J Med Primatol doi:10.1111/jmp.12170

SHORT PAPER

Prevalence of gastrointestinal parasites in captive non-human primates of twenty-four zoological gardens in China

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Keywords
captive primates – *Entamoeba* spp.
gastrointestinal parasites – *Trichuris* spp.

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Accepted February 24, 2015.

Abstract

Captive primates are susceptible to gastrointestinal (GIT) parasitic infections, which are often zoonotic and can contribute to morbidity and mortality. Fecal samples were examined by the means of direct smear, fecal flotation, fecal sedimentation, and fecal cultures. Of 26.51% (317/1196) of the captive primates were diagnosed gastrointestinal parasitic infections. *Trichuris* spp. were the most predominant in the primates, while *Entamoeba* spp. were the most prevalent in Old World monkeys ($P < 0.05$). These preliminary data will improve the management of captive primates and the safety of animal keepers and visitors.

Introduction

The exhibits of captive primates (i.e., non-human primates, NHPs) are an important highlight for visitors to zoological gardens. Captive primates, however, are susceptible to gastrointestinal (GIT) parasitic infections, which are often zoonotic [2, 8, 21]. Severe GIT helminth and protozoan infections can lead to blood loss, tissue damage, spontaneous abortion, congenital malformations, and death [24]. Numerous studies of GIT parasites in both wild and captive primates worldwide [11, 22] report that GIT helminth and protozoa parasites infect all major NHP groups, including captive animals, and cause high morbidity and mortality rates [9, 12, 24, 26]. Yet few studies have quantified prevalence data of GIT parasites in zoos [5, 15, 16, 20], and existing studies have limited their focus to specific primate species, specific parasite species, or specific zoos [18, 20]. To date, little is known about the prevalence of GIT parasitic infections in captive primates in Chinese zoos [10, 25, 27]. Systematical studies on GIT parasitic infection in captive NHPs housed in a larger range of representative Chinese zoological gardens are demanded for the management of primates and the safety of animal keepers and visitors.

Materials and methods

Ethics statement

All procedures were reviewed and approved by the Wildlife Management and Animal Welfare Committee of China. During fecal collection, animal welfare was taken into consideration.

Fecal sample collection and examination

From April 2010 to October 2012, 1196 fresh fecal samples were collected from twenty-four zoological gardens for three consecutive days in the morning. The sampled feces belonged to 57 primate species within nine families [3, 9]. The animals were housed either individually or in groups but species separately. Before fecal collection, the animals were all separated. Detailed information (i.e., sampling times, species, age, sex) was gathered using double labeling method, which means using a label paper inside and outside the plastic bags, during the sample collection. Fecal samples were transferred to plastic bags and stored at 4°C prior to laboratory analyses.

Fecal samples were examined for the presence of helminth eggs, larvae, and protozoan cysts by different methods: direct smear, fecal flotation, fecal sedimentation, and fecal cultures [7]. Direct smear staining with Lugol's iodine solution (0.3% iodine) was firstly used to detect trophozoites of amoebae and flagellates in all fecal samples [17]. Eggs, larvae, and cysts were then scanned under microscope with 10 times and 40 times objectives with the methods of fecal flotation and fecal sedimentation technique on the basis of their morphology, shape, color, size, and other visible structures [19, 26]. Given the sampling collection method and the detection threshold, McMaster's technique was only employed to assess the intensity of *Trichuris* spp. infection, with results were expressed as egg count per gram (EPG) [23]. Analysis of variance (ANOVA) test, Duncan's multiple range test, and Student's *t*-test were conducted using SAS software (SAS Institute, Cary, ND, USA). Statistical significance was set at $P < 0.05$.

Results

GIT parasitic infections in NHPs in zoological gardens

Of 1196 fecal samples, 317 (26.51%) were infected with at least one parasite taxon. Prevalence of GIT parasitic infections differed amongst the zoos from 3.77% to 100% (Fig. 1A). We detected five nematode species, one tapeworm species, and three protozoan species, of which the *Trichuris* spp. nematodes were the most abundant clade of parasites (16.30%; Table 1).

