Balantidium coli (Malmsten, 1857) (Ciliophora: Balantidiidae) is the largest protozoan and the only ciliate parasite of humans. Although numerous animal species are known to harbor B. coli, pigs have a particularly high rate of infection (20–100%) and consequently are generally considered the main natural reservoir of this parasite.1

Although B. coli infection in humans has a worldwide distribution, it is considered an uncommon infection. Prior to 1988, less than 1,000 human cases had been reported.2–4 A review of the literature has shown that the majority of reports are concerned only with individual symptomatic and fatal or complicated cases. Only a few reports of outbreaks or epidemiologic surveys have been published.5–8 On the other hand, in several reports on community-based or epidemiologic surveys of intestinal parasites in different countries worldwide, data on human balantidiasis are rarely found.9

In many large series, estimates of worldwide prevalence are only 0.02–0.1%.1 Nevertheless, rates up to 6%,10–12 with very high prevalences (up to 29%) in certain areas,13 have been found. However, although known for more than a century, the pathogenicity of the organism and how it is acquired by humans remains controversial.1

In Bolivia, there have been only three reports of B. coli in two (Santa Cruz and La Paz) of the nine Departments in this country. In the first, a prevalence of 1.8% among 381 apparently healthy subjects from three communities was reported.13 The other two reports were on two different regions of two provinces of the Department of La Paz (area = 133,985 km² with 2,406,185 inhabitants in 1990). One of them, Coroico, a village located at an altitude of only 1,828 meters in the Yungas region (Nori Yungas Province), had a prevalence rate of 1.3% in 385 children 2–9 years of age;14 the other in an Indian (Quechua ethnicity) hamlet called Amarete, at an altitude of 3,700 meters and located in the northern Altiplano region in Saavedra Province 200 km from the city of La Paz, had a prevalence rate of 8% in 100 children 4–15 years of age.15

The presence of B. coli in Indians of Aymara ethnicity inhabiting Los Andes, Omasuyos, Ingavi, and Murillo Provinces of the northern Bolivian Altiplano has been unknown until recently,16 although prevalences (2.6% and 3.9% in Corapata and Caleria, respectively) have been recently reported in studies of Fasciola hepatica infection.17

The aim of this study was to investigate human balantidiasis in a region of the northern Bolivian Northern where other human parasitoses, such as fascioliasis16–20 and cryptosporidiosis21 are considered endemic infections.

SUBJECTS, MATERIALS, AND METHODS

Human study population. This study was conducted in the Department of La Paz in a region of the northern Bolivian Altiplano at an altitude of 3,800–4,200 meters where there are four political provinces (Ingavi, Los Andes, Murillo, and Omasuyos), as shown in Figure 1. The area and human population (data from the Bolivian Ministry of Health) of these provinces (area of the country = 1,998,581 km²; total population = 6,344,396 inhabitants) are as follows: Los Andes: 1,658 km² and 61,627 inhabitants; Omasuyos: 2,065 km² and 73,415 inhabitants; Ingavi: 4,140 km² and 77,896 inhabitants; Murillo: 4,705 km² and approximately 1,200,000 inhabitants, including the two most important cities, La Paz and El Alto, with 710,940 and 392,774 inhabitants, respectively.16

The Aymara communities surveyed are fundamentally rural with the main economic activities being livestock breeding (mainly cattle, sheep, and pigs) and agriculture. Fishing is important in the communities near Lake Titicaca, and in some communities, such as Achacachi, commercial activities are more important. Most inhabitants of these zones are poor and have lived in conditions of poor health. The houses are rudimentary (roofs made of straw or calamine, walls of adobe or sun dried bricks), and the communities lack such basic services as potable water systems, sewage disposal, and trash removal. Humans and animals share the same water sources contaminated with fecal stools. Food, including local vegetables, is washed with contaminated water, increasing the risk of acquiring parasitic, bacterial, or viral diseases. Under these poor living conditions, the family members (average of five members per family) live together in crowded conditions on a small piece of land in close association with small (chicken, dogs, rabbits, guinea pigs) and large (normally 1–2 cattle, sheep, and pigs) animals. Indiscriminate defecation is commonly practiced.18 Feces as well as other materials are commonly eaten by pigs.

