LETTERS

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Hematology and Serum Chemistry of Free-Ranging Jaguars (*Panthera onca*) from a Floodplain Forest Site in Amazonia, Brazil

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ABSTRACT: We provide hematologic and biochemical information for 13 jaguars from the Amazon. Most showed increased lymphocytes, monocytes, eosinophils, aspartate aminotransferase, and alanine aminotransferase; all individuals showed lower mean red blood cell (RBC) counts compared to findings from other biomes. Males had a significantly higher RBC count and alkaline phosphatase than did females.

Jaguars (*Panthera onca*), the largest terrestrial predator within their geographic range, play an essential role in their ecosystems (Cullen, 2006). They are classified globally as Near Threatened (Quigley et al. 2017). The Amazon region is one of the few biomes with viable, long-term populations (Soares-Filho et al. 2006).

Hematologic and biochemical values are important for the assessment of wild populations (García et al. 2010). There has been only one previous such study on Brazilian free-ranging jaguars, from the southern Pantanal (Widmer et al. 2012). We describe hematologic and biochemical parameters for jaguars in the Mamirauá Sustainable Development Reserve (2°51′S, 64°55′W) in Brazil, exclusively comprised of flooded forests (várzea) in the Amazon River floodplain. Mamirauá's jaguars remain in the flooded forest throughout the high-water season (3–4 mo), living in the canopy, feeding on arboreal prey, and breeding and raising cubs (Ramalho et al. 2021).

Between 2012 and 2018, we captured 13 jaguars with snare traps (Frank et al. 2003) set on trails and checked every 6 h. Captures occurred January to March, early in the flooding season, when jaguars are probably more easily captured due to less available land for movement. We captured eight males and five females, age >3 yr (estimated by the wear and staining of the teeth; Table S1). Captured jaguars were darted with mean 8.95 mg/kg tiletamine and zolazepam (Zoletil®, Virbac, São Paulo, Brazil). Anesthetized animals were weighed and heart rate, respiratory movements, temperature, capillary refill time, and oxygen saturation were monitored by a veterinarian every 10 min. Information on the animal's clinical condition, sex, age, weight, and biometric measurements were recorded.

Blood was collected from the femoral vein using Vacutainer needles 25 × 8 mm (21 ga ×1; BD Biosciences, São Paulo, Brazil) nearly 20 min after immobilization, 4 mL into a K3 tube (Labor Import, Polymed) containing ethylenediaminetetraacetic acid for complete blood count and stored on ice packs until analysis, and 10 mL was collected in tubes without anticoagulants (BD Vacutainer, Becton Dickinson and Company) to obtain serum for biochemical evaluation; these were stored at room temperature (~27 C) until clot formation, then centrifuged (centrifuge 80-2b, Centrilab®, São Paulo, Brazil), with separated serum kept on ice packs until processing. All analyses were performed within 24 h of collection in a commercial laboratory (Laboratório de Análises Clínicas Especializadas, Tefé, Amazonas, Brazil). All jaguars were fitted with radio collars for monitoring (see Supplementary Material).

Hematocrit (Ht) was determined by microcentrifugation (SH 120, Centrilab). Red blood cells (RBC), platelets, and total leukocytes (WBC) were counted by an automated analyzer (ABX Pentra 60, HORIBA ABX, São Paulo, Brazil); the differential leukocyte count was evaluated from blood smears stained with May-Grunwald-Giemsa. The hematimetric indices were calculated using a classic formula (Thrall, 2012). Hemoglobin (He) and biochemical variables were measured using a semi-automatic biochemical device (Thermoplate Basic TP Analyzer Basic, Bioclin®, Belo Horizonte, Brazil) using commercial kits.

We calculated mean, standard deviation (SD), 95% confidence interval (CI), and parameter range for all hematologic and biochemical parameters. We tested for parameter differences between sexes using a Student's *t*-test for parametric data and a Mann-Whitney *U*-test for nonparametric data. We assessed normality of the data with a Kolmogorov-Smirnov test, homogeneity with a Levene's test, and checked for the presence of outliers with boxplots and Cleveland dot plots.

