

Risk of Disease Transmission between Conservation Personnel and the Mountain Gorillas: Results from an Employee Health Program in Rwanda

The Mountain Gorilla Veterinary Project 2002 Employee Health Group

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Abstract: Humans and gorillas share 97% of their genetic makeup which means the risk of disease transmission between the two is potentially high. Humans with high exposure and whose exposure-related activity can most easily be managed are park conservation personnel. In June 2001, the Morris Animal Foundation's Mountain Gorilla Veterinary Project initiated a health program for all employees working in Rwanda's Parc National des Volcans in collaboration with in-country government and nongovernmental agencies. The goal is to improve the health of conservation personnel and reduce the risk of zoonotic disease transmission between employees and the park's mountain gorillas. Employees annually receive a clinical examination and laboratory testing, and provide a clinical history. In 2002, analyses were performed on the dataset of 127 employees to identify potential risk factors associated with positive laboratory tests. Considering all fecal tests combined, 70.1% were positive for one or more pathogenic organisms. A high percentage (> 80%) tested positive on viral antibody titer testing for various communicable diseases including measles, chickenpox, and hepatitis. On multivariate analysis, the main risk factor for testing positive for any pathogenic organism was use of a pit latrine at home. Vaccination against childhood communicable diseases and improved human waste disposal could be critical control points for preventing disease transmission to mountain gorillas. Program results have been shared with local health officials to aid in their efforts to improve village health and sanitation standards, and with park employers as a basis for ongoing employee health education.

Key words: mountain gorilla, employee health, risk factors, disease transmission

INTRODUCTION

Poaching and habitat encroachment are the main threats to the survival of gorilla populations in unprotected areas

(Butynski and Kalina, 1998). In protected areas such as the Virunga Massif and Bwindi Impenetrable National Park, these threats remain but are greatly reduced. However, these two protected areas are surrounded by highly dense human populations, some of the most densely populated areas in Africa (Homsy, 1999). They also host intense gorilla-viewing tourism. These two points, and the fact that humans and gorillas share approximately 97% of their genetic makeup (Sibley and Ahlquist, 1984), means that the

Published online: October 6, 2004

The Mountain Gorilla Veterinary Project 2002 Employee Health Group members are listed in Appendix 1 by area of contribution.

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risk of disease transmission between the two species in this area is potentially high.

Human groups exposed to mountain gorillas can be divided into four groups:

- 1) park conservation personnel with close (≥ 7 meters) exposure on a daily basis and some direct contact (e.g., during clinical interventions);
- 2) limited numbers of daily tourists with close exposure usually for 1 or 2 days per person;
- 3) the local community with greater numbers of people but with unintentional and not usually close exposure; and
- 4) military and poachers (illegal entrants) with potentially high habitat use but little close exposure to gorillas.

The group with the highest level of exposure and whose exposure-related activity can most easily be managed is conservation personnel.

Infection prevention standards such as protective clothing, hand washing, and disinfection and decontamination of equipment have been proposed for persons working with nonhuman primates to minimize the risk of bidirectional disease transmission (Adams et al. 1995; Richardson, 1987). Risk of pathogen spread can be further reduced through occupational health programs including periodic screening and vaccinations (Nutter and Whittier, 2000). In general, employee or occupational health programs are designed to assure health and safety while on the job. In the United States (US), safe and healthful working conditions are mandated at the national and state levels, and standards exist to help employers comply with health and safety regulations (OSHA, 1970). Such laws or regulations may not exist in countries hosting mountain gorillas but this should not diminish the responsibility of employers to similarly assure safe and healthful working conditions for protected area conservation personnel in these areas (Siberman, 1993).

Morris Animal Foundation's Mountain Gorilla Veterinary Project (MGVP) has been responsible since 1986 for health concerns of the mountain gorilla (*Gorilla beringei beringei*). In a strategic planning meeting in September 2000, MGVP expanded its role from mainly performing mountain gorilla clinical interventions and postmortem examinations to supporting a more comprehensive program including human and domestic animal interventions. There was consensus among meeting participants that the establishment of an employee health program (EHP) for conservation per-

sonnel would fit within MGVP's new mandate and be a first step towards addressing human health issues as part of a more conservation medicine approach to ensuring mountain gorilla health (Cranfield et al., (2000).

