Comparative Medicine
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Vol 51, No 1
February 2001
Pages 30-37

Hematologic and Serum Biochemical Reference Intervals for the Chimpanzee (*Pan troglodytes*) Categorized by Age and Sex

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Normal reference range intervals for hematologic and serum biochemical values in the chimpanzee (*Pan troglodytes*) have seldom been reported. The few studies that have been conducted either report values on the basis of a small number of animals, report values for all age groups or both sexes combined, or were designed specifically to document the effect of a particular condition on the normal range of hematologic and serum biochemical values. On the basis of data collected from 133 chimpanzees over a 17-year period, empirically based clinical reference ranges were derived to provide a guide for basic diagnostic and clinical care of chimpanzees. For either sex within each of four age groups, there is a table that summarizes serum biochemical and a table that summarizes hematologic values. These values are compared with prior values, and their importance in the care and well being of captive chimpanzee populations is discussed.

Although the number of chimpanzees (*Pan troglodytes*) that require long-term care in laboratory-related housing has increased over the past decade (1), our knowledge of the requisite normal values for diagnostic purposes remains incomplete. In particular, there are few data describing the reference intervals for hematologic and serum biochemical values in the chimpanzee. Studies that have been done report values determined by examination of a small number of animals (2), report values for all age groups or both sexes combined (3-9), or report on a small number of analytes (10). Furthermore, some of those reports are not easily obtainable (6-9). There are two exceptional analyses of normal hematologic variables that are quite sophisticated; however, they are principally exploratory in nature (11, 12).

The study reported here was based on compilation of 1,648 blood samples collected from 133 animals over a 17-year period. Empirically based clinical reference ranges were derived and are reported to provide a guide for diagnostic bases and clinical care of chimpanzees. Male and female data are displayed separately within four age categories, and effects for sex and age were examined statistically.

Methods

Overview: The medical records of 147 chimpanzees at the University of Texas Veterinary Science Park in Bastrop, Texas, covering the period July 11, 1978 through January 3, 1996 were reviewed to identify clinically normal, healthy animals. Fourteen animals were excluded because a serious illness had been diagnosed previously or they had tested positive for a retrovirus. The illnesses included hypothyroidism, thrombocytopenia, amyloidosis, diabetes mellitus, hepatitis B and hepatitis C. Normal hematologic and serum biochemical values were abstracted from the remaining 133 medical record files. Throughout the study, animals were maintained in mixed-sex groups of variable size and composition. They were housed in either large compounds with outdoor yards (22 m in diameter) containing grass as a ground cover and an indoor area, or conventional indoor/outdoor runs (2.4 × 6.1 × 2.4 m) with concrete floors, barred ceilings, and cinder block walls. The facilities and management of the colony have been described in detail (13).

Routine physical examination, which included blood collection for complete blood counts (CBCs) and biochemical analysis, was performed on anesthetized animals on a regular basis throughout the 17-year study period. Ketamine was the anesthetic agent used prior to 1991, at which time Telazol became the primary anesthetizing drug. Although these agents differ chemically, with the addition of zolazepam in the Telazol, both are phencyclidines and have similar physiologic effects. Entries in the clinical notes indicating pregnancy, infection, or signs of illness were noted, and all values recorded from blood collected on corresponding dates were excluded from analysis. Consequently, only the blood values associated with healthy animals collected during routine physical examination were included in the "normal" database.

Two separate sets of analyses were conducted: one for the hematologic values that comprised 16 variables, and one for the serum biochemical values that consisted of 24 analytes. The animals were classified by age on the date of blood collection. The four age categories were defined as: infant (0 to 3 years), juvenile (> 3 to 6 years), adolescent (> 6 to 10 years), and adult (> 10 years). Given the timespan covered by the study, it was possible for a single chimpanzee to contribute values to any age category. For example, a chimpanzee born in the early 1980s and still living and healthy in the 1990s could have values in each of the four age groups, whereas a chimpanzee born in the 1990s might contribute only to the infant category, or possibly to the infant and juvenile categories. In addition, most of the animals were tested multiple times during their membership in a given age group or groups. To avoid inadvertently biasing the average values within an age category, the mean value for an individual was calculated for each variable within each age category prior to statistical summary. Thus, within an age category, a given animal could contribute only a single

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value for each variable in the analysis despite the fact that the same animal might appear in more than one age category.

Laboratory techniques: During the period January 1978 through May 1985 hematocrit was determined by use of the Clay Adams Autocrit II (Clay Adams, Mississauga, Ontario, Canada), hemoglobin concentration was determined by use of the Coulter hemoglobinometer with Coulter Zap-O-Globin II, and the white blood cell (WBC) and red blood cell (RBC) counts were determined by use of the Coulter ZBI cell counter (Coulter Electronics, Hialeah, Fla.). Mean corpuscular indices were calculated, using established methods (14).

The CBC, including WBC, RBC, hemoglobin, hematocrit, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC), was determined from May 1985 through October 1990 by use of the Coulter Counter S770 (Coulter Electronics), and from October 1990 through January 1996 by use of the Serono Baker System 9000S (Serono-Baker Diagnostic, Inc., Allentown, Pa.). The WBC differential count was performed manually; by identifying and counting the various cell types in the first 100 WBC encountered in a blood smear, then calculating the percentage of each cell type. The values reported in the tables for each WBC type are the absolute numbers, which were determined by multiplying the total WBC count by the percentage of the cell type.

All clinical biochemical values, with the exception of serum chloride, sodium, and potassium concentrations, were determined by use of the Smith-Kline Eskalab for the period January 1978 through 1979, and by use of the Beckman Trace III from 1979 through 1984. Sodium and potassium were analyzed during this period by use of the Orion Na/K analyzer (Orion Research, Inc., Beverly, Mass.). The Cobas Mira S with an ion-selective electrode attachment for potassium and sodium analysis (Roche Diagnostic Systems, Branchburg, N.J.) was used from 1984 through 1996. Serum chloride concentration was determined at all times by use of the Buchler digital chloridometer (Labconco, Kansas City, Mo.).

