HEMATOLOGICAL PARAMETERS OF CAPTIVE CAPUCHIN MONKEYS (*SAPAJUS LIBIDINOSUS* AND *S. APELLA*) ILLEGALLY KEPT IN HOMES IN NORTHEAST BRAZIL

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Abstract

This study presents the hematological parameters of captive capuchin monkeys (*Sapajus libidinosus* and *S. apella*) kept in homes in the state of Ceará, in Northeast Brazil. Morphometry measurements and blood samples were taken from 35 individuals illegally kept as pets in 34 houses across 12 municipalities. The sample consists of 20 females and 15 males, classified in juvenile (n = 15), adult (n = 17) and senior (n = 3) age groups. The majority of animals were chained (74.2%) and dehydrated (62.8%), and almost half of them had injuries (48.57%). Except for three obese individuals, the animals weighed less than that described in other studies (2.08 kg ± 0.65, n=24), with greater differences in adult males (1.97 kg ± 0.55, n=3). Evidence for anemia included lower median red blood cell count (4.95 x 10^6/µl ± 0.8) and higher mean corpuscular volume (76.6 fl ± 7.12) in the sample relative to other studies. Very low values of neutrophils (3.82 x 10^3/µl ± 1.8) suggest a bone marrow condition or a severe active infection. In general, animals illegally kept as pets were in worse condition (with low body weight, dehydration, anemia and worse immunological conditions) when compared to reported data from wild animal populations, indicating a need to rescue these animals and rehabilitate them in rescue centers before releasing them back to their natural habitat.

Keywords: Hematology, capuchin monkey, captivity, one health, zoonoses.

Resumo

Este estudo apresenta os parâmetros hematológicos de macacos-prego (*Sapajus libidinosus* e *S. apella*) mantidos em cativeiros domésticos no estado do Ceará, no Nordeste do Brasil. Foram coletadas medidas morfométricas e amostras de sangue de 35 indivíduos mantidos ilegalmente como animais de estimação em 34 residências de 12 municípios. A amostra é composta por 20 fêmeas e 15 machos, classificados nas faixas etárias juvenil (n = 15), adulta (n = 17) e sênior (n = 3). A maioria dos animais estavam acorrentados (74,2%) e desidratados (62,8%), e quase a metade com feridos (48.57%). Com exceção de três indivíduos obesos, os animais pesavam menos do que o descrito em outros estudos (2,08 kg ± 0,65; n=24), com maiores diferenças nos machos adultos (1,97 kg ± 0,55; n=3). Evidências de anemia incluíram menor mediana da contagem de glóbulos vermelhos (4,95 x 10^6/µl ± 0,8) e maior volume corpuscular médio (76,6 fl ± 7,12) na amostra em relação a outros estudos. Valores muito baixos de neutrófilos (3,82 x 10^3/µl ± 1,8) sugerem uma condição da medula óssea ou uma infeção ativa grave. Em geral, os animais mantidos ilegalmente como animais de estimação estavam em piores condições (com baixo peso corporal, desidratação, anemia e piores condições imunológicas) quando comparados com dados relatados de populações de animais selvagens, indicando a necessidade de resgatar esses animais e reabilitá-los em centros de resgate antes de libertá-los de volta ao seu habitat natural.

Palavras-chave: Hematologia, macaco-prego, cativeiro, uma só saúde, zoonoses.

Introduction

There are currently 525 species of non-human primates listed on the IUCN Red List of Threatened Species worldwide. Brazil is the country with the greatest diversity of primates, 133 species, with around 38% at elevated risk of extinction (IUCN, 2024). Non-human primates, and wildlife in general, suffer from the advancement of industrial agricultural production, logging, dam and highway construction causing loss of their habitats (Estrada et al.,

2018). In addition, many animals are taken from the wild and kept in captivity in homes or to meet the new demands of "biopiracy," the illegal acquisition of animals for use in biomedical research (RENCTAS, 2001).

According to data by the International Criminal Police Organization (INTERPOL), environmental crime is the third most lucrative illegal activity in the world, moving US$ 110-281 billion per year, just after counterfeiting and drug trafficking (Nellemann et al., 2018). According to the National Report on Wildlife Trafficking, in Brazil illegal trade of wild animals generates approximately 2.5 billion Brazilian Reais (currently around 440 million USD) and removes around 38 million specimens from nature per year. Only 10% of animals reach their final destination alive. It is estimated that 30,000 primates are removed annually from the Amazon region alone; taking into account the losses, these are almost half a million in a decade (RENCTAS, 2001).