GIT parasitic infections in NHP species

We found that GIT parasites species vary greatly amongst primate clades (Fig. 1B). For example, *H. nana* was the most common parasite infection amongst the prosimians, while *Trichuris* spp. were most prevalent in Old World (OW) monkeys. OW monkeys also exhibited a higher prevalence of *Entamoeba* spp. infections than did other primate clades. Indeed, the prevalence rates of GIT parasitic infections differed greatly from species to species, with no parasites in the feces of 22 of the 57 primate species represented in our collection. We found that *Colobus guereza* harbored a significantly higher prevalence of GIT parasitic infections than other primate species ($P < 0.05$).

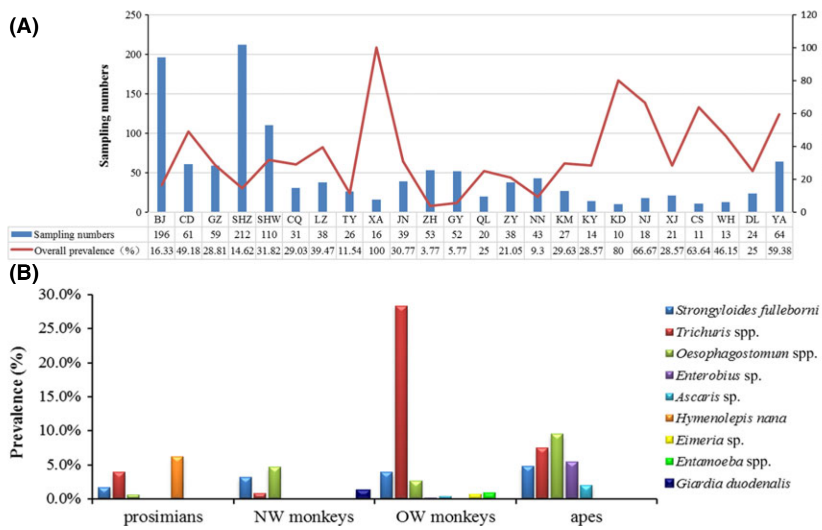

Fig. 1 (**A**). Number of feces sampled and the prevalence of gastrointestinal parasites in captive primates in twenty-four zoological gardens of China, 2010–2012. Key to zoo name abbreviations: BJ: Beijing, CD: Chengdu, GZ: Guangzhou, SHZ: Shanghai zoo, SHW: Shanghai wild zoo, CQ: Chongqing, LZ: Lanzhou, TY: Taiyuan, XA: Xi'an, JN: Jinan, ZH: Zhengzhou, GY: Guiyang, QL: Qianning, ZY: Zunyi, NN: Nanning, KM: Kunming, KY: Kunming wild zoo, KD: Kunming institute of zoology, NJ: Nanjing, XJ: Xinjiang, CS: Changsha, WH: Wuhan, DL: Dalian, YA: Ya'an. (**B**). The prevalence of GIT parasites within four primate clades based on feces obtained from 57 species of primates held captive in twenty-four zoological gardens of China.

Table 1 Prevalence of gastrointestinal parasites in fifty-seven captive primates' species from China, 2010–2012. Mean intensity = mean number of *Trichuris* spp. in eggs per gram of fecal samples