Although multiple analytic methods were used over the years in determining many of the analytes, small differences that existed in the results obtained by use of the respective methods were distributed over a large number of animals in unbiased manner. Consequently, although the additional variance introduced by the use of multiple methods may have resulted in slightly wider reference intervals than had a single method been used, the reported central tendencies are probably more accurate.

Statistical analysis: Variables were dropped from the analyses if they contained values from fewer than six chimpanzees. For adults, the reticulocyte variable was dropped from the hematologic analyses, and CO_2 and direct bilirubin values were dropped from the serum biochemical analyses, leaving 15 hematologic variables and 22 serum biochemical variables in the adult age groups. In addition to these three variables, another eight serum biochemical analytes in the remaining three age categories were dropped from the analyses. Consequently, in the non-adult age groups, there were 15 hematologic variables and 14 serum biochemical variables. Statistical outliers were identified and checked against the records for accuracy. Inaccuracies were corrected, and true outliers were retained.

In accordance with recommendations of the National Committee for Clinical Laboratory Standards (15, 16), nonparametric methods were used to summarize and analyze the data. The median represents the central value, and the 5^{th} and 95^{th} percentiles define the reference interval for each analyte. This reference interval has been converted and is reported in the customary and Systeme International (SI) units. The interquartile range, which is reported in the last column of each table, is a measure of the spread or dispersion of a data set, and is calculated by taking the difference between the upper and lower quartiles. Parametric statistics, such as the mean and standard deviation, are included in the tables for comparison purposes only.

Mann-Whitney U tests were performed to determine whether sex differences existed within each age category. The Kruskal-Wallis test was performed for each variable to determine whether there was a significant difference among age groups. A P-value ≤ 0.05 was considered significant.

Finally, to distinguish between two percentiles of a distribution that are P% apart, there must be at least (100/P)-1 observations in the distribution. Consequently, a minimum of 19 observations is required to reliably estimate the 5^{th} and 95^{th} percentiles (15). Therefore, if there were fewer than 19 observations for a particular analyte, the values reported in the table represent the extremes of the distribution, or the full range of the data collected for that variable within the given age category.

Results

The reference ranges for chimpanzees are presented in the following 16 tables. The first set of eight tables summarizes the hematologic data, and the second set of eight tables summarizes the serum biochemical data. Both sets are presented in the order of youngest age category to oldest, and within each age group, the table with female data precedes the table with male data. Thus, within each set, a given table summarizes the results for a single sex within one of the four age groups. The values reported in the second column (labeled "S") of each table represent the total number of samples used to calculate the reference range for a particular variable. The values reported in the third column (labeled "N") represent the number of animals from which the total number of samples was collected during the study period. As mentioned previously, a single mean value was calculated for each animal that contributed multiple samples to a variable in a particular age group. Therefore, the value for N is the number of means that were used in the final computation of the reference range (Tables 1-16).

Effects of sex were most often seen in the adolescent and adult animals. All RBC-related variables (hematocrit, hemoglobin concentration, and RBC measurements) were significantly lower in females of these two age categories than in males, and the differences increased as the animals moved from adolescence to adulthood. This finding is consistent with the observations of Hodson and his colleagues (11), indicating that male chimpanzees have increasing hematocrit with age, whereas hematocrit in females remains unchanged over time. These differences, although more extreme in chimpanzees, are similar to those observed between the sexes in humans (17).

Although there were no sex or age differences in the overall WBC counts, there was a sex difference among adult animals as well as a significant effect of age in the distribution of WBC types. Adult females had significantly fewer neutrophils and more lymphocytes than did adult males, although neutrophils were the predominant WBC type in both adult sexes. The age effect resulted from an increase in neutrophils and a concomitant decrease in lymphocytes with age. In the infant group lym-

Table 1. Hematologic analytes for infant females

Analyte	S	N	Central tendency Mean	Central tendency **Median**	Reference values **5%tile**	Reference values **95%tile**	Reference values **Reference interval (S.I. units)**	Variability S. D.	Variability Interquartile range
Hematocrit (%)	109	38	39.63	**39.68**	**35.71**	**44.73**	**0.357–0.447**	2.65	3.36
Hemoglobin (g/dl)	109	38	13.03	**12.90**	**11.57**	**14.87**	**7.18–9.23** mmol/L	0.97	1.08
RBC count ($\times 10^6$)	73	28	5.25	**5.16**	**4.70**	**6.16**	**4.70–6.16** $\times 10^{12}$/L	0.44	0.52
MCV (fl)	73	29	74.37	**73.45**	**66.68**	**80.56**	**66.68–80.56** fl	4.47	4.86
MCH (pg)	73	29	24.81	**24.60**	**21.94**	**28.61**	**21.94–28.61** pg/cell	1.91	1.77
MCHC (g/dl)	67	29	32.76	**32.93**	**29.91**	**34.43**	**299.1–344.3** g/L	1.33	1.35
Sed rate ($\times 10^6$/mm^3)	43	20	16.37	**13.25**	**3.38**	**38.75**	**3.38–38.75** $\times 10^6$/mm^3	10.61	10.71
WBC ($\times 10^3$)	109	38	11.39	**11.19**	**7.42**	**15.51**	**7.42–15.51** $\times 10^9$/L	2.63	4.60
Neutrophils (segs) $\times 10^3$	109	38	4.36	**3.98**	**1.82**	**7.71**	**1.82–7.71** $\times 10^9$/L	1.74	2.11
Neutrophils (bands)	109	38	60.28	**0.00**	**0.00**	**230.10**	**0.00–230.10** $\times 10^6$/L	113.25	71.00
Lymphocytes ($\times 10^3$)	109	38	6.42	**6.05**	**3.79**	**10.15**	**3.79–10.15** $\times 10^9$/L	1.90	2.52
Monocytes	109	38	254.10	**241.83**	**0.00**	**558.00**	**0.00–558.00** $\times 10^6$/L	156.76	195.00
Eosinophils	109	38	264.25	**183.03**	**51.32**	**847.90**	**51.32–847.90** $\times 10^6$/L	243.20	167.67
Basophils	109	38	3.38	**0.00**	**0.00**	**29.73**	**0.00–29.73** $\times 10^6$/L	10.40	0.00
Platelets ($\times 10^3$)	35	18	330.25	**341.92**	**160.00**	**570.00**	**160.00–570.00** $\times 10^9$/L	98.55	131.50