Human data collection. Coprologic studies were made over a five-year period from 1992 to 1996 in 22 communi-
ties. These surveys were done in June (1992), February (all communities in 1993 and some communities in 1996), and September (all communities in 1994 and 1995, and some communities in 1996) and involved 2,124 Aymara children (1,146 boys and 978 girls) 5–19 years of age from the schools in these communities (Table 1). Surveys were carried out so that the sample size in each school was representative of both the student enrollment in the school (at least 50%) and the number of children present on the day of the survey (at least 75%). The surveys were made on randomly selected persons on a given day among all participating students.

A clean, 30-ml plastic, wide-mouth, numbered container with a snap-on lid was given to every child. The students were then asked to try to fill the container with their own feces and to return it immediately. One stool sample per student was collected from all participating school children and personal data (name, sex, and age) were noted on delivery of the container. Other data related to gastrointestinal and intermittent symptoms were not considered because the answers of children appeared to be contradictory in the few cases in which an answer was obtained. Thus, the ignorance of the Aymaras concerning biological risk must be taken into account. Among the Aymaras, the so-called usu constitutes not only a concept of illness or health, or of life or death, but represents a mythic, symbolic horizon from which a series of behaviors and interpretations of this process arise. The parasitoses and other internal diseases without a specific location are usually considered as a punishment or a retaliation of the demiurgos, that is, a Pachamaman jasuti pachawá (punishment by the Pachamama). A fatalistic guilt feeling appears when faced with the possibility of death, with its existence not being questioned because of its divine and immutable character.16

Fecal specimens were transported to the Parasitology Lab-

oratory of the Instituto Nacional de Laboratorios de Salud (La Paz, Bolivia) within 5 hr of collection. In this laboratory, the consistency (formed, soft, loose, or watery) of each stool sample was evaluated and noted. From each stool sample a Kato-Katz slide22 was made, and if possible (sufficient material present) two aliquots were preserved in merthiolate-iodine-formalin (MIF) fixative and 10% formalin solution (1:16). An additional slide was made for direct MIF and MIF concentration techniques24,25 and those fixed in 10% formalin were processed by a formol-ether concentration technique.26 Four slides per specimen were fully examined by one professional and finally by one of the authors (J-GE). Microscopic slides and materials from the human parasite collection of the Parasitology Department of the University of Valencia were used for quality control when needed.

**Nutritional and health status.** The nutritional and health status of the inhabitants of the zone surveyed agreed with observations previously reported.16 This zone is markedly impoverished, with inhabitants in extreme indigence and with morbidity and mortality rates related to a deterioration of living conditions. More than 30% of the children of this zone show malnutrition and appear to be below the minimum recommended level of weight and height.16 The greatest nutritional problem seems to be chronic malnutrition,
GLAUZE INTO AN ASSAY TUBE, WHICH WAS THEN ALLOWED TO STAND

MIXTURE WAS THEN STRAINED THROUGH A FUNNEL CONTAINING STERILE

AMOUNT OF FECES WAS HOMOGENIZED IN 10% FORMALIN. THE

BOLIVIA) WITHIN 5 HR. IN THIS LABORATORY, A SMALL BUT SUFICIENT

PLASTIC BAG AND TRANSPORTED TO THE PARASITOLOGY LABORATORY

ALMOST ALL THE FAMILIES KEPT PIGS (AVERAGE

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COMMUNITY AUTHORITIES ARE RESPONSIBLE FOR TRANSMITTING PA-

R hazard from the community (among Aymaras, community authorities are responsible for transmitting parental consent after previous meetings), as well as from the Director and teachers of each school. The project was approved by the Secretaría Nacional de Salud del Ministerio de Desarrollo Humano (La Paz, Bolivia) and was performed in collaboration with the INLASA Institute in La Paz, the official disease reference center for Bolivia. Ethical aspects of the study were reviewed and approved by the European Commission as the project funding institution.