Gomes Destro and colleagues (2012) describe that of the 18,000 mammals registered by the Brazilian Wild Animal Triage Centers (CETAS), between 2002 and 2009, around 28% could not be re-introduced into the wild and another 27% died while in the rescue center. Robust capuchin monkeys (*Sapajus*) constitute the second most commonly received genus of primates in rescue centers of the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) (Levacov et al., 2011). According to Damasceno (2022), two capuchin monkeys are received per month in each CETAS in Northeast Brazil, with return to nature being the priority destination for healthy animals from a clinical and behavioral point of view.

Robust capuchin monkeys are medium-sized primates weighing between 2.5 to 3.5 kg with an adult height of around 50 cm. They form groups of around 20 animals (there may be groups with more than 60) and are organized into tolerant matrilines in a ratio of one male for every 2-3 females. They are omnivorous and are native to almost all biomes in South America (Fragaszy et al., 2004). Robust capuchin monkeys are highly insectivorous, especially in dry biomes, for example, with a diet of 20 to 48% invertebrates (Gomes-Posada, 2012; Sacramento et al., 2017). Thus, capuchins promote insect population control and disperse seeds, contributing to the regeneration of forests (Fragaszy et al., 2004).

Robust capuchin monkeys are frequently kept as pets in houses, a practice that has been encouraged by posts on social media (Nunes et al., 2021, 2023). The removal of these animals from their natural habitat changes their dispersal patterns and can cause ecosystem simplification. In addition to these losses, the zoonotic risk of sharing parasites between primates and humans is an increasing problem for public health (Zago, 2018).

Trafficked animals are generally of unknown origin, and it is not possible to determine which pathogens were already present prior to their arrival at domestic homes. Close relationships with humans intensify the chances of transmitting zoonoses such as rabies and tuberculosis (Barbosa et al., 2014; Duarte et al., 2021; ICMBio, 2023). Furthermore, the stress related to the capture and transport process, added to management failures such as inadequate feeding and exposure to extreme climates, can cause immunosuppression, which exacerbates the multiplication of pathogens (Barbosa et al., 2014; Duarte et al., 2021).

Due to the zoonotic nature of numerous diseases, and the fact that these animals present themselves as possible reservoirs of infectious agents that affect humans and other species, studies with primates have unquestionable relevance (Cardoso et al., 2021). Clinical hematology – especially in the case of primates - is essential to define the animals' health status. Captive animals can be resistant to pain and are often asymptomatic. Therefore, assessing their health status with hematological and physiological reference values of populations in different conditions is a priority to develop conservation plans and understand the factors that influence wildlife health (García-Feria et al., 2017).

There are few published hematological examinations in platyrrhine primates, especially for those that are kept illegally as pets. To fill this gap, this study describes the hematological aspects of robust capuchin monkeys (*Sapajus* sp.) in conditions of illegal home captivity in the state of Ceará, Brazil. We discuss differences found across sex, age, environmental and physical conditions and the possible influence of these factors on animal health.

Material and methods

Data collection

The study was carried out in the state of Ceará, in Northeast Brazil. Ceará has a population of approximately nine million human inhabitants and an area of 149,000 km², distributed across 184 municipalities (IBGE, 2022).

The study was conducted with the support of the municipal secretariats of the state, through the collaboration of endemic disease control agents (DCA) and community health agents (CHA) who performed a survey and registry of residences/families that raised monkeys in captivity in their homes. Home visits were carried out with the support of DCAs to collect biological material. During the visits, the team introduced themselves, explained the objective of the research and provided guidance to families on environmental legislation, the risk of transmission of zoonoses and animal welfare. We collected data from July 2019 to March 2020.

The non-human primates involved in the study were illegally raised in family homes as domestic pets and lived chained or were kept trapped in cages in the backyards (Figure 1 and 2) or inside the homes, both in rural and urban areas. To collect biological material, professionals physically restrained the animals using shaved leather gloves and nets, and chemical containment was carried out, using the anesthetic protocol of the intramuscular administration of sodium hydrochloride ketamine (10-15mg/kg) and xylazine hydrochloride (1.0–1.5 mg/kg) (Miranda et al., 2011). The activities were authorized by the Brazilian Authorization Unit for Research in Federal Conservation Units SISBIO/ICMBIO, number: 71504-1, CEP 13466719.6.0000.5054 and 13466719.6.3001.5051).