Family	Species: Scientific name	Species: Common name	N	Sf	Tri	Oesoph	Enter	Asca	Hn	Eimer	Entam	Gd	GIT parasite prevalence (%)	Mean intensity (Mean ± SD)
Cercopithecidae	*Macaca assamensis*	Assam Macaque	11	—	—	1 (9.09%)	—	—	—	—	—	—	1 (9.09)	
	M. silenus	Lion-tailed Macaque	7	2 (28.57%)	—	—	—	—	—	—	—	—	2 (28.57)	
	M. nigra	Celebes Crested Macaque	3	—	—	—	—	—	—	—	—	—	0 (0)	
	M. thibetana	Tibetan Macaque	14	—	—	—	—	—	—	—	—	—	0 (0)	
	M. fascicularis	Crab-eating Macaque	27	2 (7.41%)	1 (3.70%)	—	—	—	—	—	—	—	3 (11.11)	
	M. arctoides	Stump-tailed Macaque	13	1 (7.69%)	3 (23.08%)	1 (7.69%)	—	—	—	—	—	—	5 (38.46)	
	M. mulatta	Rhesus Macaque	63	3 (4.76%)	20 (31.75%)	1 (1.59%)	—	—	—	3 (4.76%)	—	—	27 (42.86)	
	M. nemestrina	Pig-tailed Macaque	32	—	2 (6.25%)	—	—	1 (3.13%)	—	—	1 (3.13%)	—	4 (12.5)	
	M. fuscata	Japanese Macaque	3	—	2 (66.67%)	—	—	—	—	—	—	—	2 (66.67)	
	Papio hamadryas	Hamadryas Baboon	69	3 (4.35%)	26 (37.68%)	1 (1.45%)	—	—	—	—	2 (2.90%)	—	32 (46.38)	420 ± 216.79
	P. anubis	Olive Baboon	22	—	3 (13.64%)	—	—	—	—	—	—	—	3 (13.64)	
	P. cynocephalus	Yellow Baboon	7	2 (28.57%)	4 (57.14%)	1 (14.29%)	—	—	—	—	—	—	7 (100)	
	P. papio	Baboons	4	—	1 (25%)	—	—	—	—	—	—	—	1 (25)	
	Mandrillus leucophaeus	Drill	2	—	1 (50%)	—	—	—	—	—	1 (50%)	—	2 (100)	
	M. sphinx	Mandrill	47	1 (2.13%)	—	2 (4.26%)	—	—	—	—	—	—	3 (6.38)	
	Presbytis pileatus	Capped Leaf Monkey	1	—	—	—	—	—	—	—	—	—	0 (0)	
	P. leucocephalus	White-headed Leaf-Monkey	5	—	—	—	—	—	—	—	—	—	0 (0)	
	P. francoisi	Francois's Leaf Monkey	78	2 (2.56%)	9 (11.54%)	2 (2.56%)	—	—	—	—	1 (1.28%)	—	14 (17.95)	867 ± 550.76
	P. phayrei	Phayre's Leaf Monkey	4	1 (25%)	2 (50%)	—	—	—	—	—	—	—	3 (75)	
	Rhinopithecus roxellanae	Golden Snub-nosed Monkey	95	—	76 (80%)	1 (1.05%)	—	—	—	1 (1.05%)	—	—	78 (82.11)	33275 ± 6556.61
	R. bieti	Black Snub-nose Monkey	16	—	11 (68.75%)	—	—	—	—	—	—	—	11 (68.75)	650 ± 331.66
	R. brelichi	Gray Snub-nosed Monkey	1	—	—	—	—	—	—	—	—	—	0 (0)	
	Cercopithecus neglectus	De Brazza's Monkey	18	—	—	1 (5.56%)	—	—	—	—	—	—	1 (5.56)	
	C. nictitans	Putty-nosed Monkey	5	1 (20%)	—	—	—	—	—	—	—	—	1 (20)	
	C. lhoesti	L' Hoest's Monkey	1	—	—	—	—	—	—	—	—	—	0 (0)	
	C. diana	Diana Monkey	6	1 (16.67%)	1 (16.67%)	—	—	—	—	—	—	—	2 (33.33)	
	C. aethiops	Green Monkey	24	3 (12.5%)	1 (4.17%)	—	1 (4.17%)	—	—	—	—	—	5 (20.83)	
	Colobus polykomos	Western Black-and-white Colobus	9	2 (22.22%)	2 (22.22%)	1 (11.11%)	—	1 (11.11%)	—	—	—	—	6 (66.67)	
	C. guereza	Mantled Guereza	4	—	4 (100%)	2 (50%)	—	—	—	—	—	—	6 (150)	4850 ± 1634.01
	Erythrocebus patas	Patas Monkey	26	—	6 (23.08%)	2 (7.69%)	—	—	—	—	—	—	8 (30.77)	2350 ± 777.82
Galagidae	*Galago crassicaudatus*	Thick Clump Monkey	13	—	—	—	—	—	—	—	—	—	0 (0)	
Atelidae	*Ateles paniscus*	Guiana Spider Monkey	13	1 (7.69%)	—	2 (15.38%)	—	—	—	—	—	—	3 (23.08)	
Cebidae	*Saimiri sciureus*	Common Squirrel Monkey	103	2 (1.94%)	2 (1.94%)	5 (4.85%)	—	—	—	—	—	—	9 (8.74)	
	Aotus trivirgatus	Northern Owl Monkey	7	—	—	—	—	—	—	—	—	—	0 (0)	
	Cercopithecus mitis	Blue Monkey	8	—	—	1 (12.5%)	—	—	—	—	—	3 (37.5%)	4 (50)	
	Chiropotes satanas	Black Bearded Saki	1	—	—	1 (100%)	—	—	—	—	—	—	1 (100)	
	Cebus capucinus	White-throated Capuchin	5	—	—	1 (20%)	—	—	—	—	—	—	1 (20)	
	Cebus kaapori	Ka'apor Capuchin	11	—	—	—	—	—	—	—	—	—	0 (0)	
	Sapajus apella	Tufted Capuchin	50	2 (4%)	—	2 (4%)	—	—	—	—	—	—	4 (8)	
	Cebus nigrivittatus	Weeper Capuchin	1	—	—	—	—	—	—	—	—	—	0 (0)	
	Cebus albifrons	White-fronted Capuchin	26	3 (11.54%)	—	—	—	—	—	—	—	—	3 (11.54)	
Callitrichidae	*Callithrix jacchus*	Common Marmoset	8	—	—	—	—	—	—	—	—	—	0 (0)	
	Saguinus oedipus	Cotton-top Tamarin	7	—	—	—	—	—	—	—	—	—	0 (0)	
	S. midas	Golden-handed Tamarin	9	—	—	—	—	—	—	—	—	—	0 (0)	
			7	—	—	—	—	—	—	—	—	—	0 (0)	