To this end, in June 2001, MGVP, in collaboration with the Parc National des Volcans [i.e., Office Rwandais du Tourisme des Parcs Nationaux (ORTPN)], Dian Fossey Gorilla Fund International (DFGFI), and the International Gorilla Conservation Program (IGCP) initiated an EHP for all park employees (including trackers, guides, researchers, and veterinarians) with support from the Rwandan Ministry of Health (MOH). Permission to undertake the health program and to periodically report summary findings was granted by the Rwandan MOH. Institutional review board (IRB) approval for periodic statistical analysis of the routine health program data comes through Mississippi State University.

The program goal is to improve the health of the conservation personnel and reduce the risk of zoonotic disease transmission between them and the park's mountain gorillas. The program offers health education, an annual health assessment including a clinical history, a clinical examination, diagnostic testing, appropriate treatment and vaccinations, and follow-up and referral, as appropriate. The program is intended to provide a basis for identifying critical control points for preventing disease transmission between the mountain gorilla and employees, as well as developing human health recommendations and guidelines for researchers, trackers, and their families.

A general description of the program has been presented elsewhere (Ali et al., 2004). This report summarizes initial epidemiological findings from this innovative initiative in Rwanda. While the program has been operational for over 3 years, the focus of this report is 2002 because both cleaned socio-demographic and test result data for this year were available at the time of writing. This is the first report to summarize key analytic findings regarding potential risk factors for disease transmission between conservation personnel and the mountain gorillas based on findings from an ongoing EHP.

METHODS

Clinical History-taking and Clinical Examination

MGVP first initiated the EHP in July 2001. In July 2002, employees returned for a second annual examination (or first examination for new employees or anyone who missed

the examination in 2001). Employees of the participating organizations were transported to the District Hospital in Ruhengeri, the closest hospital to the park, over a 5-day period. Upon their arrival, they were asked to read (or be read) and sign a consent form. After that, a trained local program assistant posed standardized personal history questions to each employee in French, English, or Kinyarwanda, as appropriate. Subsequently, a complete physical examination was performed in private by the local program physician (P.K.K.). The results of this examination were recorded on a standardized form. Employees then received a vaccination against tetanus.

Sample Collection and Laboratory Testing

Upon completion of the physical examination, employees went to the hospital laboratory to provide sputum, blood, urine, and fecal samples. Diagnostic tests performed by Ruhengeri Hospital laboratory technicians included: sputum testing for tuberculosis; thick smear for malaria, spun hematocrit, red blood cell (RBC) count, sedimentation rate, HIV titer (voluntary, confidential), other viral antibody titers (blood); dip stick analysis (urine); and parasitology, bacteriology, and viral cultures (feces). A special area was established within the hospital laboratory to handle the additional workload. Medical supplies and coordination required for the program were all provided by MGVP. All samples sent outside Rwanda were stored at -4°C until shipped to the US on dry ice. Samples to be stored at MGVP's Biological Resource Center in Denver first were stored at the Baltimore Zoo for a short time period before being transported to Colorado. Permission to bring human biological specimens into the US was acquired from the Centers for Disease Control and Prevention [Permit to import or transfer etiological agents or potential vectors of human disease/CDC 0728 (F13.40)].

Sputum Testing

Due to the fact that many, if not all, employees had been inoculated with Bacilli Calmette-Guerin (BCG) serum at a young age and the radiograph machine at the hospital was in disrepair, one sputum sample was collected in 2002 from each employee. A slide was made of the sputum which was then acid fast-stained and read for *Mycobacterium*. The remainder of the sputum sample was sent for storage in MGVP's Biological Resource Center in Denver.

Blood Testing

Each employee provided approximately 15 ml of blood via the VacutainerTM system (Becton Dickinson, East Rutherford, NJ). Ten milliliters of blood were deposited into a red-top tube which was spun down immediately. As agreed by individual employees, approximately 2 ml of serum were aliquoted for voluntary and confidential HIV testing. Next, 5 ml of blood were deposited into an EDTA-treated tube for thick smear, hematocrit, RBC count, and sedimentation testing. Of this, 1.5 ml of serum and/or plasma for each employee was shipped to the US and forwarded to the University of California at Davis for viral antibody titer testing using commercially available enzyme immunoassays (EIA). Cut-off values defining antibody titer test positive were based on background, negative controls, and interpretation of test results in accordance with the manufacturers' recommendations. For retroviruses (SRV, STLV, HIV/SIV) an "indeterminate" or "positive" EIA with a negative Western blot confirmatory result was considered negative. Western blots were not performed on EIA negative sera.

