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Physiological and biochemical indicators in blood of captive yellow-cheeked gibbons and northern white-cheeked gibbons

Wanrong Song[1†], Yujuan Hu[1†], Minghao Cheng[2†], Tianchun Pu[3,4], Wenhui Niu[3,4], Yizhuo Zhang[3,4], Xuefeng Liu[3,4], Yunsheng Wang[3,4], Yuguang Zhang[2], Jinpeng Liu[3,4*] and Yipeng Jin[1*]

Abstract

Background Gibbons are recognized as a critically endangered primate taxon of significant conservation importance. Given their dwindling populations, accurate disease diagnosis, treatment, and management have become crucial for species preservation. However, the lack of established physiological and biochemical reference ranges currently poses substantial challenges to effective clinical assessment and disease identification in these primates.

Materials and methods In this study, blood samples were collected from the gibbons under anesthesia to ensure safe restraint during the procedure. Thirty-four hematological and biochemical parameters were measured from three yellow-cheeked gibbons (*Nomascus gabriellae*) and six northern white-cheeked gibbons (*Nomascus leucogenys*) maintained at Beijing Zoo.

Results The results showed that there were no conspicuous differences in hematological indicators between two species ($P>0.05$). Furthermore, comparative analysis of hematological parameters between the clinically diseased individual presenting with gastrointestinal symptoms (anorexia and vomiting) and established normal physiological ranges revealed significantly elevated values in hemoglobin (HGB), white blood cell count (WBC), hematocrit (HCT), serum potassium (K), serum sodium (Na), total protein (TP), albumin (ALB), serum creatinine (SCR) and blood urea nitrogen (BUN). In contrast, neutrophil count (NSG) and alkaline phosphatase (ALP) levels were below normal reference values. Notably, both SCR and BUN exceeded normal ranges by more than three-fold. This suggests that this gibbon's indigestion was caused by impaired kidney function and reduced metabolic capacity.

Conclusion This study represents the first comprehensive measurement of thirty-four hematological indicators in both yellow-cheeked gibbons and northern white-cheeked gibbons, which provides reference for early disease diagnosis and clinical treatment of gibbons.

†Wanrong Song, Yujuan Hu and Minghao Cheng contributed equally to this work.

*Correspondence:
Jinpeng Liu
liuzun88peng@aliyun.com
Yipeng Jin
yipengjin@cau.edu.cn

Full list of author information is available at the end of the article

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Keywords Yellow-cheeked gibbons, Northern white-cheeked gibbons, Blood routine indicators, Blood biochemical indicators

Background

Gibbons, small apes primarily distributed in tropical or subtropical forest ecosystems of southern and southeastern Asia [1], belong to four genera [2] (*Nomascus*, *Hoolock*, *Hylobates*, and *Symphalangus*) [3] and encompass up to 20 species [4]. Gibbons serve as an integral component of forest ecosystems, playing a pivotal role in maintaining ecological equilibrium and biodiversity [5]. As arboreal primates, their frugivorous and florivorous foraging behaviors facilitate seed dispersal, thereby promoting forest regeneration and plant propagation [6]. Furthermore, their presence serves as a key bioindicator of forest health due to their heightened sensitivity to habitat alterations. Conservation of gibbons not only contributes to ecosystem stability but also provides critical scientific insights into primate behavior, social organization and evolutionary history [7]. However, their critically endangered status and critically small population size necessitate urgent conservation measures. Therefore, safeguarding gibbon populations holds profound implications for both ecological preservation and global biodiversity conservation initiatives. Thereinto, both yellow-cheeked gibbons (*Nomascus gabriellae*) and northern white-cheeked gibbons (*Nomascus leucogenys*) are classified within the order primates, class mammalia, family hylobatidae, genus hylobates [8]. Northern white-cheeked gibbons and yellow-cheeked gibbons have become popular zoo animals in China. But they are so rare that they are listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2025) [9]. Currently, northern white-cheeked gibbons are listed as Critically Endangered, and has not been monitored in the wild in China in the last decade [10]. There are totally about 250 northern white-cheeked gibbons and yellow-cheeked gibbons in captivity in China. Because of the scarcity of both species, research on the diagnosis, treatment, and management of their diseases is of paramount importance [11].