Table 2. Hematologic analytes for infant males

Analyte	S	N	Central tendency Mean	Central tendency **Median**	Reference values **5%tile**	Reference values **95%tile**	Reference values **Reference interval (S.I. Units)**	Variability S. D.	Variability Interquartile range
Hematocrit (%)	106	36	38.68	**38.48**	**34.68**	**43.14**	**0.347–0.431**	2.56	3.32
Hemoglobin (g/dl)	106	36	12.84	**12.65**	**11.52**	**14.47**	**7.15–8.98** mmol/L	0.96	1.35
RBC count ($\times 10^6$)	77	29	5.12	**5.08**	**4.71**	**5.73**	**4.71–5.73** $\times 10^{12}$/L	0.31	0.36
MCV (fl)	77	29	75.32	**75.75**	**70.12**	**80.79**	**70.12–80.79** fl	3.32	4.97
MCH (pg)	77	29	24.94	**25.00**	**23.22**	**26.64**	**23.22–26.64** pg/cell	1.15	1.73
MCHC (g/dl)	77	29	33.18	**33.18**	**32.49**	**33.98**	**324.9–339.8** g/L	0.45	0.46
Sed rate ($\times 10^6$/mm^3)	54	25	17.19	**15.00**	**2.00**	**35.13**	**2.00–35.13** $\times 10^6$/mm^3	10.38	16.25
WBC ($\times 10^3$)	106	36	10.81	**10.75**	**6.34**	**16.26**	**6.34–16.26** $\times 10^9$/L	2.79	3.67
Neutrophils (segs) $\times 10^3$	106	36	4.70	**3.65**	**2.00**	**10.21**	**2.00–10.21** $\times 10^9$/L	2.53	3.04
Neutrophils (bands)	106	36	36.82	**13.63**	**0.00**	**150.18**	**0.00–150.18** $\times 10^6$/L	49.46	53.95
Lymphocytes ($\times 10^3$)	106	36	5.62	**5.51**	**3.15**	**7.92**	**3.15–7.92** $\times 10^9$/L	1.41	1.84
Monocytes	106	36	256.51	**220.50**	**15.90**	**590.70**	**15.90–590.70** $\times 10^6$/L	179.19	169.75
Eosinophils	106	36	169.02	**114.83**	**0.00**	**554.20**	**0.00–554.20** $\times 10^6$/L	154.87	113.85
Basophils	106	36	2.06	**0.00**	**0.00**	**0.00**	**0.00–0.00** $\times 10^6$/L	12.33	0.00
Platelets ($\times 10^3$)	37	18	325.35	**307.83**	**202.00**	**557.00**	**202.00–557.00** $\times 10^9$/L	79.97	77.67

Table 3. Hematologic analytes for juvenile females

Analyte	S	N	Central tendency Mean	Central tendency **Median**	Reference values **5%tile**	Reference values **95%tile**	Reference values **Reference interval (S.I. units)**	Variability S. D.	Variability Interquartile range
Hematocrit (%)	99	35	40.33	**40.70**	**36.49**	**43.56**	**0.365–0.436**	2.25	3.58
Hemoglobin (g/dl)	99	35	13.35	**13.33**	**12.06**	**14.60**	**7.48–9.06** mmol/L	0.78	0.91
RBC count ($\times 10^6$)	75	28	5.01	**5.00**	**4.57**	**5.33**	**4.57–5.33** $\times 10^{12}$/L	0.22	0.30
MCV (fl)	75	29	80.07	**79.67**	**74.72**	**84.03**	**74.72–84.03** fl	2.93	4.39
MCH (pg)	75	29	26.41	**26.30**	**24.65**	**27.70**	**24.65–27.70** pg/cell	0.97	1.42
MCHC (g/dl)	75	29	33.02	**33.00**	**32.00**	**34.36**	**320.0–343.6** g/L	0.74	1.00
Sed rate ($\times 10^6$/mm^3)	50	24	18.66	**16.50**	**8.10**	**43.33**	**8.10–43.33** $\times 10^6$/mm^3	11.16	6.96
WBC ($\times 10^3$)	99	35	10.38	**9.66**	**6.77**	**16.13**	**6.77–16.13** $\times 10^9$/L	2.97	4.28
Neutrophils (segs) $\times 10^3$	98	35	5.33	**4.39**	**2.48**	**11.41**	**2.48–11.41** $\times 10^9$/L	2.57	2.91
Neutrophils (bands)	98	35	53.87	**0.00**	**0.00**	**239.25**	**0–239.25** $\times 10^6$/L	84.96	57.17
Lymphocytes ($\times 10^3$)	98	35	4.56	**4.16**	**2.31**	**7.20**	**2.31–7.20** $\times 10^9$/L	1.63	2.85
Monocytes	98	35	246.05	**221.50**	**74.75**	**556.25**	**74.75–556.25** $\times$ **10^6/L**	138.45	187.25
Eosinophils	98	35	202.36	**142.00**	**5.33**	**577.56**	**5.33–577.56** $\times 10^6$/L	175.12	222.08
Basophils	98	35	2.04	**0.00**	**0.00**	**25.50**	**0.00–25.50** $\times 10^6$/L	8.43	0.00
Platelets ($\times 10^3$)	36	19	303.63	**304.00**	**225.00**	**413.05**	**225.00–413.05** $\times 10^9$/L	56.30	64.75