After anesthesia, each animal was tagged with a microchip for individual identification, followed by biometric measurements including weight, total body length, arm, leg and tail length, teeth condition, scars and signs of wounds and presence of fleas. We used a manual caliper and tape measure for morphometry and a digital manual weight (LCD max 50kg).

Blood was collected from 35 capuchin monkeys (one household kept two animals), including 20 females (17 *Sapajus libidinosus* and three *S. apella*) and 15 males (14 *S. libidinosus* and one *S. apella*) (Figure 3). Individual species identification was defined morphologically using fur color patterns. However, as these animals were illegally kept and may have been obtained by trafficking, it is not possible to discard the possibility of the presence of hybrids in the sample (Silva Júnior, 2001). In total, 17 (48.6%) were adults, 15 (42.9%) were juveniles and 3 (8.9%) were seniors. Age was defined based on body size and presence of the third canine in adults (Fragaszy et al., 2004). Seniors were defined by teeth wear, wrinkles in the faces and reports of the owners regarding how long they had kept the individual as pet.

Figure 1. Robust capuchin monkey (*Sapajus libidinosus*), kept in a cage in a backyard along with an illegally kept blue-and-yellow macaw.

Figure 2. Robust capuchin monkey (*Sapajus apella*), kept in a cage in a backyard for 50 years.

Figure 3. Blood collection from a robust capuchin monkey (*Sapajus libidinosus*), through the femoral vein.

Blood collection was performed by puncture of the femoral vein with an approximate total of 2 ml to maximum 3 ml per animal (Diehl, 2001). The parameter for the dose quantity was the animal's weight. After collection, the blood was deposited in vials with anticoagulant (EDTA). The collected material was duly identified with a label, with a barcode identical to the microchip and each animal's record. The sample was then refrigerated and taken to the local laboratory for hematological examination within six hours after collection. Cell counting was done using automated analyzers (Mindray™ BC–2800Vet, Shenzhen Mindray Bio-Medical Electronics Co., Ltd. or Alere™ Bio 2900 VET™, Diagno Co., Ltd.). Leucocyte differential counting

analyses were conducted using an optical microscopy. Plasmatic protein was counted in a veterinary refractometer (Highmed).

At the end of the collection procedures, the researcher waited until the animal returned to the pre-anesthesia state to ensure the animal was in good condition. After our data collection at the homes, the animals remained in their original location. The official environmental agency rescued some of these animals at a later moment. All procedures such as physical and chemical containment and collection of biological material were carried out by a qualified veterinarian who used ethical and animal welfare principles.

Variables and data analyses

Municipality locations where biological data were collected were mapped using QGIS® version 3.34.5-Prizren (Open-Source Geospatial Foundation, 2016).

Hematological analysis included erythrocyte count, hemoglobin, hematocrit, mean corpuscular volumœ (MCV), mean corpuscular hemoglobin (HCM), mean corpuscular hemoglobin concentration (MCHC), total and differential leukocyte counts with their absolute and relative numbers (segmented neutrophils, rod neutrophils, lymphocytes, monocytes, eosinophils and basophils), platelet count, mean platelet volume (MPV), and total proteins. However, as not all laboratories offered all these analyses, in some samples data were not available for all measures. The data were analyzed using GraphPad Prism 9.2.0 (Dotmatcs) for descriptive statistical analysis. Values were expressed as mean, standard deviation, median, maximum and minimum values, and confidence intervals.

Inferential statistics were applied to determine significant differences in hematological parameters between sex, age, captive condition and hydration status, and between reference values present in the literature. As hematological data did not present a normal distribution, the non-parametric Mann Whitney test was applied to test differences by sex and age class of the animals. To analyze statistical significance of differences between the medians of the present study and data presented in the literature, the one sample Wilcoxon was used to test for blood variables; weight was analyzed via one sample T test due to the normal distribution of the variable. Two-tailed $\alpha \leq 0.05$ was established as the significance limit. Data with $\alpha \leq 0.1$ were considered as complementary to the discussion due to the tendency toward type 2 error when there is a low sample size.