(continued)

Table 1 (continued)

Family	Species: Scientific name	Species: Common name	N	Sf	Tri	Oesoph	Enter	Asca	Hn	Eimer	Entam	Gd	GIT parasite prevalence (%)	Mean intensity (Mean ± SD)
	Leontopithecus chrysomelas	Golden-headed Lion Tamarin												
Lemuridae	*Lemur catta*	Ring-tailed Lemur	139	3 (2.16%)	7 (5.04%)	1 (0.72%)	—	—	11 (7.91%)	—	—	—	22 (15.83)	
	L. variegatus	Ruffed Lemur	1	—	—	—	—	—	—	—	—	—	0 (0)	
	L. macaco	Black Lemur	1	—	—	—	—	—	—	—	—	—	0 (0)	
Hylobatidae	*Hylobates lar*	White-handed Gibbon	1	—	—	—	—	—	—	—	—	—	0 (0)	
	H. hoolock	Hoolock Gibbon	14	1 (7.14%)	3 (21.43%)	1 (7.14%)	—	—	—	—	—	—	5 (35.71)	
	H. concolor	Black Crested Gibbon	1	—	—	—	—	—	—	—	—	—	0 (0)	
	H. leucogenys	White-cheeked Gibbon	57	4 (7.02%)	6 (10.53%)	3 (5.26%)	—	1 (1.75%)	—	—	—	—	14 (26.42)	
Pondinae	*Pan troglodytes*	Common Chimpanzee	53	2 (3.77%)	2 (3.77%)	10 (18.87%)	8 (15.09%)	2 (3.77%)	—	—	—	—	24 (45.28)	
	Gorilla gorilla	Western Lowland Gorilla	9	—	—	—	—	—	—	—	—	—	0 (0)	
	Pongo pygmaeus	Bornean Orangutan	12	—	—	—	—	—	—	—	—	—	0 (0)	
Lorisidae	*Nycticebus pygmaeus*	Pygmy Loris	12	—	—	—	—	—	—	—	—	—	0 (0)	
	N. coucang	Greater Slow Loris	10	—	—	—	—	—	—	—	—	—	0 (0)	
Overall prevalence			1196	42 (3.68%)	195 (16.30%)	43 (3.60%)	9 (0.75%)	5 (0.42%)	11 (0.92%)	4 (0.33%)	5 (0.42%)	3 (0.25%)		