Table 4. Hematologic analytes for juvenile males

Analyte	S	N	Central tendency Mean	Central tendency **Median**	Reference values **5%tile**	Reference values **95%tile**	Reference values **Reference interval (S.I. units)**	Variability S. D.	Variability Interquartile range
Hematocrit (%)	83	32	39.71	**38.84**	**35.67**	**46.08**	**0.357–0.461**	3.03	3.85
Hemoglobin (g/dl)	83	32	13.13	**13.00**	**11.92**	**15.20**	**7.40–9.43** mmol/L	0.96	1.05
RBC count ($\times 10^6$)	72	28	5.01	**4.96**	**4.53**	**5.51**	**4.53–5.51** $\times 10^{12}$/L	0.33	0.43
MCV (fl)	71	28	78.66	**78.73**	**74.91**	**82.20**	**74.91–82.20** fl	2.38	2.78
MCH (pg)	71	28	26.11	**26.13**	**23.91**	**27.60**	**23.91–27.60** pg/cell	1.00	0.98
MCHC (g/dl)	71	28	33.20	**33.20**	**31.92**	**34.15**	**319.2–341.5** g/L	0.72	0.96
Sed rate ($\times 10^6$/mm^3)	55	25	17.99	**19.00**	**3.38**	**39.94**	**3.38–39.94** $\times 10^6$/mm^3	12.98	17.00
WBC ($\times 10^3$)	83	32	10.77	**10.97**	**7.23**	**16.38**	**7.23–16.38** $\times 10^9$/L	2.65	3.70
Neutrophils (segs) $\times 10^3$	83	32	6.28	**6.21**	**2.88**	**10.93**	**2.88–10.93** $\times 10^9$/L	2.53	4.44
Neutrophils (bands)	83	32	54.18	**0.00**	**0.00**	**216.88**	**0.00–216.88** $\times 10^6$/L	99.51	74.79
Lymphocytes ($\times 10^3$)	83	32	4.04	**3.94**	**2.02**	**5.74**	**2.02–5.74** $\times 10^9$/L	1.38	1.65
Monocytes	83	32	265.22	**235.00**	**5.80**	**529.35**	**5.80–529.35** $\times 10^6$/L	170.61	206.42
Eosinophils	83	32	141.68	**113.00**	**0.00**	**397.90**	**0.00–397.90** $\times 10^6$/L	120.84	129.38
Basophils	83	32	3.31	**0.00**	**0.00**	**0.00**	**0.00–0.00** $\times 10^6$/L	18.74	0.00
Platelets ($\times 10^3$)	46	22	341.30	**328.00**	**246.53**	**487.00**	**246.53–487.00** $\times 10^9$/L	73.90	102.00

Table 5. Hematologic analytes for adolescent females

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Hematocrit (%)	125	33	41.27	**41.15**	**37.45**	**45.59**	**0.375–0.456**	2.40	3.57
Hemoglobin (g/dl)	125	33	13.87	**13.67**	**12.76**	**15.51**	**7.92–9.63** mmol/L	0.85	1.33
RBC count ($\times 10^6$)	74	23	5.04	**5.02**	**4.63**	**5.52**	**4.63–5.52** $\times 10^{12}$/L	0.28	0.39
MCV (fl)	74	23	80.75	**81.78**	**74.54**	**86.51**	**74.54–86.51** fl	3.41	4.11
MCH (pg)	74	23	27.00	**26.93**	**24.95**	**29.09**	**24.95–29.09** pg/cell	1.27	1.87
MCHC (g/dl)	74	23	33.47	**33.52**	**32.44**	**34.31**	**324.4–343.1** g/L	0.62	1.04
Sed rate ($\times 10^6$/mm^3)	58	19	19.26	**15.00**	**5.00**	**59.65**	**5.00–59.65** $\times 10^6$/mm^3	15.44	10.44
WBC ($\times 10^3$)	125	33	11.85	**11.32**	**6.61**	**16.01**	**6.61–16.01** $\times 10^9$/L	2.80	4.46
Neutrophils (segs) $\times 10^3$	125	33	6.67	**6.38**	**3.33**	**11.68**	**3.33–11.68** $\times 10^9$/L	2.44	2.74
Neutrophils (bands)	125	33	66.83	**23.75**	**0.00**	**213.84**	**0.00–213.84** $\times 10^6$/L	104.84	100.75
Lymphocytes ($\times 10^3$)	125	33	4.64	**4.32**	**2.53**	**8.19**	**2.53–8.19** $\times 10^9$/L	1.80	1.76
Monocytes	125	33	204.84	**166.00**	**23.30**	**439.69**	**23.3–439.69** $\times 10^6$/L	132.03	215.85
Eosinophils	125	33	262.18	**215.50**	**24.31**	**689.53**	**24.31–689.53** $\times 10^6$/L	191.95	242.38
Basophils	125	33	2.81	**0.00**	**0.00**	**17.65**	**0.00–17.65** $\times 10^6$/L	11.01	0.00
Platelets ($\times 10^3$)	41	17	279.94	**278.00**	**184.00**	**365.25**	**184.00–365.25** $\times 10^9$/L	53.15	76.03