Urinalysis

Urine samples were analyzed using a Bayer[®] (Brussels, Belgium) Multi-stix strip within 1 hour of collection. A 2-ml sample was sent to MGVP's Biological Resource Center.

Fecal Testing

Fecal direct smears were prepared within 1 hour of collection. The remainder of the fecal sample was aliquoted into different tubes: one culture swab was sent to the École Science pour la Santé microbiology laboratory in Ruhengeri; one aliquot was placed in formalin and sent to the US, to Johns Hopkins University, Bloomberg School of Public Health, for immunofluorescent antibody (IFA) testing to identify *Cryptosporidium* and *Giardia*, and flotation testing to identify helminths; 1 cc aliquot was placed in a 1.8 cc Nunc vial and shipped to the US where it was sent on dry ice to Esoterix, Inc. (Austin, TX) for viral culturing.

All Ruhengeri Hospital laboratory results were reviewed by the program physician. Anyone judged as needing follow-up medical attention was notified through their employing organization and arrangements made to see a health care provider. Employees with acute health care problems received immediate treatment, and more com-

Table 1. Definition of Variables Used in Bivariate and Regression Analyses

Variables	Definition
Independent	
Age	Age at time of testing
Household size	No. of people with whom living
Days worked	No. days worked in the park
Latrine	Type of latrine used at residence
Exposure to gorilla	Ever seen a gorilla in the wild
Animal exposure	Exposure to other animals (domestic and wild)
Distance to gorilla	How close have they ever been to a gorilla
Education level	Highest education level completed
Ever absent	Ever absent from work last 6 months
Ever Dr. visit	Ever visited a doctor last 6 months
No. of visits	No. of clinic visits last 6 months
Health	Had any health problems last 1 month
Planting	Regularly engaged in planting (≥ 1 time/week)
Smoker	Currently smoke
Drinker	Currently drink
Dependent	
Any helminth	Positive for any helminth-like parasite on fecal testing
Any protozoan	Positive for any protozoan parasite on fecal testing
Any organism in-country	Positive for any organism on Rwandan fecal testing
Any organism US	Positive for any organism on USA fecal testing
Any organism either country	Positive for any organism on fecal testing from either country laboratory
Any positive test	Positive on any fecal, blood, sputum, or urine test

plicated cases were referred to an appropriate health care center or program. Rwanda recently initiated a health insurance scheme (RAMA), which provides for coverage of government employees after a co-pay of 15%. To promote positive health-seeking behavior among employees, many of whom are not familiar with health insurance programs, as part of the program, MGVP and the other employers agreed to finance the first co-pay obligation for anyone requiring follow-up care at another health facility or with another provider.

Data Processing and Analysis

Data were entered into an Access database (Microsoft Access 2002) and then imported into the software program Statistical Package for the Social Sciences (SPSS Version 11.0) for epidemiological analysis. Continuous variables were converted into categorical variables based on literature findings and the distribution of the data in the 2002 dataset. Bivariate (chi square) analysis was used to identify significant associations between laboratory test results

(outcome variables) and select questionnaire data (independent variables). Variables significant on bivariate analysis or known from the literature to be potential risk factors for disease were included in a logistic regression analysis (Table 1). A level of 0.05 was used as the threshold for variable entry into the regression model equation and to assess the value of the variable's contribution to the overall regression model.

RESULTS

Univariate Analysis

Participant Characteristics

A total of 127 employees participated in the EHP in 2002. Data were not recorded for everyone for each variable, so the denominators for the various analyses vary. One hundred and sixteen (91.3%) employees were male, seven (5.5%) were female, and four (3.1%) did not respond. Employees ranged in age from 18 to 65 years (mean =

Table 2. Education Level Results

Education level	Frequency	%
0 years/none	4	3.2
Attended primary/elementary	9	7.2
Completed primary/elementary	40	32.0
Attended secondary/high school	38	30.4
Completed secondary/high school	25	20.0
Attended university	9	7.2
Total	125	100.0

35.1 years). The majority (96.8%) of participants said that they had some years of education (Table 2).