All jaguars had good body weight and condition, pink mucous membranes, and no detected ectoparasites. All had edema of the snared paw; an anti-inflammatory gel (DM Gel, Vetnil, São Paulo, Brazil) was applied to the affected area. One jaguar (ID11) was pregnant, one (ID3) had palpable hepatomegaly, and one (ID5) had healing wounds (2.0-cm long and 2.5-cm deep) of undefined cause on the forelimbs, plus periodontal disease.

Most jaguars showed higher lymphocytes, monocytes, eosinophils, aspartate aminotransferase (AST), and alanine aminotransferase (ALT) compared with previous means described for free-ranging and captive jaguars (Table 1). Female ID11 and male ID3 were found to be outliers for alkaline phosphatase (ALP) and AST, respectively, and so were excluded from the test for differences between sexes (Table S1). In general, males tended to have higher values than the females (Table 2); these differences were significant for He (t=2.79, P=0.01) and ALP (t=3.28, P=0.01). However, when including the outlier (ID11) for the ALP, we found males and females did not differ significantly (t=–1.02, P=0.33). Removal of outliers for the AST did not affect the results. Jaguars were monitored after capture for 14–458 d.

During monitoring, five individuals died: two killed by local people and three from unknown causes. The others were monitored throughout radio collar battery life. Dead animals could not be located soon enough for necropsy. However, two of the dead animals (ID3 and ID5; Table S2) were those with abnormal clinical findings when captured.

According to previously described parameters for jaguars (Hawkey and Hart 1986; Widmer et al. 2012), ID3 showed increased lymphocytes, AST, and ALT, and decreased albumin. The oldest individual (ID5) showed decreased Ht and He, decreased neutrophils, creatinine, and albumin, and increased AST and ALT.

Hematologic and biochemical profiles with increased lymphocytes, monocytes, eosinophils, AST, and ALT have been found in wild-caught felids such as red lynx (*Lynx rufus*) and Bornean leopard cat (*Prionailurus bengalensis borneoensis*) and were attributed to the acute stress caused by capture; intense physical exertion due to pulling against the trap (Fuller, 1985) suggesting muscle injury or hepatocellular damage (Allison, 2012a, b), which has been previously described for jaguars (Widmer et al. 2012).

We also found significantly higher RBC counts in males than in females. Such a difference has previously been described for Iberian lynx (*Lynx pardinus*; Beltrán et al. 1991),cougars, tigers, leopards, and jaguars (Hawkey and Hart 1986).

We found lower RBC counts than in previous jaguar studies (Table 1). This might be related to relatively small prey: Mamirauá's jaguars have peculiar feeding habits, feeding mostly on medium-sized prey such as primates and sloths during the flooded season and caimans during the dry season (Ramalho et al. 2021). Florida panthers (*Puma concolor coryi*) feeding on smaller prey also showed lower reference values for RBC, He, and Ht compared to panthers feeding on larger prey (Dunbar, 1997). Our finding of higher ALP

TABLE 1. Comparison of hematologic and serum chemistry parameters among free-ranging jaguars from central Amazonia, Brazil, and from Brazilian Pantanal, and from captive jaguars.[a,b]