Results

Of the 184 municipalities in the state of Ceará, we recorded animals kept in domestic captivity in 13 (7.06%). Our team visited 34 residences that housed robust capuchin monkeys in captivity. The municipality of Boa Viagem had

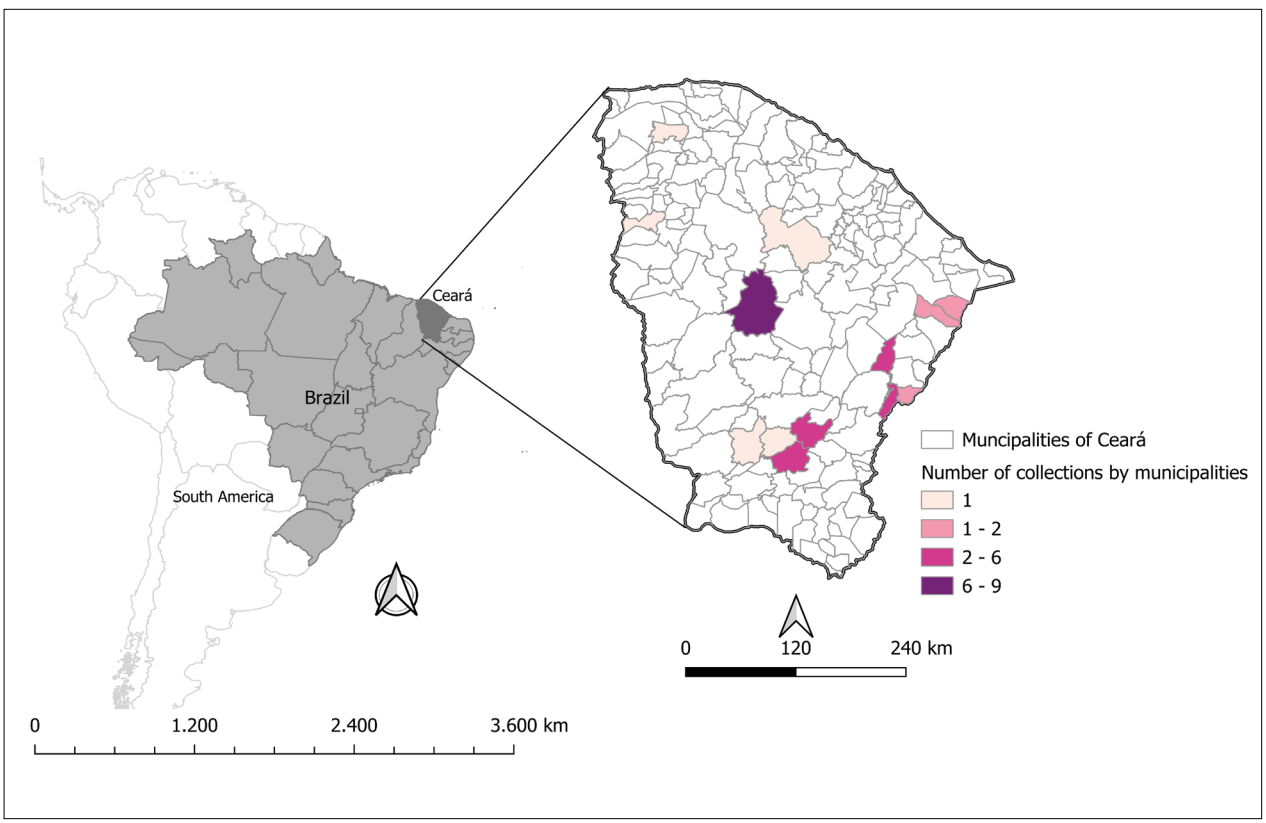

Figure 4. Spatial distribution of municipalities with collection of biological material from robust capuchin monkeys (*Sapajus* spp.), Ceará, Brazil. Map built on QGIS® version 3.34.5-Prizren.

the highest number of residences with monkeys, with nine (25.71%) animals, followed by Iguatu with six (17.14%), Jaguaribara, Pereiro and Cariús with three (8.57%) each, and Limoeiro do Norte, Erere and Quixeré with two each (5.71%) (Figure 4).

Of the 35 animals, 25 lived chained in the backyards of homes (74.2%), 22 (62.8%) were dehydrated and 17 (48.57%) had injuries (such as laceration or deformity due to collars, missing toes, docked tails and broken teeth), alopecia, tartar on teeth and ectoparasites (fleas, mites). The adult males (n=6) had a bimodal weight distribution with three individuals weighing less than 3 kg and three males weighing between 6 kg and 8 kg. These were considered obese individuals since they were twice to three times heavier than the sample mean and the mean genus weight (Fragaszy et al., 2004). To avoid bias, these obese animals were excluded from the general sample and were subjected to a different analysis presented in Appendices 1, 2 and 3. We used all individuals in analyses without differentiating by putative species type since classification was done visually without genetic testing. Appendix 4 presents the mean weight and length of individuals divided by species as classified by the authors. Subadults were included in the adult age group. Table 1 compares the weights of the animals, excluding obese ones, with the weights of animals from previous studies.