Blood physiological and biochemical indexes form a crucial basis for the clinical diagnosis and treatment of animal diseases [12–14]. Among these, blood routine indexes provide valuable insights into the immune status of animals [15], assisting in the detection of anemia [16], acute infections and certain infectious diseases [17]. On the other hand, blood biochemical indicators reveal the nutritional status and metabolic capacity of animals [18], allowing veterinarians to identify malnutrition and metabolic disorders. By regularly measuring these indexes, health monitoring and disease prevention can be conducted, serving as invaluable references for animal clinical medicine [19].

In recent years, there have been studies on the hematology of primates such as Rhesus macaque (*Macaca mulatta*) [20], Long-tailed Macaque (*M. fascicularis*) [21], Golden snub-nosed monkey (*Rhinopithecus roxellana*), Cotton-eared Marmoset (*Callithrix jacchus*) [22], Mantled howler monkey (*Alouatta palliata*) [23], black leg Douc Langu (*Pygathrix nigripes*), Olive baboon (*Papio Anubis*) [24], Ring-tailed Lemur (*Lemur catta*) [25, 26]. These studies mainly focus on the determination of blood physiological and biochemical indicators, and the influence on hematological indicators by different factors such as genotype, age, physiological condition, gender, diet, season, and pathological factors [27–29]. However, there is still a lack of information on the hematological studies of gibbons. The main objective of this work was to investigate blood physiological and biochemical indexes of three yellow-cheeked gibbons and six white-cheeked gibbons in Beijing Zoo and evaluate potential interspecies differences. It can be used for more accurate assessment of health of gibbons in common clinical practice [19].

General clinical practice

Animals and procedures

Blood physiological and biochemical indicators were studied in three yellow-cheeked gibbons and six north white-cheeked gibbons. These animals ranging in age from eight to thirty-three years old were reared in Beijing Zoo (China, Beijing; 39.942131°N, 116.336551°E) in controlled conditions, using identical husbandry procedures and diets with the same nutritional content, including fruits and vegetables supplemented with refined feed. Except for one northern white-cheeked gibbon suffering from dyspepsia, all the other gibbons were healthy. The specific individual information is shown in Table 1.

Sample collection

The anesthetic agent Zoletil 50 (Virbac S.A, France) was administered at a dose of 20 mg/kg in sweet bread cubes, a preferred food of gibbons. Approximately 40 min after administration, muscle relaxation and sedation were observed. Depending on the level of anesthesia, Zoletil 50 (3 mg/kg) was injected intramuscularly for maintenance. During sampling, the anesthetized gibbons were secured in place with their heads positioned sideways and eyes covered. A veterinarian shaved the fur over the left forelimb's blood vessel, disinfected the area with 5% iodine tincture and 75% alcohol, and inserted a 21G

Table 1 Individual information of Gibbons

Species name	Name	Sex group	Age	Body weight/kg	Physical condition
Nomascus gabriellae	04–4	Female	18	8.5	Healthy
Nomascus gabriellae	07 – 2	Female	15	9.7	Healthy
Nomascus gabriellae	j2014-3	Male	8	8.8	Healthy
Nomascus leucogenys	j2013-1	Male	9	9	Healthy
Nomascus leucogenys	93 – 1	Male	33	8	Healthy
Nomascus leucogenys	j2010-1	Male	12	9.2	Healthy
Nomascus leucogenys	06 – 3	Male	16	9	Healthy
Nomascus leucogenys	06 – 2	Female	16	9	Healthy
Nomascus leucogenys	j2012-2	Female	10	9	Dyspeptic

disposable venous blood needle (Shandong Oxet Medical Equipment Co., LTD.) into the basilic vein of the gibbon's forelimb for blood collection. The samples were immediately processed for analysis. A total of 6 mL peripheral blood was aseptically collected from each gibbon. 1 mL of blood was collected into EDTA anticoagulant tubes for routine hematological analysis. Additionally, 5 mL of blood was drawn into tubes without additives for serum separation, followed by subsequent physiological and biochemical analysis. Another veterinarian monitored the gibbon's respiratory and heart rate throughout the procedure, promptly detecting and addressing any abnormalities. The process had no obvious adverse effect on the physiological functions of gibbons. The subjects recovered naturally after 2 h of sampling.