Most (75.6%) employees were born in Rwanda. The primary employer was ORTPN (64%); DFGFI employees totaled 32%, and MGVP and IGCP employees accounted for the remaining 4%. The majority (65%) of participants indicated that they were employed as trackers. Table 3 shows the full distribution of job types. The number of adults in the employees' household ranged from 1 to 36 (mean/median was 9.8/2.0, respectively). The 36 represents the number of people sharing the living quarters of Karisoke Research Center in the village of Bisate.

Almost all (96.1%) participants indicated they had some sort of latrine or toilet in their living compound. Table 4 summarizes the type of toilet that they said they used while at home. Table 4 also summarizes water source results. As noted, the majority (70.9%) said that they routinely got their water from a community source (tank or well).

When asked about their medical history, 24% reported having had some kind of health problem in the last month. Table 5 provides more details about health-related variables. Approximately 80% (103/127) responded that they had had no absences from work in the past 6 months, a potential proxy indicator for severity of illness. However, one person indicated that they had been absent more than 11 days, and six people indicated that they had been absent 6–10 days over the past 6 months.

When asked about time spent in the park, the majority of respondents (80.0%) said that they spent between 4 and 7 days per week in the park. For those spending any time in the park, the amount of time was between 5–8 hours per day. Most participants (95%) had seen a gorilla in the park sometime in their life, and the vast majority (71.8%) said that they had seen the animal from over 5 meters away (the recommended distance for tourists at that time — more

Table 3. Job Type Results

Position	Frequency	%
Tracker/guide	82	68.3
Veterinarian	3	2.5
Researcher/assistant	3	2.5
Office administrator	2	1.7
Field administrator	11	9.2
Support staff (not field-based)	19	15.8
Total	120	100.0

Table 4. Hygiene-related Results

Type	Frequency	%
Toilet use		
Outhouse ^a	70	57.4
Pit in the ground ^b	36	29.5
Flush toilet	16	13.1
Total	122	100.0
Water use		
Pumped to the house ^c	18	14.2
Natural source outside park	19	15.0
Community tank/well	90	70.9
Total	127	100.0

^aSolid structure with door and roof surrounding the hole/pit/seat.

^bSimple or no structure around the pit/hole.

^cPump/tap/running water to the house.

Table 5. Health-related Results

Variable	Frequency	%
Had cough in last month	19/122	15.6
Had fever in last month	11/123	8.9
Had diarrhea in last month	6/123	4.9
Saw a doctor in last month	25/45	55.6
Visited a health clinic in last 6 months	5/127	3.9
Used government clinic in last 6 months	82/127	64.6
Used local hospital in last 6 months	36/127	28.3

recently it has been changed to >7 meters). Twenty seven (21.8%) employees indicated that they had touched a gorilla and two (1.6%) additional employees indicated that they had been closer than 5 meters. Twenty five (20%) participants indicated that they had been involved in a clinical intervention in the field and 20 of the 25 (80%)

Table 6. US-based Viral Antibody Titer Testing Results

Code	Name	No. tested	Positive	Ind ^a	Negative	% positive
SRV	Simian type D retrovirus	125	0	8	117	0
SIV/HIV ^b	Simian immunodeficiency virus	125	11	0	114	8.8
STLV/HTLV ^b	Simian T-lymphotrophic virus	125	0	2	148	0
SFV	Simian foamy-virus	121	0	0	121	0
HAV	Hepatitis A	125	120	1	4	96
HBV	Hepatitis B	124	86	2	36	69.4
HEV	Hepatitis E	74	2	5	67	2.7
HSV1	Herpes simplex virus 1	125	121	3	1	96.8
CMV	Human cytomegalovirus	125	120	1	4	96
EBV	Epstein-Barr virus	125	121	0	4	96.8
VZV	Varicella zoster virus	125	125	0	0	100
MV	Measles virus	75	61	3	11	81.3
Parvovirus B19	Human parovirus	123	23	10	90	18.7

^aIndeterminate result (neither positive nor negative).