The overall average weight of the 27 animals whose weight was recorded was 2.71 kg (Figure 5), with no statistical differences between the weight of adults and juveniles in our sample (U=8; p = 0.63). Excluding the obese animals, the capuchin monkeys illegally kept in home captivity had a median of 1.9 kg and a mean of 2.08 kg, significantly lighter than the free-ranging group studied by Sousa and others (2020), confirming the thinness detected in the physical examination. Adult males were lighter than wild adult males studied by Ribeiro et al. (2015) in the Cerrado biome and significantly lighter than males in rescue centers studied by Hernandes Cruz et al. (2022). On the other hand, the females were significantly heavier than the wild females described by Ribeiro et al. (2015). It is noteworthy

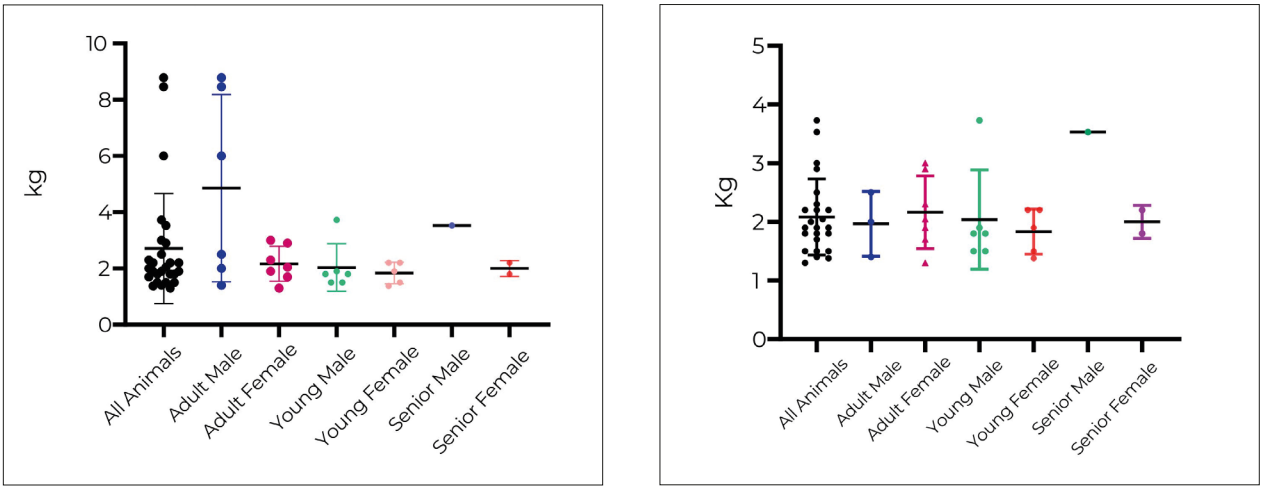

Figure 5. Mean weight values and standard deviations of captive robust capuchin monkeys (*Sapajus* spp.). A) with obese animals (n = 27); B) without obese animals (n = 24). A = adult; Y = young; S = senior.

Table 1. Mean values with standard deviations of the weight of capuchin monkeys (*Sapajus libidinosus* and *S. apella*) kept illegally in homes in the state of Ceará, compared to other studies of *S. libidinosus* (Mean + Standard deviation).

Category	This study ɨ	n	Hernández-Cruz et al. 2022 #	n	Sousa et. al. 2020 w	n	Ribeiro et. al. 2015 w	n
General (kg)	2.08 (0.65)	24	2.23 (0.75)	26	2.4 (-)*	17	-	
Adult males (kg)	1.97 (0.55)	3	3.12 (0.56)*	8	-		2.8 (0.47)	5
Adult females (kg)	2.16 (0.62)	7	2.02 (0.36)	11	-		1.58 (0.27)*	10
Young males (kg)	2.04 (0.94)	6	1.62 (0.27)	4	-		-	
Young females (kg)	1.84 (0.38)	5	1.44 (0.32)	3	-		-	
Senior males (kg)	3.53 (-)	1	-		-		-	
Senior females (kg)	2 (0.28)	2	-		-		-	

n = population; * = significant difference between this and the present study; ɨ = illegal captivity; # = captivity; w = free-living, and standard deviation = (x).

to mention the very low weight of the adult sample in the Ribeiro et al. (2015) study. There was no significant difference in the weight of young capuchins for either sex across illegal and legal captive living conditions.