Table 6. Hematologic analytes for adolescent males

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Hematocrit (%)	103	27	43.56	**43.73**	**37.30**	**49.65**	**0.373–0.497**	4.04	6.51
Hemoglobin (g/dl)	103	27	14.72	**14.52**	**12.97**	**16.92**	**8.05–10.50** mmol/L	1.32	1.66
RBC count ($\times 10^6$)	58	20	5.29	**5.22**	**4.59**	**5.97**	**4.59–5.97** $\times 10^{12}$/L	0.41	0.58
MCV (fl)	58	21	80.34	**80.00**	**76.46**	**84.71**	**76.46–84.71** fl	2.54	3.44
MCH (pg)	58	21	27.06	**27.00**	**25.31**	**28.67**	**25.31–28.67** pg/cell	0.95	1.29
MCHC (g/dl)	58	21	33.71	**33.70**	**32.52**	**35.15**	**325.2–351.5** g/L	0.79	1.15
Sed rate ($\times 10^6$/mm^3)	49	18	12.66	**9.97**	**3.00**	**46.50**	**3.00–46.50** $\times 10^6$/mm^3	10.76	9.08
WBC ($\times 10^3$)	103	27	10.51	**10.46**	**5.71**	**15.72**	**5.71–15.72** $\times 10^9$/L	2.89	4.36
Neutrophils (segs) $\times 10^3$	102	27	6.23	**5.94**	**2.67**	**10.49**	**2.67–10.49** $\times 10^9$/L	2.45	3.68
Neutrophils (bands)	102	27	22.52	**0.00**	**0.00**	**86.01**	**0.00–86.01** $\times$ 1 0^6/L	32.21	37.00
Lymphocytes ($\times 10^3$)	102	27	3.83	**3.71**	**1.84**	**7.09**	**1.84–7.09** $\times 10^9$/L	1.40	1.86
Monocytes	102	27	209.21	**222.75**	**0.00**	**546.59**	**0.00–546.59** $\times$ 1 0^6/L	157.16	166.29
Eosinophils	102	27	207.84	**138.00**	**68.63**	**508.73**	**68.63–508.73** $\times 10^6$/L	149.85	129.07
Basophils	102	27	4.04	**0.00**	**0.00**	**16.35**	**0.00–16.35** $\times 10^6$/L	20.98	0.00
Platelets ($\times 10^3$)	34	17	273.19	**304.00**	**84.00**	**385.00**	**84.00–385.00** $\times 10^9$/L	83.05	124.42

Table 7. Hematologic analytes for adult females

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Hematocrit (%)	627	49	41.69	**41.75**	**37.57**	**45.76**	**0.376–0.458**	2.63	2.31
Hemoglobin (g/dl)	627	49	13.86	**13.92**	**12.29**	**15.28**	**7.63–9.48** mmol/L	0.88	1.10
RBC count ($\times 10^6$)	350	49	5.14	**5.11**	**4.65**	**5.78**	**4.65–5.78** $\times 10^{12}$/L	0.36	0.55
MCV (fl)	350	49	81.36	**81.10**	**75.96**	**87.66**	**75.96–87.66** fl	3.37	4.50
MCH (pg)	350	49	27.03	**26.95**	**24.37**	**29.56**	**24.37–29.56** pg/cell	1.56	1.83
MCHC (g/dl)	350	49	33.14	**33.18**	**32.05**	**34.16**	**320.5–341.6** g/L	0.64	0.69
Sed rate ($\times 10^6$/mm^3)	237	48	22.82	**18.40**	**3.92**	**63.12**	**3.92–63.12** $\times 10^6$/mm^3	17.35	18.43
WBC ($\times 10^3$)	627	49	10.62	**10.73**	**7.28**	**14.47**	**7.28–14.47** $\times 10^9$/L	2.13	3.22
Neutrophils (segs) $\times 10^3$	627	49	5.42	**5.18**	**2.99**	**8.04**	**2.99–8.04** $\times 10^9$/L	1.49	1.79
Neutrophils (bands)	627	49	41.99	**34.79**	**0.00**	**109.08**	**0.00–109.08** $\times 10^6$/L	38.61	54.00
Lymphocytes ($\times 10^3$)	627	49	4.61	**4.56**	**1.96**	**7.27**	**1.96–7.27** $\times 10^9$/L	1.51	2.12
Monocytes	627	49	250.14	**278.80**	**64.60**	**401.68**	**64.80–401.68** $\times 10^6$/L	119.44	156.17
Eosinophils	627	49	255.64	**210.89**	**68.77**	**629.59**	**68.77–629.59** $\times 10^6$/L	187.46	135.56
Basophils	627	49	2.63	**0.00**	**0.00**	**14.73**	**0.00–14.73** $\times 10^6$/L	9.27	0.00
Platelets ($\times 10^3$)	168	48	242.64	**247.29**	**150.87**	**323.68**	**150.87–323.68** $\times 10^9$/L	49.67	67.467

Table 8. Hematologic analytes for adult males

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Hematocrit (%)	432	27	46.50	**46.87**	**40.47**	**50.95**	**0.405–0.509**	3.09	3.97
Hemoglobin (g/dl)	432	27	15.51	**15.58**	**13.23**	**17.26**	**8.21–10.71** mmol/L	1.19	1.16
RBC count ($\times 10^6$)	221	27	5.65	**5.60**	**4.99**	**6.36**	**4.99–6.36** $\times 10^{12}$/L	0.44	0.71
MCV (fl)	221	27	82.17	**81.51**	**76.35**	**88.56**	**76.35–88.56** fl	3.85	5.89
MCH (pg)	221	27	27.03	**27.37**	**24.69**	**29.61**	**24.69–29.61** pg/cell	1.42	2.23
MCHC (g/dl)	221	27	32.98	**32.99**	**32.29**	**33.78**	**322.9–337.8** g/L	0.44	0.52
Sed rate ($\times 10^6$/mm^3)	154	27	19.75	**11.43**	**3.53**	**59.83**	**3.53–59.83** $\times 10^6$/mm^3	18.66	19.15
WBC ($\times 10^3$)	431	27	11.17	**10.83**	**8.24**	**15.67**	**8.24–15.67** $\times 10^9$/L	2.32	3.00
Neutrophils (segs) $\times 10^3$	426	27	6.70	**6.23**	**4.54**	**10.67**	**4.54–10.67** $\times 10^9$/L	1.84	1.81
Neutrophils (bands)	426	27	69.88	**42.96**	**0.00**	**202.01**	**0.00–202.01** $\times 10^6$/L	67.38	96.71
Lymphocytes ($\times 10^3$)	426	27	3.88	**3.75**	**2.01**	**6.13**	**2.01–6.13** $\times 10^9$/L	1.21	1.53
Monocytes	426	27	309.66	**285.15**	**157.91**	**572.15**	**157.91–572.15** $\times 10^6$/L	131.21	200.29
Eosinophils	426	27	153.91	**152.26**	**20.61**	**307.00**	**20.61–307.00** $\times 10^6$/L	91.87	146.15
Basophils	426	27	4.52	**0.00**	**0.00**	**23.60**	**0.00–23.60** $\times 10^6$/L	12.18	4.24
Platelets ($\times 10^3$)	109	27	231.93	**218.60**	**130.50**	**379.93**	**130.50–379.93** $\times 10^9$/L	73.56	99.26