Institutional ethical review procedure. The surveys were carried out after informed consent was obtained from the local authorities of the community (among Aymaras, community authorities are responsible for transmitting parental consent after previous meetings), as well as from the Director and teachers of each school. The project was approved by the Secretaría Nacional de Salud del Ministerio de Desarrollo Humano (La Paz, Bolivia) and was performed in collaboration with the INLASA Institute in La Paz, the official disease reference center for Bolivia. Ethical aspects of the study were reviewed and approved by the European Commission as the project funding institution.

Pig samples and data collection. For comparison purposes, 50 stool samples of pigs were obtained from several of the zones surveyed. In the human communities studied, almost all the families kept pigs (average = 1–9 pigs per family).16 Fresh feces were collected off the ground as animals were observed defecating. Stool samples were put in a plastic bag and transported to the Parasitology Laboratory of the Instituto Nacional de Laboratorios de Salud (La Paz, Bolivia) within 5 hr. In this laboratory, a small but sufficient amount of feces was homogenized in 10% formalin. The mixture was then strained through a funnel containing sterile gauze into an assay tube, which was then allowed to stand for 2 hr to allow sedimentation. Finally, several drops of the sediment were examined with a microscope.

Statistical analysis. Statistical analyses were done using the chi-square test or Fisher’s exact test when appropriate for comparison. A P value < 0.05 was considered significant.

RESULTS

Only 11 of the 22 communities surveyed showed B. coli infection. The prevalence ranged from 1.0% to 5.3%, with an overall prevalence in the area studied of 1.2% (Table 1). Among the 26 positive stool samples, 21 were formed and containing only cysts and five were soft and contained trophozoites (3), cysts (1), and both (1). The trophozoites were 50–88 (70 ± 10 [mean ± SD]) μm by 40–68 (56 ± 8) μm and the cysts were 35–60 (51 ± 6) μm by 30–58 (49 ± 6) μm. Loose and/or watery stool specimens were detected in 5% of the total of 2,124 samples analyzed.

The distribution of prevalences of infection according to age and sex is shown in Table 2. Prevalences did not differ significantly among the various age groups; the highest prevalence was found in the 5–8-year-old age group. Although no significant differences were observed between boys and girls, there appeared to be a trend for increased number of infections in males.

Thirteen or 14 protozoan and seven helminth species were detected in all school children studied. These included Entamoeba histolytica/E. dispar complex, E. coli, E. hartmanni, Endolimax nana, Iodamoeba buetschlii, Chilomastix mesnili, Retortamonas intestinalis, Giardia intestinalis, Enteromonas hominis, Dientamoeba fragilis, Cryptosporidium sp., Balantidium coli, Blastocystis hominis, Fasciola hepatica, Hymenolepis nana, Teenia spp., Trichuris trichiura, Enterobius vermicularis, Ascaris lumbricoides, and undetermined ancylostomids. More than 90% of the total children studied showed infection with at least one of these parasite species. Multiple parasite infections were detected, i.e., one girl showed 11 different parasites (eight protozoan and three helminth species).

Among the 26 samples positive for B. coli infection, the number of other parasite species found varied from one to five or six. The multiparasitism cases were one case of B. coli concomitantly with the E. histolytica/E. dispar complex, G. intestinalis, Blastocystis hominis, H. nana, and T. trichi-
urá, and another case of *B. coli* with *E. histolytica/E. dispar* complex, *E. coli*, Cryptosporidium sp., *Taenia* spp., and *T. trichiura.*

Coprologic analyses of the 50 porcine stool samples showed *B. coli* infection in 54% of the pigs.