When compared with other hematological studies of populations of *Sapajus libidinosus* reported in the literature (Table 2), the animals in home captivity showed lower quantities of red blood cells per microliter of blood and higher MCV. Table 3 details the hematological parameters of the study sample, and Table 4 presents significant differences ($p < 0.05$) or trends toward significance ($p < 0.10$) among the main categories analyzed.

The median value of monocytes was significantly higher in adult females than in adult males; the total leukocyte values were higher among young animals than among adults; the MCV value was higher among hydrated animals than dehydrated ones, and MPV values were lower in dehydrated and caged animals than in hydrated and chained animals (Table 4).

Males tended to have higher amounts of eosinophils than females; the MCV of young females tended to be lower than that of adult females; segmented neutrophils tended to be more abundant in young males than in adults; and the MCHC tended to be higher in hydrated animals than in dehydrated ones (Table 4).

Besides the much heavier weight, the obese animals differed from the main sample regarding a considerably higher red blood count. Appendix 1 shows the individual parameters of these three animals. Appendices 2 and 3 present the values of blood parameters and statistical results with the inclusion of these animals in the sample.

Discussion

To the best of our knowledge, this is the first hematological study carried out on robust capuchin monkeys (*Sapajus libidinosus* and *S. apella*) kept in conditions of illegal home captivity. Capuchin monkeys as pets were identified in 12 municipalities and 34 houses, the majority located close to an interstate highway, a possible wildlife trafficking route as indicated by Santos et al. (2021). Of the 35 animals, three were obese, two-thirds lived chained in the backyard of their homes, and more than half were dehydrated and had injuries. Appendix 5 provides photos taken at the time of the study of the capuchins in their captive environments.

With the exception of three obese individuals, the capuchin monkeys in our study population were about 10% lighter than those described in rescue centers (Hernández-Cruz et al., 2022) and 20% lighter than animals in the wild (Sousa et al., 2020). This difference was more pronounced for adult males (Núñez et al., 2008; Hernández-Cruz et al., 2022). In contrast, no statistical difference in weight was found for immatures in illegal captivity versus other conditions. Although we cannot discard the possibility of hybrids in our sample, the adult weight values were significantly lower than the reference values

Table 2. Medians of hematological parameters of robust capuchin monkeys (*Sapajus*) in home captivity in the state of Ceará compared to those reported in the literature.

	Present study (n = 32) ɨ	Hernándes-Cruz et al., 2022 (n = 26) #	Ferreira et al., 2018 (n = 50) #	Sousa et al., 2020 (n = 17) *w*
Hematological parameters	**Median**	**Median**	**Median**	**Median**
Red blood cells (x10⁶/µl)	4.95	5.44*	5.75**	5.59**
Hemoglobin (g/dl)	11.95	11.15**	12.1	13.5*
Hematocrit (%)	39.65	40	39	41*
MCV (fl)	76.6	72.05**	68.10**	73**
MCHC (%)	31.65	25.65**	31.4	33**
Leukocytes (x10³/µl)	7.05	13.2**	8.67	8.5
Neutrophils (x10³/µl)	3.83	6.95**	4.04	2.73**
Rods (x10³/µl)	0	0	0	0
Lymphocytes (x10³/µl)	3.28	3.8	3.46	4.03
Monocytes (x10³/µl)	0.34	0.69**	0.27*	0.47
Eosinophils (x10³/µl)	0.07	0.47**	0.09	0.47**
Basophils (x10³/µl)	0	0	0	0
Platelets (x10³/µl)	255	321**	268.6	252
Total Proteins (g/dl)	7.2	-	-	7.4

n = sample size; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; RDW = red cell distribution width; MPV = mean platelet volume. Asterisks indicate significant differences from present study (* = P < 0.05, **= P < 0.01). ɨ = illegal captivity; # = captivity; w = free-living.

Table 3. Mean values, standard deviations, 95% confidence interval of means, medians and ranges of hematological parameters of robust capuchin monkeys (*Sapajus*) in illegal home captivity in the state of Ceará.