Sample detection

Automatic blood cell analyzer (Mindray BC5390) [30] was used to detect the following 8 routine blood indexes: hemoglobin (HGB), red blood cell count (RBC), white blood cell count (WBC), hematocrit (HCT), neutrophilic segmented granulocyte (NSG%), neutrophil stab form (NST%), Lymphocyte percentage (LYMP%) and Monocytes (MONO%). A total of 26 blood biochemical indexes were determined by automatic biochemical instrument (COBAS C501): serum potassium (K), serum sodium (Na), serum calcium (Ca), serum iron (Fe), serum magnesium (Mg), serum chlorine (Cl), serum phosphorus (P), blood glucose (GLU), serum creatinine (SCR), uric acid (UA), blood urea nitrogen (BUN), total protein (TP), albumin (ALB), globulin (GLOB), albumin/globulin (A/G), total bilirubin (TBIL), total cholesterol (TC), triglyceride (TG), amylase (AMS), lipase (LPS), creatine kinase (CK), alkaline phosphatase (ALP), lactate dehydrogenase (LDH), alanine aminotransferase (ALT), aspartate aminotransferase (AST), total vitamin D (VD).

Statistical evaluation

The results were calculated by Excel and statistical methods using the statistical program SPSS 26.0 to describe the observed range of value. The difference of each index between the two species of yellow-cheeked gibbon and northern white-cheeked gibbon was evaluated by *t*-test, at a level of significance being $P \leq 0.01$ and $P \leq 0.05$. Each indicator was presented by the mean value (x) and standard deviation (± SD).

Results

Thirty-four blood indexes were measured for each sample. Each sample was tested three times to establish the normal range and mean value. The results of eight healthy gibbons by species are shown in Table 2. A comparison of individual indicators between yellow-cheeked gibbon and northern white-cheeked gibbon showed that the mean values of HGB, RBC, Fe, Ca, GLU, SCR, AMS, ALP, LDH, ALT and AST of northern white-cheeked gibbon were higher than another. However, the trend was opposite in NSG%, UA, CK and VD. When comparing the biological data between different species, the result showed that there was no significant difference ($P > 0.05$).

The gibbon exhibited gastrointestinal symptoms, including loss of appetite and vomiting, leading to a preliminary suspicion of digestive tract disease. The measured blood physiological and biochemical indexes of gibbon with indigestion were compared with the normal range. The results indicated that the HGB, WBC, HCT, K, Na, SCR, BUN, TP, ALB of the diseased individual were higher than normal value. But NSG and ALP were lower than normal. Moreover, the SCR and BUN were more than three times higher than the normal values (Table 3). Therefore, we speculate that the indigestion in this gibbon was caused by renal function impairment and reduced metabolic capacity, accompanied by mild dehydration (slightly elevated HCT) and electrolyte imbalance due to vomiting.

Discussion

The value of HGB, RBC, Fe, P, GLU, SCR, ALP, ALT and AST of northern white-cheeked gibbons in our study were higher than yellow-cheeked gibbons. However, there is no significant differences in 34 blood indexes between the two species. We hypothesized that the differences were relatively small in physical characteristics and physiological indexes between the yellow-cheeked gibbons and the northern white-cheeked gibbons, which have interspecific hybridized [31]. Some studies compared the blood indexes of African elephant (*Loxodonta africana*) [32] and Asian

Table 2 The comparison of blood physiological and biochemical indicators between Northern white-cheeked Gibbons and yellow-cheeked Gibbons