^bThe tests used were designed to detect simian viruses but crossreact with the human viruses. Sensitivity of tests used is slightly lower than that of tests designed specifically to detect the human virus [C. Whittier, personal communication].

indicated that they always wore gloves and a mask during the clinical intervention. Another four indicated that they wore gloves and a mask either some or most of the time. (Some members of the intervention team have responsibilities other than assisting at a close range with the clinical procedure, such as keeping other gorillas away).

Employees were exposed to animals other than gorilla that could also serve as a source for zoonotic disease transmission. Of the 127 employees 59.8% said that they regularly came within 5 meters of some other animal. The frequency of exposure varied by animal. The most common exposure to domestic animals was to ruminants (goats, cattle, sheep) and poultry (45.7 and 22.8% of the employees, respectively). Regular exposure to wildlife other than the mountain gorilla occurred among eight (6.3%) of the employees.

Clinical Findings

One hundred and twenty-one people received a physical examination in 2002, the majority of whom were assessed by the program physician as being healthy.

Blood testing. Blood was drawn from 127 people in 2002. Of those, RBC counts were reported for 115, spun hematocrit levels for 127, and sedimentation rates for 102 (insufficient supplies were responsible for the majority of

those without results). Spun hematocrit levels normal (>40%) for 89%, and RBC counts were normal ($>4.5 \times 10^6$ RBC/mm³) for 86%. Sedimentation rates were normal (<10 mm/per hour for 75% per hour) suggesting that 25% possibly had an underlying disease process. Analysis of blood thick smears revealed no malarial parasites.

Viral antibody titer testing. The results of the viral antibody titer testing can be found in Table 6. As noted, everyone tested positive for chickenpox (*Varicella zoster*) antibody, indicating infection with this virus at some point in their lives. A very high proportion (>69%) of employees tested positive for hepatitis A and B, cytomegalovirus, measles, Epstein-Barr, and herpes simplex virus.

Urinalysis. A total of 127 people provided urine samples in 2002. Glucose, specific gravity, urobilinogen, pH, nitrate, and bilirubin levels were normal for all employees tested that year; 6.2% had abnormal ketone levels and 49.5% tested positive for protein in their urine.

Fecal testing. Out of 126 fecal direct smear tests performed in-country in 2002, 123 results were reported (Table 7). Overall, 24.1% tested positive for any helminth (21.3% had one type of helminth, 2.8% had two types); 15.7% tested positive for any protozoa [14.8% had one, and 0.9% (one person) had two]; and 56.9% tested positive for

Table 7. In-country Fecal Direct Smear Testing Results ($n = 108$)

Organism	Frequency	% Positive
<i>Ascaris</i>	18	16.7
<i>Giardia</i>	3	2.8
<i>Trichomonas</i>	9	8.3
Tapeworm	8	7.4
Yeast	1	0.9
<i>E. coli</i>	6	5.6
<i>Trichocephalus</i>	3	2.8
Any protozoa	17	15.7
Any helminth	26	24.1
Any organism	61	56.9

any organism (helminth or protozoa; 50.5% had one, and 6.4% had two).

Table 8 summarizes findings from IFA and fecal flotation tests performed in the US. Considering the results of both tests, 48.8% were positive for any organism. IFA results revealed 8 individuals (6.3%) to be positive for *Cryptosporidium*, and 18 (14.2%) were positive for *Giardia*. On flotation, 15 individuals (11.8%) were positive for *Ascaris* and 12 (9.4%) were positive for hookworm. The total number of people positive for any organism on any fecal test, regardless of where testing was performed, was 70.1%.

In-country fecal bacteria culturing identified no pathogenic organisms in 2002. The following year, a few employees tested positive for *Campylobacter*, *Salmonella* and/or *Shigella* which suggests there was a problem in 2002 with the culturing process.

Of the 108 fecal samples sent for viral culturing in the US, six (5%) showed signs of cytopathology on A549 monolayers with inclusions typical of adenovirus and four (3.7%) showed signs of cytopathology on MRC-5 monolayers with inclusions typical of enterovirus.

Sputum testing. One person (0.8%) out of 105 persons with an informative sputum result had a positive test. He was referred for further care to the national health system.