Hematological parameters	n	Mean	SD	95% CI	Median	Min – Max
Red blood cells (x10⁶/µl)	32	4.98	0.8	4.69 – 5.27	4.95	1.82 – 6.37
Hemoglobin (g/dl)	32	11.93	2.04	11.2 – 12.67	11.95	4.3 – 16.5
Hematocrit (%)	32	38.75	5.64	36.72 – 40.79	39.65	18.2 – 48
MCV (fl)	32	78.72	7.12	76.15 – 81.29	76.6	67.8 – 100
MCH (pg)	32	23.88	1.52	23.34 – 24.43	23.8	21.7 – 30.4
MCHC (%)	32	30.64	2.68	29.53 – 31.60	31.65	23.63 – 34.4
RDW (%)	11	14.68	1.14	13.92 – 15.41	14.4	13.3 – 16.7
Leukocytes (x10³/µl)	32	8.26	3.1	7.13 – 9.38	7.05	3 – 15.4
Neutrophils (x10³/µl) (%)	32	4.01 48.7	1.8	3.36 – 4.65	3.82	0.84 – 8.78
Rods (x10³/µl) (%)	32	0	0.02	0 – 0.11	0	0 – 0.12
Lymphocytes (x10³/µl) (%)	32	3.6 43.8	1.59	3.04 – 4.18	3.28	1.74 – 8.4
Monocytes (x10³/µl) (%)	32	0.47 5.7	0.38	0.33 – 0.61	0.34	0 – 1.39
Eosinophils (x10³/µl) (%)	32	0.15 1.8	0.32	0.03 – 0.27	0.07	0 – 1.8
Basophils (x10³/µl) (%)	32	0 0	0	0 – 0	0	0
Platelets (x10³/µl)	32	234.1	79.2	205 – 263	255.5	76 – 349
MPV (fl)	10	11.08	0.7	10.58 – 11.56	10.95	9.9 – 12.6
Protein Totals (g/dl)	21	7.54	0.74	7.2 – 7.82	7.2	6.8 – 9.95

for *S. libidinosus*, *S. apella* and for the genus overall. This indicates that animals kept in these captive conditions tend to be more cachectic the longer they spend in illegal captivity, with a greater impact on male individuals. The females were heavier than the wild females studied by Ribeiro et al. (2015), possibly due to the absence of the energetic costs of gestation. The lack of difference in weight between age groups may indicate a lack of development of muscle mass in adulthood. A weight of 2 kg with low variation (except for the three obese animals) may be due to limited space for development and incorrect, calorie-poor feeding.

Erythrocyte count is commonly used as an indicator for anemia. Our study sample had a lower erythrocyte count per microliter of blood than in other populations previously studied. However the MCV was higher than that seen in other groups of *Sapajus* (Ferreira A., et al., 2018; Sousa et al., 2020; Hernández-Cruz et al., 2022). The main pathophysiological cause for this increase is the greater quantity of reticulocytes.

The variation we found in relative hemoglobin values compared to other studies may be due to the fact that the amount of hemoglobin, when measured from dehydrated animals, tends to be overestimated (Thrall, 2015). When compared to wild animals or animals in rescue centers (Naves et al., 2006; Flaiban et al., 2007; Ribeiro et al., 2015; Ferreira A. et al., 2018; Hernández-Cruz et al., 2022), the animals of this study showed low leukocyte values, indicating greater vulnerability to diseases. Very low values of leukocytes, especially neutrophils, may suggest a bone marrow disorder, especially when this reduction is not associated with a left shift (Weiser, 2015).

The number of platelets was similar to some studies carried out in healthy animals of the same genus (Ferreira A., et al., 2018; Sousa et al., 2020), suggesting protection for the animals from more severe hemorrhages. However, the platelet counts were lower than that observed in some other capuchin populations (Núñez, 2007; Wirz et al., 2008; Hernández-Cruz et al., 2022). This difference may be due to the energetic expense arising from the injuries found.

The analysis of plasma proteins was similar to that found by Sousa et al. (2020); however, in dehydrated animals this value may be overestimated. Decreases in this index can be seen in animals with nutritional deficiencies (Allison, 2015).

Table 4. Parameters with significant and/or strongly suggestive differences among the different categories of *Sapajus* spp. studied.

Group	Parameters	Median	Median	U	P
Sex		**Females (n=20)**	**Males (n=12)**		
	Eosinophils (x10³/ µl)	0.04	0.16	72.5	0.06
		Adult Females (n=10)	Adult Males (n=5)		
	Monocytes (x10³/µl)	0.51	0.14	5	0.04
		Young Females (n=8)	Young Males (n=7)		
	-	-	-	-	-
Age		Juveniles (n=15)	Adults (n=14)		
	Leukocytes (x10³/µl)	7.9	6.45	59	0.04
		Young Females (n=8)	Adult Females (n=10)		
	MCV (fl)	72.75	78.4	20	0.08
		Young Males (n=7)	Adult Males (n=4)		
	Neutrophil (x10³/µl)	4.05	2.29	4	0.07
State		Dehydrated (n=21)	Hydrated (n=11)		
	MCV (fl)	79.3	74.2	60.5	0.03
	MCHC (%)	31.3	32	68	0.06
	MPV (fl)#	10.91	12.6	45	<0.01
		Caged (n=8)	Chained (n=24)		
	MPV (fl)##	10.7	11.2	1	0.03

