g., male or female host; children or adults). The worm sex ratio (WSR) per person was defined as the ratio between the numbers of male worms and female worms expelled from an individual after anthelmintic treatment, and the overall WSR as the ratio between the numbers of male worms and female worms expelled by people with the same egg profile.

Two sets of data were analysed. One set represented the records of 11 surveys of the entire human population, which included the numbers of unfertilized and fertilized eggs per person. The other represented the number of worms, their sex and individual worm measurements for each person after anthelmintic treatment. Since there were some changes in structure between the natural and re-established *Ascaris* populations (see Peng, Zhou & Cui, 2002), data relating to each treatment were processed separately.

The SPSS statistical program was used for statistical analysis. The Chi-square test was used to compare frequency, and one-way analysis of variance (ANOVA) to compare the means. Raw data were transferred logarithmically before using ANOVA. A non-parametric rank correlation test (Spearman) was used as required.

RESULTS

General characteristics of Ascaris *egg profiles in human faeces*

All 3 egg profiles were recorded in each survey throughout the 2-year period, and the percentage for UEO profile was usually the lowest compared with the other 2 egg profiles. For each profile, fluctuations in values were detected in each year. However, the trend for each profile was relatively stable in year 1 (except survey 5) and more variable in year 2 after chemotherapy. The overall percentages of FEO, FUE and UEO profiles for year 1 (before universal treatment 1) were ~40, 40 and 20%, respectively, which then became ~50, 30 and 20% in year 2 after chemotherapy. A significant difference between these annual egg profiles was detected ($\chi^2 = 30{\cdot}6$, $P < 0{\cdot}001$, D.F. = 2), which was related to an increase in percentage for both FEO and UEO, and a decrease for the FUE profile ($\chi^2 = 7{\cdot}5$–$30{\cdot}1$, $P = 0{\cdot}006$–$0{\cdot}001$, D.F. = 1 for all) (see Table 1).

Egg profiles in relation to host age and gender

The egg profiles were analysed further for children and adults. Different patterns of egg profile, characterized by a much higher UEO profile percentage in adults compared with children, were found for all surveys (see Table 2). A significant difference between children and adults for the annual 3 egg profiles as well as for the UEO profile was detected for both years ($\chi^2 = 72{\cdot}5$–$114{\cdot}0$, $P = 0{\cdot}001$, D.F. = 1 and 2). A comparison of overall UER between children and adults also showed a higher value in adults for most of the 11 surveys (see Table 3), and there was a significant difference in the annual UER between children and adults for both years ($\chi^2 = 172\,282$ and $414\,032$, respectively, $P < 0{\cdot}001$, D.F. = 1).

After universal treatment, all 3 egg profiles in both children and adults changed in a similar manner, reflected in an increase in the percentages of FEO and UEO, and a decrease in the percentage of FUE ($\chi^2 = 27{\cdot}4$ and $35{\cdot}8$, respectively, $P < 0{\cdot}001$, D.F. = 2). However, there was a remarkable difference in magnitude between the two groups of people (see Table 2). Also, the treatment resulted in a significant decrease in the overall UER for both children and adults as well as for the whole population ($\chi^2 = 22\,467$–$161\,908$, $P < 0{\cdot}001$, D.F. = 1; see Table 3).

The unusually low values for the UEO profile and the overall UER for survey 5 (see Tables 1–3) may have been attributable to a bias resulting from the examination of faecal slides by different examiners, since no large-scale chemotherapeutic intervention aimed at ascariasis or other helminthiases had been carried out prior to treatment 1 (Peng *et al.* 1996).

Previous research on *Ascaris* in the same study area did not reveal significant differences in either EPG or worm load between male and female humans (Peng *et al.* 1996, 1998, 2002; Peng & Zhou, 2001). In this investigation, a discordance in the overall UER between male and female hosts was recorded. For surveys 1, 3, 6, 7 and 11, the overall UER in males was higher than that in females, which was in contrast to the other 6 surveys. Thus, the Spearman's correlation test was used to establish any possible correlation between host gender and UER. The results showed no significant correlation for 10 surveys ($r = -0{\cdot}074$–$0{\cdot}055$, $P = 0{\cdot}235$–$0{\cdot}951$) and a significant correlation only for survey 7 ($r = -0{\cdot}212$, $P = 0{\cdot}019$), which was the first survey after treatment 1.