Bivariate Analysis

Of the variables tested, only “days worked” (categorical) was statistically significantly ($P = 0.004$) associated with

Table 8. US-based Fecal IFA and Flotation Testing Results ($n = 127$)

Organism	Frequency	% positive
<i>Giardia</i>	18	14.2
<i>Ascaris</i>	15	11.8
<i>Cryptosporidium</i>	8	6.3
<i>Eimeria</i>	4	3.1
<i>Microsporidia</i>	1	0.8
<i>Strongyloides</i>	5	3.9
<i>Trichuris</i>	6	4.7
<i>Echinostoma</i>	0	0.0
<i>Enterobius</i>	0	0.0
<i>Entamoeba</i>	0	0.0
Hookworm	12	9.4
Tapeworm	0	0.0
Any organism	62	48.8

being positive for any organism on in-country fecal direct smear testing. Latrine type at home (pit in the ground) was marginally significantly associated with testing positive for any organism ($P = 0.057$). Being positive for one or more helminths on in-country fecal direct smear testing was not significantly associated ($P < 0.05$) with any independent variable listed in Table 2.

Being positive for any organism on US-based testing was also not significantly associated ($P < 0.05$) with any independent variable tested. Combining the US and in-country fecal results, two variables, “days worked” and “planting” were singularly significantly associated ($P = 0.006$ and $P=0.034$, respectively) with testing positive for any organism.

Abnormal RBC levels were not statistically significantly associated with any laboratory testing outcome at $P < 0.05$. RBC level was, however, significantly associated ($P = 0.044$) with water source only (abnormal RBC levels being associated with community water sources).

Cross-tabulations between HIV status and various other laboratory outcome variables were performed to assess the potential confounding role of HIV status. Of note, there were no statistically significant relationships ($P < 0.05$) between HIV status and laboratory test results in this dataset (between 9–11% of employees tested positive for HIV, depending on the test used. This analysis incorporated data on the 9% who tested positive on SIV/HIV testing, unlinked to any variable indicating the employee’s name).

The number of days an individual worked in the park and the type of toilet used were very significantly associated with one another ($P = 0.000$) (pit in the ground toilet being associated with more days working in the park).

A proportion of employees indicated in 2002 that they had visited a doctor in the last month (20%) or a health clinic in the past 6 months (31%), but neither variable was significantly associated with testing positive for: i) any organism, or ii) any helminth on in-country direct smear fecal examinations. Whether employees saw a doctor in the last 6 months was marginally associated ($P = 0.054$) with low RBC counts ($<4.5 \times 10^6/\text{mm}^3$).

Multivariate Regression Analysis

Logistic regression analysis was used to examine the association between variables deemed to be potential risk factors and testing positive on any laboratory test (combining fecal, blood, urine, and sputum testing results). Analyses were also run examining risk factors and test-positive status for any helminth, any protozoa, and any fecal pathogen on in-country testing, US testing, and results from the two countries combined. Testing positive for any helminth or any protozoa at any site was not significantly associated (model and all variable contributions $P < 0.05$) with any risk factors in Table 1. No single model best predicted the probability of being positive for any fecal organism regardless of testing site (r^2 ranged from 0.05–0.21). However, the type of toilet the individual typically used in their home compound was statistically significant in all “any fecal pathogen” models ($P < 0.05$). The highest accuracy level for these models was 67.7%. This was the accuracy level for identifying the presence of any fecal organism on in-country testing using: toilet type, days worked in the park, HIV status, and the individual’s job type as predictor variables (model $r^2 = 0.17$). For those who tested positive, the model correctly identified 87%. This model, however, only correctly classified 44.2% of individuals as test negative for any pathogenic organism.

DISCUSSION

According to the 2002 clinical examination results, the majority of park employees appeared healthy or to have minimal health problems. Identified health care problems that required treatment and/or referral included: poor eyesight (need for glasses), high blood pressure or HIV-positive status. Fecal testing results revealed low-to-mod-

erate rates of infection with individual pathogens—the highest rate of infection being *Ascaris* (16.7%) and motile bacteria (15.7%) according to in-country direct smear testing and *Ascaris* and *Giardia* (11.8% and 14.2%, respectively) according to US-based IFA and flotation testing. This report summarizes findings from the 2nd year of the program and, as prophylactic antihelminthic medication had been given twice during the previous year to employees, relatively low rates of helminth infection this year were expected. Considering both fecal tests, 70.1% were positive for one or more organisms. This overall infection rate is high and could contribute to reported absenteeism and doctor/clinic visits. However, the low number of clinical signs observed during the physical examination suggests that these employees were sub-clinically or chronically infected. Abnormally low RBC levels among some employees support this. Clearly, prevention of repeat infections and treatment of extant conditions needs to be a program priority.