'—', negative; N, number of samples collected and examined; Sf, *Strongyloides fulleborni*; Tri, *Trichuris* spp.; Oesoph, *Oesophagostomum* spp.; Enter, *Enterobius* sp.; Asca, *Ascaris sp.*; Hn, *Hymenolepis nana*; Eimer, *Eimeria* sp.; Entam, *Entamoeba* spp.; Gd, *Giardia duodenalis*.

Trichuris spp. infections in NHPs

The prevalence of *Trichuris* spp. infections differed greatly amongst the 24 species observed to harbor GIT infections (range = 1.94% to 100%; Table 1). *Trichuris* spp. prevalence was highest for *Colobus guereza* and *Rhinopithecus roxellanae*, with 100% and 80% of their fecal sampled infected, respectively. In addition, *R. roxellanae* exhibited a significantly higher average egg count of *Trichuris* spp. than many other species (*Erythrocebus patas*, *Papio hamadryas*, *C. guereza*, *Presbytis francoisi,* and *R. bieti*; $P < 0.05$; Table 1).

Discussion

This study presents the first extensive survey of GIT parasitic infections in captive primates in China. The prevalence of parasites in primates housed in the zoos varies according to husbandry practices, disease prophylaxis, and anthelmintic treatment administered. Efficacious control measures have been taken by the zoos to reduce the environmental contamination, such as frequent dung removal. In addition, the primates are treated twice a year with anthelmintic drugs to prevent and control the parasite burdens. So, we found a low prevalence of GIT parasites in many of the sampled species. Nevertheless, Helminths, especially *Trichuris* spp., *S. fulleborni*, and *Oesophagostomum* spp., were the most prevalence parasites amongst the captive primate species. This supports the findings of previous studies [6, 13]. *Trichuris* spp. seems to be a globally distributed parasite in primates and should be considered in the management practices of captive primates.

Surprisingly, protozoan infections were rare and of low prevalence within our samples, which may be a consequence of host susceptibility or behavior [4]. For example, OW monkeys in the wild harbor high parasite infection rates as a result of their ground-dwelling habits [1, 14], although in zoos they were housed in clean cages. It is also possible that the prevalence of protozoan infection was underestimated in this study due to low detection rates by the methods used. Molecular techniques offer a robust means of corroborating prevalence of protozoan infections in captive primates, once technical difficulties can be overcome (e.g., eliminating the influence of preservatives, such as potassium dichromate [21, 28]).

Many parasites are known to be transmissible between non-human primates and humans [2, 8]. In zoos, there is an increased risk of parasite transmission from primates to visitors or keepers as a result of direct or indirect contact through contaminated food, water, and hands. The GIT parasites detected in this study are amongst those known to represent human public health concerns (*Trichuris* spp. [8], *Entamoeba* spp. [8], and *G. duodenalis* [21]). Hence, our results highlight that proper precautions should be taken by the zoological gardens with large number of animals to mitigate against parasite transmission. This includes adhering to basic hygiene standards, undertaking regular deworming of animals, and ensuring cages are cleaned and disinfected daily.

Acknowledgment

The authors would also like to thank to Chengdu Research of Giant Panda Breeding for financial support (CPF-08005).

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