Indicators	Yellow-cheeked gibbons ($n=3$)		Northern white-cheeked gibbons ($n=5$)	
	Average	Ranges	Average	Ranges
HGB/(g·L^{-1})	168.00 ± 13.23	153.00 ~ 178.00	176.60 ± 10.99	164.00 ~ 193.00
RBC/(×10^{12}·L^{-1})	7.37 ± 0.67	6.78 ~ 8.10	9.05 ± 1.06	7.80 ~ 10.47
WBC/(×10^{9}·L^{-1})	8.83 ± 2.86	6.80 ~ 12.10	8.25 ± 2.33	5.95 ~ 11.70
HCT/(L·L^{-1})	0.47 ± 0.02	0.45 ~ 0.49	0.50 ± 0.02	0.47 ~ 0.53
NSG/%	68.33 ± 14.84	52.00 ~ 81.00	58.00 ± 5.70	52.00 ~ 65.00
NST/%	4.67 ± 3.21	1.00 ~ 7.00	2.60 ± 2.19	0.00 ~ 6.00
LYMP/%	24.00 ± 20.07	10.00 ~ 47.00	35.80 ± 5.81	31.00 ~ 45.00
MONO/%	1.33 ± 1.15	0.00 ~ 2.00	3.00 ± 2.00	1.00 ~ 6.00
K/(mmol·L^{-1})	3.84 ± 1.35	3.02 ~ 5.40	4.50 ± 0.51	3.90 ~ 5.30
Na/(mmol·L^{-1})	142.67 ± 13.43	133.00 ~ 158.00	138.60 ± 2.30	135.00 ~ 141.00
Ca/(mmol·L^{-1})	1.76 ± 1.01	0.59 ~ 2.36	2.41 ± 0.18	2.24 ~ 2.69
Fe/(μmol·L^{-1})	12.60 ± 0.06	12.55 ~ 12.64	20.45 ± 1.41	19.45 ~ 21.44
Mg/(mmol·L^{-1})	0.66 ± 0.04	0.63 ~ 0.69	0.83 ± 0.14	0.69 ~ 1.02
Cl/(mmol·L^{-1})	96.50 ± 3.54	94.00 ~ 99.00	101.60 ± 3.97	95.00 ~ 105.00
P/(mmol·L^{-1})	0.96 ± 0.07	0.88 ~ 1.01	1.75 ± 0.81	1.04 ~ 2.95
GLU/(mmol·L^{-1})	2.92 ± 1.66	1.00 ~ 3.92	5.51 ± 2.15	3.10 ~ 7.20
SCR/(μmol·L^{-1})	62.51 ± 20.58	39.00 ~ 77.23	89.51 ± 14.73	73.01 ~ 103.00
UA/(μmol·L^{-1})	237.60 ± 0.35	237.35 ~ 237.84	196.50 ± 222.67	3.80 ~ 410.00
BUN/(mmol·L^{-1})	6.49 ± 0.77	5.60 ~ 6.95	6.29 ± 2.35	3.00 ~ 9.08
TP/(g·L^{-1})	64.80 ± 5.37	61.56 ~ 71.00	71.36 ± 5.28	67.00 ~ 80.00
ALB/(g·L^{-1})	43.74 ± 14.08	35.56 ~ 60.00	44.97 ± 4.96	37.69 ~ 50.00
GLOB/(g·L^{-1})	21.16 ± 8.80	11.00 ~ 26.33	26.40 ± 4.40	20.00 ~ 30.45
A/G	1.41 ± 0.01	1.40 ~ 1.42	1.78 ± 0.54	1.20 ~ 2.50
TBIL/(μmol·L^{-1})	4.90 ± 2.68	3.35 ~ 8.00	5.55 ± 1.68	3.79 ~ 8.00
TC/(mmol·L^{-1})	4.30 ± 0.05	4.26 ~ 4.33	4.82 ± 0.61	4.32 ~ 5.80
TG/(mmol·L^{-1})	0.71 ± 0.01	0.70 ~ 0.72	0.71 ± 0.11	0.59 ~ 0.83
AMS/(U·L^{-1})	187.78 ± 0.31	187.56 ~ 188.00	229.06 ± 71.58	184.00 ~ 334.68
LPS/(U·L^{-1})	25.07 ± 0.05	25.03 ~ 25.10	29.00 ± 24.54	6.30 ~ 60.00
CK/(U·L^{-1})	404.20 ± 1.91	402.85 ~ 405.55	289.96 ± 145.50	145.00 ~ 415.38
ALP/(U·L^{-1})	63.92 ± 47.57	9.00 ~ 91.45	166.62 ± 108.78	91.20 ~ 353.91
LDH/(U·L^{-1})	265.37 ± 0.89	264.74 ~ 266.00	322.40 ± 195.84	181.30 ~ 611.30
ALT/(U·L^{-1})	18.65 ± 2.30	16.00 ~ 20.01	25.09 ± 16.44	13.00 ~ 53.65
AST/(U·L^{-1})	21.00 ± 0.03	20.98 ~ 21.02	48.30 ± 66.63	12.98 ~ 148.22
VD/(ng·ml^{-1})	38.13 ± 0.11	38.05 ~ 38.20	26.25 ± 14.64	15.90 ~ 36.60