Table 9. Serum biochemical analytes for infant females

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Total bilirubin (mg/dl)	62	24	0.29	**0.26**	**0.09**	**0.60**	**1.54–10.26** μmol/L	0.14	0.16
AST (U/L)	87	36	23.78	**22.63**	**12.67**	**38.10**	**0.21–0.64** μkat/L	7.80	10.71
ALT (U/L)	87	36	32.41	**30.83**	**21.00**	**43.85**	**0.35–0.73** μkat/L	7.87	8.83
Alkaline phosphatase (U/L)	86	36	611.32	**597.92**	**409.40**	**1064.55**	**6.82–17.75** μkat/L	182.77	239.75
Glucose (mg/dl)	64	25	86.23	**80.50**	**64.88**	**121.50**	**3.60–6.74** mmol/L	20.36	34.63
BUN (mg/dl)	85	36	11.48	**11.00**	**7.55**	**19.65**	**2.70–7.02** mmol/L	4.15	3.75
Creatinine (mg/dl)	63	24	0.60	**0.60**	**0.49**	**0.79**	**43.32–69.84** μmol/L	0.11	0.05
Total protein (g/dl)	86	36	6.66	**6.65**	**6.00**	**7.47**	**60.00–74.70** g/L	0.40	0.43
Albumin (g/dl)	86	36	3.68	**3.70**	**3.10**	**4.17**	**31.00–41.70** g/L	0.30	0.35
Globulin (g/dl)	86	36	2.98	**2.92**	**2.42**	**3.50**	**24.20–35.00** g/L	0.35	0.53
Cholesterol	21	14	275.55	**263.75**	**177.00**	**363.67**	**4.58–9.40** mmol/L	53.18	79.50
HDL (mg/dl)	17	11	78.33	**82.00**	**45.00**	**112.67**	**1.16–2.91** mmol/L	22.43	39.25
LDL (mg/dl)	17	11	180.21	**188.00**	**99.00**	**240.33**	**2.56–6.21** mmol/L	46.34	49.50
Triglycerides (mg/dl)	20	13	70.96	**59.33**	**32.00**	**135.00**	**0.36–1.52** mmol/L	30.91	44.38

Table 10. Serum biochemical analytes for infant males

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Total bilirubin (mg/dl)	72	30	0.31	**0.30**	**0.10**	**0.60**	**1.71–10.26** μmol/L	0.15	0.23
AST (U/L)	104	37	22.06	**23.00**	**13.70**	**31.52**	**0.23–0.53** μkat/L	5.35	8.63
ALT (U/L)	104	37	37.01	**35.00**	**24.35**	**54.40**	**0.41–0.91** μkat/L	11.33	13.71
Alkaline phosphatase (U/L)	87	37	609.34	**607.00**	**393.92**	**857.51**	**6.57–14.29** μkat/L	146.83	258.08
Glucose (mg/dl)	72	30	88.85	**84.33**	**69.00**	**127.00**	**3.83–7.05** mmol/L	17.26	27.00
BUN (mg/dl)	87	37	11.58	**11.33**	**7.68**	**18.65**	**2.74–6.66** mmol/L	2.98	2.50
Creatinine (mg/dl)	73	31	0.59	**0.55**	**0.50**	**0.76**	**44.20–67.18** μmol/L	0.10	0.14
Total protein (g/dl)	89	37	6.81	**6.80**	**6.14**	**7.73**	**61.40–77.30** g/L	0.47	0.57
Albumin (g/dl)	89	37	3.65	**3.63**	**3.20**	**4.10**	**32.00–41.00** g/L	0.25	0.30
Globulin (g/dl)	89	37	3.17	**3.10**	**2.44**	**3.84**	**24.40–38.40** g/L	0.44	0.55
Cholesterol (mg/dl)	30	16	259.91	**258.50**	**170.00**	**349.00**	**4.40–9.03** mmol/L	46.63	55.50
HDL (mg/dl)	25	14	77.08	**69.00**	**43.00**	**116.67**	**1.11–3.02** mmol/L	25.33	48.00
LDL (mg/dl)	24	14	163.83	**159.00**	**97.00**	**245.50**	**2.51–6.35** mmol/L	39.69	57.50
Triglycerides (mg/dl)	29	16	63.53	**56.38**	**38.00**	**140.00**	**0.43–1.58** mmol/L	26.80	23.75