The high rate of positive antibody titers to measles is consistent with MOH data indicating relatively high historic immunizations coverage levels for early childhood communicable diseases in Rwanda. Measles is a disease of particular concern for its potential devastating effects on mountain gorilla populations. Therefore, attention needs to be paid to monitoring measles levels in local communities where employees live or frequent.

Chickenpox is a disease usually contracted during childhood and essentially all of the employees tested antibody positive for this virus. Ensuring that children in the district, in particular in communities surrounding the park, receive this and other childhood vaccinations, including measles, would be a complementary strategy for reducing the risk of human disease transmission to the mountain gorillas (as well as improving the health status of community members).

The high antibody test-positive rates for hepatitis A and B (96 and 70%, respectively) is also an important finding. Both of these are highly infectious, debilitating diseases that could be prevented through vaccinations and health education about hygiene practices. Although usually asymptomatic in apes, these are potentially anthrozoootic organisms (Ott-Joslin, 1986). It is important to mountain gorilla conservation that vaccination for these pathogens and/or sanitation and hygiene interventions be considered in the future to interrupt the spread of disease.

The lack of any positive bacterial fecal cultures in 2002 is a highly unusual finding since similar programs for

animal personnel in the US reveal higher prevalence rates for these organisms—and the standard of hygiene in the latter is generally higher. After repeat culturing in a different laboratory, one or more employees tested positive for *Salmonella*, *Campylobacter*, or *Shigella*; laboratory technique likely accounts for the original lack of test positives.

Tuberculosis is another disease of particular concern both for its potential devastating effects on mountain gorillas as well as the health consequences in infected humans. Radiographs performed in-country the previous year (with a repeat reading in the US at Johns Hopkins Medical Center, Baltimore) supported the validity of year 2002's mostly negative sputum testing results. Despite apparent low prevalence among current employees, improvements to this screening component of the EHP are critical to minimizing the spread of this disease.

Bivariate analysis indicated a statistically significant association between the number of days worked and testing positive for any in-country fecal organism. If the potential for confounding had not been investigated, this would suggest spending time in the park was an occupational hazard for employees. Forward entry logistic regression analysis revealed, however, that after adjusting for other factors, number of days in the park was no longer statistically significantly associated with being positive for any fecal organism. The only significant risk factor for being positive on in-country fecal testing, adjusting for the presence of other potential risk factors in the model, was toilet type (pit in the ground) at the employees' place of residence. And, this variable was significant in all regression models, regardless of where the fecal sample was analyzed. Toilet type is obviously a proxy for unmeasured environmental and hygiene variables related to pathogen transmission. The role of well constructed latrines in reducing disease transmission is well documented in the human public health literature, and the 2002 EHP findings warrant further and continued epidemiologic analysis of these program data to better elucidate environmental and behavioral risk factors, especially ones for which cost-effective interventions exist to reduce their effect.

A review of the published literature on rates of human infection in East and Southern Africa with fecal pathogens over the past 20 years reveals wide variability in prevalence rates depending on gender, age, and HIV status of study subjects, and whether the study was community- or hospital-based. Variability can also be introduced through differences in type and accuracy of diagnostic test used, and sample collection and storage technique employed, among a

host of other factors. For example, compared to the published literature, the *Strongyloides* prevalence rate for employees in 2002 was similar to that measured in previous years in Rwanda and Tanzania (around 3%) (Scaglia et al., 1983; Pampiglione, 1972). However, for *Ascaris lumbricoides*, the rates in the published literature range from 5 to 82% (Chunge et al., 1991; Scaglia et al., 1983; Bukenya and Abongomera, 1985, Chandiwana, 1989; Gryseels and Grigase, 1985) compared to 12–16% from the two laboratories in this analysis. Of note, *E. histolytica* was not identified on fecal testing by either laboratory in this study although repeat independent testing by a third lab [Lilly, unpublished data] did identify this organism. And, it is cited in the published literature for the region at 10–45% prevalence (Chunge et al., 1991; Gathiram and Jackson, 1985; Scaglia et al., 1983). These observations suggest that comparisons across studies and across laboratories need to be attempted with caution, and highlight the importance of standardized collection, processing, and reporting protocols.