elephant (*Elephas maximus*) [33], found that WBC, NSG, UA, BUN, CHOL and other indexes were significantly different between the two species. These variations can be attributed to the distinct habitat environments and variations in nutrition content. In this case, the absence of significant differences between the two gibbon species in the study could be due to their shared living environment and identical feeding procedures.

The mean values and reference ranges of various blood indexes of female and male healthy northern white-cheeked gibbons in our study are similar to the results of Tibetan macaques (*M. thibetana*) [34] and green monkeys (*Chlorocebus aethiops sabaeus*) [35] published by Yang et al. The Cl value of male was higher than female, but the LYMP, TP and CHOL values were lower than female.

Concerning the age of healthy northern white-cheeked gibbons in our study, HCT, NSG and CK in juvenile (less than 15 years old) group were higher than adult (more than 15 years old) group. Hematological studies on crab-eating macaques (*Macaca fascicularis*) indicated that HCT of adult individuals was significantly higher than juvenile individuals ($P<0.05$) [36]. In addition, CK of northern pig-tailed macaques (*M. leonina*) also showed significant differences between juvenile and adult group ($P<0.01$) [37].

As the close relatives of humans, the hematological research of gibbons and chimpanzees has certain reference significance for human clinical medical

Table 3 The blood physiological and biochemical indexes between sick Northern white-cheeked gibbon and healthy Northern white-cheeked Gibbons

Indicators	Ailing gibbon($n=1$)	Average ($n=5$)	Ranges ($n=5$)
HGB/(g·L^{-1})	202.00	176.60 ± 10.99	164.00 ~ 193.00
RBC/(×10^{12}·L^{-1})	10.40	9.05 ± 1.06	7.80 ~ 10.47
WBC/(×10^{9}·L^{-1})	12.90	8.25 ± 2.33	5.95 ~ 11.70
HCT/(L·L^{-1})	0.56	0.50 ± 0.02	0.47 ~ 0.53
NSG/%	50.00	58.00 ± 5.70	52.00 ~ 65.00
NST/%	2.00	2.60 ± 2.19	0.00 ~ 6.00
LYMP/%	43.00	35.80 ± 5.81	31.00 ~ 45.00
MONO/%	5.00	3.00 ± 2.00	1.00 ~ 6.00
K/(mmol·L^{-1})	6.10	4.50 ± 0.51	3.90 ~ 5.30
Na/(mmol·L^{-1})	169.00	138.60 ± 2.30	135.00 ~ 141.00
P/(mmol·L^{-1})	1.53	1.75 ± 0.81	1.04 ~ 2.95
GLU/(mmol·L^{-1})	6.60	5.51 ± 2.15	3.10 ~ 7.20
SCR/(μmol·L^{-1})	320.00	89.51 ± 14.73	73.01 ~ 103.00
BUN/(mmol·L^{-1})	36.10	6.29 ± 2.35	3.00 ~ 9.08
TP/(g·L^{-1})	82.00	71.36 ± 5.28	67.00 ~ 80.00
ALB/(g·L^{-1})	55.00	44.97 ± 4.96	37.69 ~ 50.00
GLOB/(g·L^{-1})	27.00	26.40 ± 4.40	20.00 ~ 30.45
A/G	2.04	1.78 ± 0.54	1.20 ~ 2.50
TBIL/(μmol·L^{-1})	6.00	5.55 ± 1.68	3.79 ~ 8.00
ALP/(U·L^{-1})	20.00	166.62 ± 108.78	91.20 ~ 353.91
ALT/(U·L^{-1})	21.00	25.09 ± 16.44	13.00 ~ 53.65

research. Comparing the result of the northern white-cheeked gibbons in our study with the blood indexes of humans [38–40] and captive chimpanzees [41] published, found that the HGB, RBC, WBC, P, GLU and BUN of northern white-cheeked gibbons were higher than those of humans and chimpanzees. ALP and ALT were lower than chimpanzees but higher than human normal values. MONO, SCR, UA, TBIL, TG and other indicators were lower than human. Other indicators were basically consistent with the physiological data from the previous studies of humans and chimpanzees.