	Free-ranging jaguars								Captive jaguars				
	Amazon (this study)				Pantanal (Widmer et al. 2012)				Hawkey and Hart 1996			Deem 2004	
Parameter[a]	*n*	Mean±SD	95% CI	Range	*n*	Mean±SD	95% CI	Range	*n*	Mean±SD	Range	*n*	Mean±SD
RBC (10^6/mL)	13	4.1±0.7	3.7–4.6	3.0–5.7	11	7.2±1.0	6.5–7.9	5.5–8.7	18	7.4±0.4	6.3–8.3	161	7.3±1.4
Hemoglobin (g/dL)	13	11.2±1.9	10.1–12.4	7.5–14.3	11	10.7±1.2	9.8–11.4	8.8–12.5	18	12.8±1.0	11.0–15.0	166	11.8±2.3
Hematocrit (%)	13	34.9±5.5	31.6–38.3	25.0–43.0	11	35.4±4.2	32.6–38.3	30.0–43.0	18	38.0±4.0	33.0–48.0	199	34.8±5.7
MCV (fL)	13	84.1±9.8	78.2–90.0	52.1–89.0	11	49.3±2.8	47.4–51.1	46.0–55.0	18	49.0±5.0	42.0–62.0	159	48.8±9.3
MCH (pg)	13	26.2±2.5	24.7–27.7	25.0– 28.0	11	14.7±1.0	14.0–15.4	13.0–16.0	18	16.9±1.5	15.5–20.7	154	16.6±3.9
MCHC (g/dL)	13	31.3±1.5	30.3–32.2	30.0–35.5	11	29.8±1.3	28.9–30.6	28.0–32.0	18	34.1±1.4	31,7–36.7	165	33.7±3.3
WBC (10^3/mL)	13	18.8±9.1	13.3–24.3	7.6–37.0	11	28.8±4.8	17.6–24.0	15.1–29.0	18	9.3±2.2	4.2–12.4	191	12.0±4.1
Bands (10^3/mL)	13	1.1±1.1	0.5–1.8	0–3.6	11	1.4±1.2	0.6–2.3	0.4–4.6	—	—±—	—	77	0.8±1.6
Neutrophils (10^3/mL)	13	7.4±6.4	3.5–11.2	0.4–19.9	11	14.4±3.0	12.4–16.4	10.5–19.2	18	7.2±2.0	3.4–10.6	179	8.6±3.9
Eosinophils (10^3/mL)	13	0.7±0.5	0.4–0.9	0–1.6	10	0.4±0.3	0.2–0.7	0.0–1.0	18	0.2±0.1	0.0–0.5	135	0.3±0.3
Lymphocytes (10^3/mL)	13	8.2±6.7	4.2–12.3	1.6–24.3	11	3.5±1.7	2.4–4.6	2.1–7.7	18	1.8±0.9	0.8–3.7	182	2.1±2.1
Monocytes (10^3/mL)	13	1.3±1.9	0.1–2.4	0–6.8	11	0.9±0.4	0.6–1.1	0.3–1.4	18	0.1±0.1	0.0–0.3	142	0.3±0.4
Basophils (10^3/mL)	13	0,0	0,0	0,0	11	0,0	0,0	0,0	18	—	—	41	0.0±0.1
Platelet count (10^3/mL)	9	264.4±142.8	154.6–374.2	154.0–596.0	11	232.4±81.3	177.9–287.0	128.0–420.0	18	217.0±51.0	109.0–306.0	37	273.0±107.0
Urea nitrogen (mg/dL)	13	52.8±21.2	40.0–65.6	20.0–95.0	11	106.4±24.0	86.3–126.5	70.0–130.0	—	—	—	155	24.0±9.0
Creatinine (mg/dL)	13	1.0±0.2	0.9–1.1	0.7–1.2	11	1.1±0.3	0.8–1.3	0.7–1.5	—	—	—	152	2.0±0.7
ALP (U/L)	12	65.0±61.0	26.3–103.8	9.0–180.0	11	44.9±24.0	24.8–64.9	19.0–80.0	—	—	—	147	33.0±33.0
AST (U/L)	12	45.9±22.8	31.4–60.4	20.0–95.0	10	42.0±10.4	34.6–49.4	28.0–60.0	—	—	—	150	35.0±16.0
ALT (U/L)	13	45.9±18.9	34.4–57.3	20.0–82.0	10	44.3±14.7	33.8–54.8	20.0–68.0	—	—	—	119	55.0±25.0
GGT (U/L)	12	12.3±9.0	6.5–18.0	1.0–32.0	8	8.6±2.1	6.9–10.3	5.0–12.0	—	—	—	56	3.0±3.0
Total bilirubin (mg/dL)	8	0.9±0.2	0.8–1.1	0.6–1.2	11	0.5±0.1	0.4–0.5	0.3–0.5	—	—	—	133	0.2±0.1
Conjugated bilirubin (mg/dL)	8	0.5±0.2	0.4–0.7	0.3–0.9	11	0.3±0.1	0.2–0.3	0.2–0.3	—	—	—	45	0.0±0.1
Unconjugated bilirubin (mg/dL)	8	0.4±0.2	0.2–0.6	0.2–0.8	11	0.2±0.0	0.2–0.2	0.1–0.2	—	—	—	45	0.1±0.1
Total cholesterol (mg/dL)	13	138.8±21.0	126.1–151.5	109.0–173.0	10	142.6±22.0	128.2–165.0	125.0–182.0	—	—	—	140	246.0±60.0
HDL (mg/dL)	12	26.0±12.3	18.2–33.9	8.0–48.0	8	91.1±23.2	71.7–110.5	70.0–140.0	—	—	—	—	—
Triglycerides (mg/dL)	13	44.0±23.2	30.0–58.0	5.0–90.0	10	42.7±17.0	30.5–54.9	18.0–71.0	—	—	—	75	32.0±19.0
Total protein (g/dL)	12	6.6±1.4	5.7–7.5	4.5–8.9	11	7.5±0.4	7.2–7.8	7.1–8.2	—	—	—	142	7.3±0.6
Albumin (g/dL)	12	3.3±1.2	2.6–4.1	1.5–4.9	11	2.4±0.2	2.2–2.6	2.0–2.7	—	—	—	114	3.4±0.4
Globulin (g/dL)	12	3.3±1.0	2.6–3.9	1.8–5.1	11	5.1±0.3	4.9–5.3	4.7–5.6	—	—	—	113	3.9±0.8