Egg profiles in relation to worm load and sex ratio

Statistical analysis showed that the UER was negatively correlated both to EPG ($r = -0{\cdot}295$, $P = 0{\cdot}000$, $n = 170$ for year 1; $r = -0{\cdot}264$, $P = 0{\cdot}007$, $n = 103$ for year 2) and to WSR ($r = -0{\cdot}265$, $P = 0{\cdot}001$, for

Table 2. *Ascaris* egg profiles (%) from children and adults throughout the 2-year study period (cf. Fig. 1)

	Children			Adults		
Survey (*n*)*	FEO†	FUE†	UEO†	FEO†	FUE†	UEO†
Year 1						
1 (141, 220)	36·9	56·0	7·1	53·6	26·9	19·5
2 (151, 192)	41·7	47·7	10·6	32·3	37·5	30·2
3 (169, 204	43·8	46·7	9·5	45·1	27·4	27·5
4 (147, 156)	34·0	58·5	7·5	41·0	37·8	21·2
5 (126, 118)	33·3	60·3	6·3	53·4	36·4	10·2
6 (166, 170)	33·3	56·0	10·8	37·6	37·6	24·7
Subtotal (900, 1060)	37·3	53·9	8·8	43·7	33·2	23·1
Year 2						
7 (86, 36)	46·5	32·6	20·9	52·7	16·7	30·6
8 (136, 67)	32·4	60·2	7·4	26·9	34·3	38·8
9 (124, 88)	52·4	45·2	2·4	48·9	15·9	35·2
10 (107, 102)	61·7	28·0	10·3	52·9	10·8	36·3
11 (139, 122)	49·6	36·0	14·4	45·9	21·3	32·8
Subtotal (592, 415)	48·0	41·5	10·5	45·8	19·3	34·9

* Numbers of infected children and adults in each survey, respectively.
† FEO: fertilized eggs only; FUE: fertilized and unfertilized eggs; UEO: unfertilized eggs only.

Table 3. Overall UER (%) of *Ascaris* for children and adults throughout the 2-year study period (cf. Fig. 1)

Survey (*n*)*	Children (<15 years)	Adults (⩾15 years)	For all infected people
Year 1			
1 (141, 220)	9·7	10·0	9·8
2 (151, 192)	7·9	13·6	9·5
3 (169, 204)	5·6	14·5	8·1
4 (147, 156)	8·4	15·7	9·7
5 (126, 118)	3·0	2·2	2·8
6 (166, 170)	10·8	13·9	11·7
Subtotal (900, 1060)	7·9	12·0	9·0
Year 2			
7 (86, 36)	5·9	4·6	5·6
8 (136, 67)	4·7	8.9	5·2
9 (124, 88)	4·2	9·9	5·1
10 (107, 102)	5·4	10·1	6·2
11 (139, 122)	6·6	9·2	7·3
Subtotal (592, 415)	5·3	9·2	6·0

* Numbers of infected children and adults in each survey, respectively.

year 1; $r = -0{\cdot}274$, $P = 0{\cdot}007$, for year 2). In relation to worm load, a significant correlation was detected for year 1 ($r = -0{\cdot}241$, $P = 0{\cdot}002$) but not for year 2 ($r = -0{\cdot}118$, $P = 0{\cdot}236$). Humans with different faecal egg profiles had significantly different mean worm loads and mean EPG. Those with an UEO profile harboured substantially lower numbers of both male and female worms, and had lower EPGs compared with persons with an FEO or FUE profile (Table 4). Indeed, of 45 persons with the UEO profile, 33 were found to harbour no male worms, 9 had only 1 male worm and only 3 harboured 2 male worms. Of the latter 3 persons, 2 carried immature worms only. Although the highest worm load was recorded for people with an FUE profile, the higher fecundity of female worms was detectable for people with an FEO profile. The latter profile related to the highest overall WSR of ~0·7 when compared with the other two profiles (Table 4). One year after treatment 1, the worm load for the entire human population decreased from 8·7 *Ascaris* per person to 6·4 ($F = 5{\cdot}550$, $P = 0{\cdot}019$), but this decrease was related only to people with the FEO profile (see Table 4).