n = sample size; SD = standard deviation; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; RDW = red cell distribution width; MPV = mean platelet volume; p-value = probability of significance; U-value = Mann-Whitney test; Due to limitations in laboratory analyses we do not have the readings of all hematological indices for all animals, # indicates a sample size n= 9 & 1 and ## sample size n= 3 & 7 for MPV readings

Regarding age and sex differences, in literature on larger samples in legal captive conditions (rescue centers and research labs), hematological indices of capuchin monkeys (genus *Sapajus*) tended to be higher in males than in females (Riviello and Wirz, 2001; Núñez et al., 2008; Witz et al., 2008; Ferreira A., et al., 2018). This is explained by the inhibitory effect of estrogen on erythropoiesis (Stockham and Scott, 2011). In addition, higher values have been reported for young individuals (Núñez et al., 2008; Ferreira A., et al., 2018). likely due to a higher proportion of red marrow in these animals (da Silva G., et al., 2023). Our study did not show sex or age class differences; the very poor environmental quality to which the animals in this study were subjected can predispose pathological conditions such as anemia in both sexes and at all ages (Stockham and Scott, 2011).

In our sample, females tended to have lower numbers of eosinophils than males, and adult females had higher numbers of circulating monocytes than adult males. Increased levels of the steroid hormone cortisol are the most discussed cause of eosinophilia and monocytosis (Weiser, 2015), with females being more affected by chronic stress (Garber, 2020). However, we did not assess cortisol levels or the presence of active infections that may modify neutrophil levels.

When stratified by age, there was a relative leukopenia in the adult group of our study population, as compared to young animals, similar to what was found by Ferreira A, and colleagues (2018). In the male group, there was a tendency towards neutropenia in adult males when compared to young males. Inflammations are the main cause of leucopenia and neutropenia, however, when not accompanied by left shift, it can suggest bone marrow injury (Weiser, 2015). Adult females had a larger MCV than young females, indicating larger cells, probably reticulocytes (Thrall, 2015).

The dehydrated animals showed increased MVC values and a strong decrease in MCHC, indicating regenerative anemia (Thrall, 2015). These findings indicate erythrocyte regeneration in our sample (Thrall, 2015). Dehydrated animals may be suffering from an illness that requires increased production of erythrocytes. The fact that this group did not demonstrate other reduced hematological parameters does not rule out the possibility of anemia, since dehydration may lead to overestimation of these figures.

In our opinion, blood parameters of obese animals should be analyzed separately since these animals are not in the wild and including their weight parameters could cause

bias in defining reference limits for the genus. When including these animals there are two main differences in results: animals are no longer lighter or anemic relative to other groups, and the differences in monocytes and eosinophils between males and females disappear. Thus, the presented analysis (excluding obese individuals) is a better picture of the reality of the animals: mostly cachectic, dehydrated, with wounds. Of the 35 animals studied, 26 (75%) were later voluntarily delivered by owners to environmental agents and sent to qualified institutions. The remaining animals were not rescued, either due to lack of willingness from the keeper, or due to logistical and infrastructure issues of the responsible agencies.

Conclusions

This is the first description of hematological parameters for robust capuchin monkeys while they are actively illegally kept in captivity in homes, before rescue to rehabilitation centers. Animals kept in home captivity were in worse clinical conditions than animals kept in rescue centers or in wild populations. In general, individuals were cachectic and hematological parameters indicated anemia, leukopenia, infection and parasitism. Home captivity and proximity to humans are highly harmful to the quality of life of capuchin monkeys and a risk to human health due to the greater chance of zoonosis transmission. This reinforces the need for more detailed studies on health conditions, in addition to the need for educational campaigns focusing on wild animal trafficking, environmental legislation and the risk of transmission of zoonotic diseases. The better condition of animals in rescue centers indicates that these places play a fundamental role in caring for animals with specific nutrition, examination and rehabilitation work preparing them for reintroduction to suitable wild environments in the species range, such areas legally registered for the release of rescued animals.

Acknowledgments

We thank the municipal health departments of the state of Ceará, endemic disease control agents (ACE) and community health agents (ACS). This research was carried out with our own funding.

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