**DISCUSSION**

This study is believed to be the largest parasitologic survey carried out to determine infection rates in *B. coli*. The prevalences observed may be some of the highest reported among apparently healthy school children up to the present time.

While *B. coli* is considered to be a commensal organism (rare occurrences of acute infection are reported) in pig populations, different types of infection have been described in humans. Chronic and acute infections can occur sporadically and in epidemics. In these cases, different symptoms are present and the stools may be watery or dysenteric (bloody). Fulminating acute balantidiasis has been reported to have a case fatality rate of 30%. Patients may die of intestinal perforation or fulminating dysentery with hemorrhage and shock. Involvement of the lymphatics of the colonic wall is common and this may extend to the mesenteric lymph nodes. The appendix and terminal ileum may be affected. Balantidial vaginitis has been reported as have two instances of liver abscess and four of lung and/or pleural involvement. Nevertheless, in populations in which the parasite is endemic, *B. coli* is usually found in asymptomatic persons.

The prevalences obtained, the apparent absence of symptoms or signs of illness due to this parasite in the school children surveyed at the moment of stool sampling (ill children did not go to school), and the consistency of stool samples suggest that the infected students are apparently asymptomatic carriers.

In relation to the source of *B. coli* infection in humans, most of the patients with balantidiasis reported in the literature had a history of contact with pigs, and the infection was acquired as a result of contamination of water supplies by pig feces. Results obtained by other investigators suggest the existence of different *B. coli* strains. A few strains of porcine *B. coli* can be transmitted among different experimental animals. Attempts to infect human volunteers with either human or animal strains of this ciliate have failed. Antigenic differences between human and porcine strains have been found. Strains from humans have been transmitted to monkeys, pigs, cats, and rodents, but experimental infection of humans with strains from pigs and humans has not been successful, and it appears that humans are relatively refractory to this parasite, whatever the source or strain. Diarrhea in piglets and monkeys experimentally infected with *B. coli* isolated from human feces have been demonstrated.

Features such as infections occurring in people who had no contact with pigs, in institutions, or in people who work closely with swine even in poor sanitary conditions suggest that person-to-person transmission may be important. Moreover, the possibility exists that other animals, notably domestic rodents, may act as reservoirs and play an important role in the transmission dynamics of human balantidiasis.

It appears from our observations that there might be a relationship between human infections and *B. coli* in swine in the northern Bolivian Altiplano. The parasite was found in pig feces around the homes of several families in some of the communities surveyed (i.e., Caleria and Huacullani) in which human infection was found. Moreover, we know that pigs are commonly fed raw garbage and they are allowed to roam freely in search of food; in the Altiplano area surveyed there is a lack of potable water systems and water may have been contaminated with pig excreta.

The detection of positive human cases in different provinces in different years and no significant differences based on the sex and age of the groups studied indicates the existence of an environment highly contaminated with fecal material. Thus, infection with *B. coli* must be considered an endemic anthropozoonosis in the area studied.

In relation to the pathogenicity of *B. coli*, several host factors have been suggested to explain whether an infected person becomes ill: malnutrition (low protein, high carbohydrate diet), intestinal bacterial flora, concomitant helminthic infection, achlorhydria, alcoholism, and other chronic, debilitating diseases. Nevertheless, some of these host factors do not explain the apparently healthy state of the school children studied. For example, in the Altiplano, the native Bolivian prepubertal girls and boys with a low socioeconomic status showed overall relatively low energy and nutrient intake (fundamentally protein and fat); thus, the lower energy intake and the higher energy expenditure of these children is related to their smaller body size.

The results suggest the possibility of a high degree of natural or acquired resistance to this parasite. A similar situation was observed in the outbreak in Truk, where the people were quite resistant to porcine *B. coli* even when living in close association with pigs and under poor sanitary conditions. Nevertheless, the possibility that asymptomatic balantidiasis becomes invasive when the immune state of the body is depressed must be considered.

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