Egg profiles in relation to worm measurements

The parameters of mean length, width and weight of the worms from people with different egg profiles were compared for each of the study years. At treatment 1, female worms from people with different egg profiles had significant differences for each of the parameters. Smaller and lighter females were expelled from people displaying UEO and FUE profiles, compared with worms from persons with the FEO profile. For male worms, a significant difference in mean weight and width but not in length was recorded among people with the 3 egg profiles. However, the pattern in mean width of male worms was not concordant with that of the weight of males or with the measurements for female worms. The small number of male worms ($n = 12$) from persons with the UEO profile may have affected the statistical results. In contrast to the situation relating to treatment 1, no statistical significance was detected for any parameter examined among the 3 egg profiles at treatment 2 (Table 5).

Table 4. Worm load, egg production (mean ± s.d.) and overall sex ratio for *Ascaris* from people with different egg profiles in faeces (cf. Fig. 1)

Egg profile (*n*)*	Male worms	Female worms	EPG per person†	FEPG per female worm‡	Worm sex ratio (male/female)
Treatment 1					
FEO (51)	3·18 ± 3·43	4·45 ± 5·21	22·88 ± 26·67	8·82 ± 13·15	0·73
FUE (92)	3·66 ± 3·82	7·71 ± 9·26	33·94 ± 6·84#	5·91 ± 8·67	0·48
UEO (27)	0·33 ± 0·55	1·37 ± 1·11	2·17 ± 3·36	0	0·30
P (F or χ^2) value	< 0·001 s (19·5)	< 0·001 s (19·0)	< 0·001 s (67·8)	< 0·001 s (529·9)	< 0·001 s (14·7)
Treatment 2					
FEO (54)	1·98 ± 2·24	2·74 ± 2·90	23·96 ± 29·31	11·57 ± 16·53	0·75
FUE (31)	4·77 ± 7·26	7·03 ± 8·07	33·20 ± 9·61#	7·06 ± 10·03	0·70
UEO (18)	0·33 ± 0·69	1·83 ± 2·07	2·73 ± 4·35	0	0·21
P (F or χ^2) value	< 0·001 s (13·1)	< 0·001 s (11·8)	< 0·001 s (22·5)	< 0·001 s (303·5)	0·008 s (9·6)

* Numbers of people who expelled worms after treatments 1 and 2, respectively. FEO: fertilized eggs only; FUE: fertilized and unfertilized eggs; UEO: unfertilized eggs only.

† Eggs per gram of faeces (× 10^3).

‡ Fertilized eggs per gram of faeces per female worm (× 10^3).

Of which the mean fertilized eggs are 28·78 ± 35·14 and 29·34 ± 29·67 for treatments 1 and 2, respectively.

s, Statistically significant, d.f. = 2 for all.

DISCUSSION

There is a paucity of published information on *Ascaris* egg profiles in human faeces, although there is some mention in studies where the percentages of people excreting unfertilized eggs were used to assess anthelmintic efficacy (Seo, 1990; Fallah *et al.* 2002). Faecal egg profile data could be of importance for better understanding the population biology and transmission dynamics of *Ascaris*, and thus may assist in the control of ascariasis in human communities. This study reports, for the first time, detailed information on *Ascaris* egg profiles from humans based on a quantitative coprological examination over a 2-year period of longitudinal investigation and based on worm counts after each of the 2 annual universal treatments.