Table 11. Serum biochemical analytes for juvenile females

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Total bilirubin (mg/dl)	78	31	00.31	**0.30**	**0.00**	**0.70**	**0.00–11.97** μmol/L	0.19	0.28
AST (U/L)	91	35	20.43	**20.00**	**13.00**	**27.25**	**0.22–0.45** μkat/L	4.71	6.75
ALT (U/L)	91	35	38.58	**39.33**	**28.50**	**48.56**	**0.48–0.81** μkat/L	6.94	7.42
Alkaline phosphatase (U/L)	91	35	536.00	**523.50**	**361.78**	**671.00**	**6.03–11.19** μkat/L	100.49	129.04
Glucose (mg/dl)	79	31	91.12	**90.00**	**66.25**	**117.65**	**3.68–6.53** mmol/L	15.23	19.00
BUN (mg/dl)	91	35	13.93	**14.00**	**10.13**	**19.08**	**3.61–6.81** mmol/L	2.67	4.06
Creatinine (mg/dl)	80	32	0.67	**0.63**	**0.50**	**0.85**	**44.2–75.14** μmol/L	0.14	0.14
Total protein (g/dl)	91	35	7.08	**7.13**	**6.30**	**7.71**	**63.00–77.10** g/L	0.42	0.45
Albumin (g/dl)	91	35	3.81	**3.87**	**3.29**	**4.18**	**32.90–41.80** g/L	0.31	0.48
Globulin (g/dl)	91	35	3.27	**3.27**	**2.66**	**3.84**	**26.60–38.40** g/L	0.48	0.65
Cholesterol (mg/dl)	35	17	238.22	**238.00**	**179.00**	**292.00**	**4.63–7.55** mmol/L	32.68	53.44
HDL (mg/dl)	31	15	69.27	**68.50**	**42.00**	**104.00**	**1.09–2.69** mmol/L	15.63	15.58
LDL (mg/dl)	31	15	153.19	**152.00**	**114.25**	**206.00**	**2.95–5.33** mmol/L	27.81	45.00
Triglycerides (mg/dl)	34	16	71.99	**71.38**	**35.00**	**118.75**	**0.40–1.34** mmol/L	18.59	21.83

Table 12. Serum biochemical analytes for juvenile males

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Total bilirubin (mg/dl)	72	30	0.32	**0.31**	**0.00**	**0.70**	**0.00–11.97** μmol/L	0.19	0.22
AST (U/L)	80	32	23.98	**22.54**	**15.70**	**34.73**	**0.26–0.58** μkat/L	8.27	6.50
ALT (U/L)	80	32	45.34	**43.83**	**30.00**	**69.10**	**0.50–1.15** μkat/L	11.60	10.38
Alkaline phosphatase (U/L)	80	32	509.26	**497.75**	**361.58**	**706.70**	**6.03–11.78** μkat/L	101.27	144.25
Glucose (mg/dl)	72	30	85.76	**83.42**	**55.00**	**121.50**	**3.05–6.74** mmol/L	18.84	18.50
BUN (mg/dl)	80	32	15.54	**14.75**	**10.55**	**26.25**	**3.77–9.37** mmol/L	4.06	4.29
Creatinine (mg/dl)	72	30	0.63	**0.60**	**0.45**	**0.80**	**39.78–70.72** μmol/L	0.11	0.13
Total protein (g/dl)	81	32	7.29	**7.30**	**6.62**	**7.80**	**66.20–78.00** g/L	0.39	0.56
Albumin (g/dl)	81	32	3.83	**3.86**	**3.47**	**4.19**	**34.70–41.90** g/L	0.22	0.42
Globulin (g/dl)	81	32	3.46	**3.47**	**2.77**	**4.22**	**27.70–42.20** g/L	0.43	0.51
Cholesterol (mg/dl)	20	9	235.94	**229.00**	**192.75**	**283.00**	**4.98–7.32** mmol/L	30.33	44.06
HDL (mg/dl)	19	8	68.09	**65.33**	**44.00**	**103.00**	**1.14–2.66** mmol/L	19.59	22.79
LDL (mg/dl)	19	8	151.65	**154.00**	**133.25**	**179.00**	**3.45–4.63** mmol/L	16.21	25.04
Triglycerides (mg/dl)	20	9	78.48	**73.00**	**54.00**	**144.00**	**0.61–1.63** mmol/L	25.93	14.15

Table 13. Serum biochemical analytes for adolescent females

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Total bilirubin (mg/dl)	75	23	0.31	**0.28**	**0.08**	**0.54**	**1.37–9.23** μmol/L	0.13	0.14
AST (U/L)	107	33	18.41	**16.67**	**10.72**	**27.93**	**0.18–0.47** μkat/L	7.32	10.02
ALT (U/L)	107	33	29.30	**27.00**	**17.63**	**44.31**	**0.29–0.74** μkat/L	8.26	11.48
Alkaline phosphatase (U/L)	107	33	314.97	**304.75**	**143.13**	**533.09**	**2.39–8.89** μkat/L	110.83	147.75
Glucose (mg/dl)	76	24	90.90	**89.08**	**68.55**	**116.00**	**3.81–6.44** mmol/L	12.12	14.67
BUN (mg/dl)	107	33	14.05	**14.00**	**9.43**	**21.63**	**3.37–7.72** mmol/L	3.63	3.04
Creatinine (mg/dl)	80	25	0.81	**0.77**	**0.62**	**1.32**	**54.81–116.69** μmol/L	0.20	0.15
Total protein (g/dl)	109	33	7.40	**7.40**	**6.73**	**8.29**	**67.30–82.90** g/L	0.42	0.58
Albumin (g/dl)	109	33	3.87	**3.80**	**3.46**	**4.47**	**34.60–44.70** g/L	0.29	0.40
Globulin (g/dl)	109	33	3.54	**3.47**	**2.91**	**4.38**	**29.10–43.80** g/L	0.43	0.66
Cholesterol (mg/dl)	30	17	220.87	**224.00**	**163.00**	**333.00**	**4.22–8.61** mmol/L	45.47	59.38
HDL (mg/dl)	27	15	64.66	**65.67**	**33.00**	**102.00**	**0.85–2.64** mmol/L	17.86	23.38
LDL (mg/dl)	27	15	136.63	**136.00**	**109.67**	**174.67**	**2.84–4.52** mmol/L	22.71	37.13
Triglycerides (mg/dl)	28	16	77.06	**77.00**	**33.00**	**109.00**	**0.37–1.23** mmol/L	21.23	30.83