[a] RBC = red blood cells; MCV = mean cell volume; MCH = mean cell hemoglobin; MCHC = mean cell hemoglobin concentration; WBC = white blood cells; ALP = alkaline phosphatase; AST = aspartate aminotransferase; ALT = alanine aminotransferase; GGT = gamma glutamyl transpeptidase; HDL = high-density lipoprotein.

[b] Dashes indicate _____.

Table 2. Hematologic and serum chemistry parameters for 13 free-ranging adult jaguars (*Panthera onca*), captured between 2012 and 2018 in central Amazonia, Brazil, showing data for males and females separately.[a,b]

Parameter[a]	Females				Males			
	n	Mean±SD	95% CI	Range	*n*	Mean±SD	95% CI	Range
RBC (10^6/mL)*	5	3.6±0.5	3.0–4.2	3.0–4.3	8	4.5±0.6	3.9–5.0	3.6–5.7
Hemoglobin (g/dL)	5	9.9±2	7.4–12.3	7.5–12.2	8	12.1±1.4	10.9–13.2	10.5–14.3
Hematocrit (%)	5	31.2±5.3	24.7–37.7	25.0–38.0	8	37.3±4.5	33.5–41.0	30.0–43.0
MCV (fL)	5	85.4±1.9	83.0–87.8	83.0–88.0	8	83.3±12.6	72.7–93.8	52.1–89.0
MCH (pg)	5	26.2±1.1	24.8–27.6	25.0–28.0	8	26.2±3.2	23.5–28.9	18.5–28.0
MCHC (g/dL)	5	30.6±0.9	29.5–31.7	30.0–32.0	8	31.7±1.8	30.2–33.2	30.0–35.50
WBC (10^3/mL)	5	13.9±7.2	5.0–22.9	7.6–24.3	8	21.9±9.2	14.2–29.6	9.7–37.0
Bands (10^3/mL)	5	1.2±1.5	−0.7–3.0	0.2–3.6	8	1.1±1	0.3–1.9	0.0–2.7
Neutrophils (10^3/mL)	5	3.9±2.2	1.1–6.6	0.7–6.7	8	9.5±7.3	3.5–15.6	0.4–19.9
Eosinophils (10^3/mL)	5	0.7±0.6	−0.04–1.4	0.0–1.6	8	0.6±0.4	0.3–1.0	0.0–1.3
Lymphocytes (10^3/mL)	5	6.0±4.0	1.1–11.0	2.9–11.2	8	9.6±7.9	3.0–16.2	1.6–24.3
Monocytes (10^3/mL)	5	1.7±2.9	−1.9–5.3	0.0–6.8	8	0.9±0.9	0.2–1.8	0.2–3.2
Basophils (10^3/mL)		0.0	0.0	0.0	—	0.0	0.0	0.0
Platelet count (10^3/mL)	2	240.5±122.3	−858.6–1,339.6	154.0–327.0	7	271.3±156.4	126.6–416.0	155.0–596.0
Urea nitrogen (mg/dL)	5	48.6±23.1	20.0–77.2	20.0–80.0	8	55.4±21.1	37.7–73.0	37.0–95.0
Creatinine (mg/dL)	5	1.0±0.2	0.7–1.3	0.7–1.2	8	1.0±0.1	0.9–1.1	0.9–1.2
ALP (U/L)*	4	16.3±10.7	−0.8–33.3	9.0–32.0	8	89.4±61.3	38.1–140.6	26.0–180.0
AST (U/L)	5	57.4±31.2	18.7–96.1	20.0–95.0	7	37.7±11.0	27.6–47.9	24.0–56.0
ALT (U/L)	5	49.8±20.5	24.3–75.3	20.0–75.0	8	43.4±18.8	27.7–59.1	22.0–82.0
GGT (U/L)	5	9.0±6.6	0.9–17.1	4.0–20.0	7	14.6±10.2	5.1–24.0	1.0–32.0
Total bilirubin (mg/dL)	3	1.0±0.2	0.6–1.3	0.8–1.1	5	0.9±0.3	0.6–1.2	0.6–1.2