Firstly, this study showed that the humans infected with *Ascaris* displayed 3 different egg profiles throughout the 2-year period, before and after universal treatment. This finding suggests that the presence of the 3 profiles represents a 'normal' situation rather than an occasional event in a community where ascariasis is endemic. Throughout the study period of 2 years, the annual overall percentages of people with FEO, FUE and UEO profiles were ~41–47%, 32–42% and 17–21%, respectively, although some fluctuation was detectable from time to time during the 2 years. All unfertilized eggs shed by the human population accounted for < 10% of the total number of eggs produced. Secondly, there was no correlation of egg profile data to host gender, but there was to host age, because the overall UER was significantly lower in children, and distinct egg profile features were identified between children and adults. Thirdly, *Ascaris* worms from people with different egg profiles related to significantly different loads, sex ratios and developmental status (based on fecundity of females, and worm size and weight). Finally, universal chemotherapy appears to have led to a decrease in the overall UER for the entire population (from ~12% in survey 6 to ~6% in survey 7, or from 9% in year 1 to 6% in year 2), and to some changes in the percentages of egg profiles (i.e. increasing FEO and UEO values, and decreasing FUE values).

Theoretically, the production of unfertilized eggs could relate directly to the chance and/or the efficiency of the processes of mating and fertilization, which could be further associated with the sex ratio, burden and development of the parasite in the human host (Seo *et al.* 1979; Janssens, 1985; Crompton, 1989; Jungersen *et al.* 1997). In addition, worm burden and development could be linked to host factors, such as age, nutrition, immunity and/or behaviour (Jones, 1977; Palmer *et al.* 1995; Cooper *et al.* 2000; Crompton, 2001). In the present study, people with distinct egg profiles had significantly different worm loads and WSR, suggesting that these parameters in individual hosts were linked to variation in egg profiles. Furthermore, the developmental status of the parasite also showed some relationship to egg profiles. However, it was not possible to establish whether the difference in the development of worms was associated solely with an unsuitable WSR or with one or more of these host- and parasite-related factors.

Recently, some significant changes in structure were demonstrated between the natural and the re-established *Ascaris* populations before and after a universal treatment in this community (Peng *et al.* 2002). It was shown that the re-established *Ascaris* population had a much lower mean density, with more immature and less fertile males, and less fertile and more senile females being present. Hence,

Table 5. Measurements (mean ± s.d.) of *Ascaris* worms from people with different egg profiles in faeces (cf. Fig. 1)

	Male worms			Female worms		
Egg profiles (*n*)*	Length (mm)	Width (mm)	Weight (g)	Length (mm)	Width (mm)	Weight (g)
Treatment 1						
FEO (157, 216)	159·79 ± 26·81	3·54 ± 0·81	1·62 ± 0·92	207·73 ± 46·52	4·90 ± 1·34	3·72 ± 1·77
FUE (337, 706)	155·39 ± 26·54	3·38 ± 0·78	1·42 ± 0·68	200·78 ± 48·49	4·70 ± 1·40	3·36 ± 1·77
UEO (12, 40)	153·75 ± 31·20	4·00 ± 0·74	1·62 ± 0·52	177·73 ± 70·49	4·20 ± 1·81	2·89 ± 2·04
P (*F*) value	0·185 n.s. (1·7)	0·006 s (5·2)	0·038 s (3·3)	< 0·001 s (11·0)	0·007 s (5·1)	0·001 s (7·0)
Treatment 2						
FEO (119, 158)	153·27 ± 30·68	3·40 ± 0·77	1·38 ± 0·61	211·39 ± 52·88	5·17 ± 1·49	3·61 ± 1·65
FUE (155, 222)	156·11 ± 29·19	3·52 ± 0·86	1·45 ± 0·63	214·16 ± 43·71	5·06 ± 1·38	3·49 ± 1·54
UEO (7, 33)	134·00 ± 34·66	3·29 ± 0·11	1·26 ± 41·23	203·30 ± 34·32	4·82 ± 1·07	2·88 ± 1·13
P (*F*) value	0·106 n.s. (2·26)	0·423 n.s. (0·7)	0·225 n.s. (1·5)	0·495 n.s. (0·7)	0·532 n.s. (0·6)	0·291 n.s. (1·2)

* Numbers of male and female worms from people with different egg profiles at each treatment. FEO: fertilized eggs only; FUE: fertilized and unfertilized eggs; UEO: unfertilized eggs only.

n.s., Not significant; s, statistically significant, d.f. = 2 for all.

the changes in each of the egg profiles after chemotherapy demonstrated herein may also relate, to some extent, to the changes in population structure of the re-established *Ascaris*. For example, that no significant difference in worm size or in weight was detectable among people with each of the 3 profiles at treatment 2 may relate to the homogeneity of all measurements for the re-established *Ascaris* from people with different worm loads (see Table 4 in Peng *et al*. 2002), because the UER, by which the 3 egg profiles were classified, was found to have a significant correlation to worm load prior to treatment 1 but not thereafter.