In this study, individual gibbons with gastrointestinal diseases exhibited symptoms such as vomiting and anorexia. While symptomatic treatment targeting gastrointestinal symptoms may temporarily improve the overall condition in clinical practice, this research reveals that the underlying cause is rooted in renal dysfunction. By measuring biochemical values in healthy individuals, it was found that the SCR and BUN levels in diseased individuals were significantly higher than the established reference ranges for healthy gibbons in this study (SCR: 73.01–103.00 μmol·L^{-1}; BUN: 3.00–9.08 μmol·L^{-1}). Previous research has confirmed that gastrointestinal symptoms are manifestations of secondary azotemia, directly associated with the accumulation of metabolic waste due to declining renal function [42, 43]. Therefore, in addition to symptomatic treatment, a comprehensive diagnostic and therapeutic approach should be directed at addressing the renal dysfunction in the diseased gibbon. This may include kidney ultrasonography, dietary adjustments aimed at renal health (such as phosphorus restriction [44]), ensuring adequate hydration [45], and management of secondary diseases arising from renal insufficiency, such as hypertension [46], hypokalemia [47] and hyperphosphatemia [48]. This study demonstrates that clinical management based on symptomatic treatment in the absence of established biochemical reference intervals may compromise diagnostic accuracy and potentially delay critical interventions.

A notable limitation of this study is that blood collection was performed under anesthesia, which could induce stress in the animals and potentially affect the measured blood indexes [49]. To mitigate this, future studies could consider using non-anesthetic blood collection methods through long-term training to enable animals to actively cooperate with venous blood collection [50], obtaining more accurate physiological data under natural conditions. At the same time, the study has other limitations, including restricted age ranges, small sample sizes and varying husbandry practices across institutions. While the findings may offer valuable insights into what could be expected for other gibbons, the differences in zoo environments, such as diet, enclosure conditions and management protocols, could influence blood parameters.

Conclusion

The study's findings shed light on the blood physiological and biochemical indexes of northern white-cheeked gibbons and their comparison with yellow-cheeked gibbons. Understanding these parameters is crucial for the conservation and health management of these endangered species. The optimization of standardized blood collection protocols may significantly enhance the rigor of future clinical diagnosis and treatment, providing foundational support for understanding the physiological homeostasis of both captive and wild gibbon populations.

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Author contributions
Wanrong Song and Yujuan Hu: Methodology, Data curation, Formal analysis, Writing–original draft. Yipeng Jin and Jinpeng Liu: Conceptualization, Methodology, Writing–review & editing. Minghao Cheng, Tianchun Pu, Wenhui Niu and Yizhuo Zhang: Methodology, Data curation. Xuefeng Liu, Yunsheng Wang and yuguang Zhang: Methodology, Formal analysis.

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Declarations

Ethics approval and consent to participate

All animal procedures were carried out after obtaining approval from the China Agricultural University Laboratory Animal Welfare and Animal Experimental Ethical Committee (Approval ID: AW30302202-2-1).

Consent for publication

Informed consent was obtained from all individual participants included in the study. Participants signed informed consent regarding publishing their data.

Competing interests

The authors declare no competing interests.

Author details

[1]College of Veterinary Medicine, China Agricultural University, Beijing 100193, P. R. China
[2]Ecology and Nature Conservation Institute, Key Laboratory of Biodiversity Conservation of National Forestry and Grassland Administration, Chinese Academy of Forestry, Beijing 100091, P. R. China
[3]Beijing Key Laboratory of Captive Wildlife Technologies, Beijing Zoo, Beijing 100044, P. R. China
[4]Beijing Zoo, Beijing 100044, P. R. China

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