Conjugated bilirubin (mg/dL)	3	0.5±0.2	0.003–1.0	0.3–0.7	5	0.6±0.2	0.3–0.8	0.4–0.9
Unconjugated bilirubin (mg/dL)	3	0.5±0.3	−0.3–1.2	0.3–0.8	5	0.3±0.2	0.1–0.5	0.2–0.6
Total cholesterol (mg/dL)	5	131.8±23.3	102.9–160.7	109.0–165.0	8	143.1±19.8	126.5–159.7	115.0–173.0
HDL (mg/dL)	5	22.0±12.2	6.8–37.2	8.0–34.0	7	28.9±12.5	17.3–40.4	13.0–48.00
Triglycerides (mg/dL)	5	36.4±20.9	10.4–62.4	14.0–70.0	8	48.8±24.6	28.2–69.3	5.0–90.0
Total protein (g/dL)	4	6.1±1.6	3.6–8.6	4.5–8.0	8	6.9±1.3	5.7–8.0	5.4–8.9
Albumin (g/dL)	4	2.8±1.1	1.0–4.6	2.1–4.5	8	3.6±1.2	2.6–4.6	1.5–4.9
Globulin (g/dL)	4	3.3±0.8	2.0–4.6	2.4–4.3	8	3.3±1.1	2.3–4.2	1.8–5.1

* *t*-test: statistically significant differences ($P<0.05$).

[a] RBC = red blood cells; MCV = mean cell volume; MCH = mean cell hemoglobin; MCHC = mean cell hemoglobin concentration; WBC = white blood cells; ALP = alkaline phosphatase; AST = aspartate aminotransferase; ALT = alanine aminotransferase; GGT = gamma glutamyl transpeptidase; HDL = high-density lipoprotein; SD = standard deviation from the mean; CI = confidence interval.

[b] Dashes indicate _____.

values in males than in females is unexplained. Increased ALP was not associated with immaturity (Nájera et al. 2014) or with healing bone fractures (Allison, 2012b); none of our jaguars were immature or had any evidence of fractures. In future analyses, it may be important to perform other diagnostic tests to identify the causes of increased ALP activity in males. Higher ALP also has been observed in a pregnant lynx (*Lynx rufus*; Fuller et al. 1985), which may explain the high ALP observed in the outlier pregnant jaguar (ID11).

We provide the first health assessment associated with clinical condition and movement monitoring for Amazonian jaguars. Most of the individuals were healthy and one was pregnant, suggesting that this jaguar population remains healthy and with reproductive success (Ramalho et al. 2021). Our hematologic and biochemical findings for Amazonian jaguars may improve jaguar health assessments across the biome.

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SUPPLEMENTARY MATERIAL

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