The results of the present study may have implications relating to the dynamics of *Ascaris* subpopulations in host individuals. Theoretically, the sex determination process in the parasite should ensure equal numbers of males and females (Anya, 1976), but a number of investigations have shown more females than males in the human host (e.g. Holland *et al*. 1987; Elkins & Haswell-Elkins, 1989; Seo, 1990; Monzon, 1991; Peng *et al*. 2002). This may indicate either that *Ascaris* males do not live as long as females or that some form of competition or sexual selection can occur within the host and, thus, only strong males survive (Crompton, 1989). If this were true, the UEO profile with the lowest worm sex ratio and density may represent an aged or 'stunted' subpopulation, or recently established premature worms. In contrast, the FEO profile (associated with a moderate worm load, and high WSR and fecundity for female worms) may indicate a stable subpopulation which is in 'balance' in terms of both density and sex ratio. Indeed, the mean worm load in people relating to the latter profile was ~8 worms per person, which falls within the range considered to represent an optimal density (i.e. 6–10 worms per person) in the community (see Table 4 in Peng *et al*. 2002). People with an FUE profile had the highest worm burden (>11), with a moderate WSR value and a lower fecundity per female worm compared with values relating to the FEO profile, which may suggest that this subpopulation was undergoing a disturbance and/or adjustment triggered by worm loss and/or recruitment. Indeed, people with the FUE profile had similar worm burdens prior to and after one year of treatment 1, suggesting a relatively rapid recruitment of worms, because the entire re-established population had not yet restored to its original mean density after 1 year since treatment 1 (Peng *et al*. 2002).

The egg profile data obtained suggest a minor impact of unfertilized eggs on the transmission of ascariasis in the study area, considering the low overall UER values and the large numbers of eggs produced by female *Ascaris* (WHO, 1967; Crompton, 1989). Different egg profiles can be associated with significant variability in worm loads, worm fecundity and egg excretion rates, and thus are likely to contribute to different degrees to the successful transmission of ascariasis. For example, before treatment 1, an average of 23·1% of infected adults and 8·8% of infected children had an UEO profile, and thus would not serve as the source of infection, whereas people with other egg profiles could. Of people with a UEO profile, 76% were adults in year 1, and, in year 2, still 61·8% of them were adults. That children had substantially lower UEO and UER values than adults provides additional support for the targeted chemotherapy control strategy, aimed at treating children only (WHO, 1996), the original rationale of which was based on the high prevalence and intensity of *Ascaris* in children in endemic areas (e.g. Thein Hlaing *et al*. 1987; Hall, Anwar & Tomkins, 1992; Holland *et al*. 1996; Peng *et al*. 1996, 1998, 2002).

Since differences in egg profiles occur over time, some caution is warranted when using a single egg profile to evaluate an anthelmintic control program. Within the present study period of 2 years, variation in the 3 egg profiles was detected between some surveys. Also, after treatment 1, not only the UEO but also the FEO values increased significantly. The overall UER of the entire human population is proposed to be informative for the comparison of pre- and post-chemotherapy, because the UER values were usually stable throughout each year of the study period.

Based on the findings and interpretations of this study, it is suggested that the monitoring of faecal egg profiles in humans can provide useful epidemiological and biological information, which should assist in the implementation of effective control programs for ascariasis. More studies from different geographical regions (with varying prevalence and intensity of infection) (Hall & Holland, 2000) as well as genetic studies of *Ascaris* from humans (and pigs) representing the 3 different egg profiles may also assist in elucidating the population biology and transmission dynamics of ascariasis.

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