The main outcomes in this study were those associated with fecal testing. The relatively high number of fecal pathogen test positives allowed for an analysis of the likelihood of any statistically significant association between being infected and socio-demographic or exposure-related information, routinely collected at the time of the annual health assessment. Results of blood, urine, and sputum testing, and clinical examination were also considered, but employees were relatively healthy according to these tests. Given time and resource constraints, only a limited set of standardized questions can be posed to employees before they get examined. A larger questionnaire was tested the previous year, and the 2002 tool was limited to questions for which it was thought that responses: 1) would potentially affect outcomes; 2) might change over time; 3) could be answered by employees; and/or 4) would be variable among employees. Consequently, the analyses reported on in this article only reflect observed relationships between variables measured. This analysis does, however, provide useful insights into the quality and usefulness of EHP data for continually updating the epidemiologic profile, and exploring potential risk factors for infection and ill health as a means of identifying possible critical control points for reducing disease transmission to mountain gorillas.

CONCLUSIONS

Mountain gorillas only exist in the wild, and disease from humans has been identified as a key threat to the survival of

this primate species (Werikhe et al., 1998). Providing health services to park employees, the majority of whom come into repeated close contact with the mountain gorillas, is a logical intervention for reducing this source of potential disease threat. Because many veterinary preventive measures such as the use of antihelminthics and vaccines on wild gorillas are not practical (and considered by some not ethical), providing health care to park personnel to reduce potential pathogen exposure to the gorillas can be considered an active veterinary preventive measure, once removed.

Each year MGVP, in collaboration with other park conservation employers and the Rwandan MOH, offers a clinical examination, supports laboratory testing, and provides preventive vaccinations, health education, and anti-helminthic treatment. Based on the results of this epidemiologic analysis, future analyses of trends over time in test-positive rates, and the clinical progress of individuals treated as part of the program, details of the EHP can be modified to better meet employee health needs as well as to minimize disease transmission possibilities. An EHP like this makes sense as it engenders good relations and increases morale, promotes good health, and likely reduces disease threats to the mountain gorillas from this human group. Addressing health needs of the conservation personnel through an EHP, however, involves human, financial, and other resources, and must be sustainable. Only in this way will the likelihood of pathogen flow between humans and the mountain gorillas be reduced, as well as the rights of employees to minimal occupational hazards be maintained. These findings have been shared with the MOH officials at the national and local levels, as well as other relevant parties, to help inform planning of public health interventions in the area. This will contribute to improving employees' health and hopefully further reducing the risk of disease transmission to mountain gorillas in the park.

ACKNOWLEDGMENTS

The Employee Health Program is ongoing and is supported by Partners in Conservation (PIC) of the Columbus Zoo and the efforts of various people in the field and the US. This report summarizes the epidemiologic findings from the year 2002; the results of other years and comparisons across time will be available in other articles. The specific contribution of the members of the MGVP 2002 Employee Health Group to this report is provided in Appendix 1. In addition to these persons directly involved, the team

acknowledges the Ministry of Health, Rwanda, and Ruhengeri Hospital officials for their support. Special thanks go to the team of health professionals at the Ruhengeri Hospital who have provided assistance to the EHP effort every year. The team thanks Elizabeth Nyirakaragire, in particular, for ensuring that the questionnaire data are collected and recorded appropriately. Our gratitude is extended to students and others at Mississippi State University who assist with data cleaning and processing. Recognition goes to the various professionals worldwide involved in analyzing the employee biological samples, in particular, DFGFI and Alecia Lilly. We recognize ORTPN, DFGFI, and IGCP's role in supporting their employees to participate in this program and, of course, the employees themselves who dedicate their time to ensuring the safekeeping of the mountain gorillas.

APPENDIX 1. THE MGVP 2002 EMPLOYEE HEALTH GROUP

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