Table 14. Serum biochemical analytes for adolescent males

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Total bilirubin (mg/dl)	62	24	0.44	**0.41**	**0.00**	**0.82**	**0.00–14.02** μmol/L	0.24	0.34
AST (U/L)	96	27	22.20	**22.00**	**11.57**	**31.77**	**0.19–0.53** μkat/L	6.34	9.38
ALT (U/L)	97	27	33.47	**32.00**	**17.00**	**47.15**	**0.28–0.79** μkat/L	8.64	13.20
Alkaline phosphatase (U/L)	97	27	466.30	**410.60**	**145.60**	**943.93**	**2.43–15.74** μkat/L	209.38	126.53
Glucose (mg/dl)	66	25	87.76	**85.50**	**67.10**	**115.63**	**3.72–6.42** mmol/L	15.26	22.29
BUN (mg/dl)	97	27	15.05	**13.50**	**8.85**	**24.10**	**3.16–8.60** mmol/L	4.98	6.28
Creatinine (mg/dl)	70	25	0.94	**0.86**	**0.60**	**1.73**	**53.04–152.93** μmol/L	0.32	0.28
Total protein (g/dl)	100	27	7.33	**7.32**	**6.80**	**8.01**	**68.00–80.10** g/L	0.35	0.42
Albumin (g/dl)	100	27	4.01	**4.03**	**3.54**	**4.33**	**35.40–43.30** g/L	0.24	0.31
Globulin (g/dl)	100	27	3.31	**3.30**	**2.63**	**4.03**	**26.30–40.30** g/L	0.45	0.58
Cholesterol (mg/dl)	25	10	218.83	**229.54**	**161.00**	**247.33**	**4.16–6.40** mmol/L	30.82	31.00
HDL (mg/dl)	15	6	52.33	**53.00**	**31.67**	**68.00**	**.82–1.76** mmol/L	14.58	27.67
LDL (mg/dl)	15	6	151.06	**152.17**	**129.00**	**173.00**	**3.34–4.47** mmol/L	20.72	40.67
Triglycerides (mg/dl)	18	7	81.26	**74.33**	**45.33**	**109.00**	**0.51–1.23** mmol/L	23.02	33.13

Table 15. Serum biochemical analytes for adult females

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	Median	5%tile	95%tile	Reference interval (S.I. units)	S.D.	Interquartile range
Total bilirubin (mg/dl)	341	49	0.33	**0.31**	**0.20**	**0.50**	**3.42–8.55** μmol/L	0.09	0.10
AST (U/L)	515	49	18.33	**17.94**	**11.87**	**24.73**	**0.20–0.41** μkat/L	5.16	4.84
ALT (U/L)	516	49	26.49	**26.80**	**20.17**	**35.87**	**0.34–0.60** μkat/L	4.98	5.90
Alkaline phosphatase (U/L)	516	49	100.70	**89.29**	**53.68**	**205.36**	**0.89–3.42** μkat/L	39.88	43.22
Glucose (mg/dl)	349	49	85.04	**82.40**	**65.67**	**117.61**	**3.65–6.53** mmol/L	4.27	11.05
BUN (mg/dl)	514	49	12.15	**11.75**	**8.27**	**17.16**	**2.95–6.13** mmol/L	2.58	2.78
Creatinine (mg/dl)	349	49	0.92	**0.90**	**0.70**	**1.11**	**61.88–98.12** μmol/L	0.14	0.15
Total protein (g/dl)	529	49	7.59	**7.67**	**6.70**	**8.25**	**67.00–82.50** g/L	0.46	0.61
Albumin (g/dl)	529	49	3.69	**3.71**	**3.27**	**4.11**	**32.70–41.10** g/L	0.24	0.30
Globulin (g/dl)	529	49	3.92	**3.97**	**3.20**	**4.51**	**32.00–45.10** g/L	0.42	0.47
Calcium (mg/dl)	36	20	9.20	**9.20**	**8.15**	**10.50**	**2.04–2.63** mmol/L	0.67	0.71
Phosphorus (mg/dl)	37	20	2.83	**2.93**	**1.50**	**4.08**	**0.48–1.32** mmol/L	0.74	1.04
Chloride (mmol/L)	26	17	105.09	**105.50**	**94.00**	**113.00**	**94.00–113.00** mmol/L	4.58	5.88
Sodium (mmol/L)	42	24	141.75	**142.00**	**136.57**	**145.30**	**136.57–145.30** mmol/L	2.82	4.00
Potassium (mmol/L)	41	24	3.72	**3.63**	**3.29**	**4.43**	**3.29–4.43** mmol/L	0.32	0.45
Cholesterol (mg/dl)	133	38	228.52	**227.83**	**169.96**	**296.18**	**4.40–7.66** mmol/L	40.17	58.75
HDL (mg/dl)	107	38	55.68	**53.88**	**36.04**	**81.96**	**0.93–2.12** mmol/L	14.34	17.33
LDL (mg/dl)	107	38	154.88	**151.67**	**102.57**	**214.00**	**2.65–5.53** mmol/L	34.84	52.50
Triglycerides (mg/dl)	130	38	109.74	**103.00**	**56.10**	**181.60**	**0.63–2.05** mmol/L	42.42	75.83
CK (U/L)	37	20	335.42	**267.50**	**71.50**	**850.92**	**1.19–14.18** μkat/L	225.62	133.00
LD (U/L)	59	24	273.44	**268.83**	**192.50**	**423.80**	**4.32–10.31** μkat/L	75.46	73.17
Uric acid (mg/dl)	19	15	1.92	**2.10**	**0.70**	**3.03**	**95.17–356.88** μmol/L	0.73	0.78

CK = creatine kinase; LD = lactate dehydrogenase

phocytes were actually the predominant WBC type for both sexes (Fig.1). This finding was consistent with human data (18). However, it is inconsistent with the observations of Hodson and his colleagues (11), who failed to find a significant trend with age.

The renal function-related serum biochemical parameters (i.e., blood urea nitrogen [BUN] and creatinine concentrations) increased significantly with age and were significantly lower in adult females than males. Liver function analytes, such as total bilirubin concentration and activities of the enzymes alanine transaminase (ALT) and aspartate transaminase (AST) were significantly lower overall in adolescent and adult females than in comparable males. As with many species, alkaline phosphatase activity decreased with age (19).

Total protein, albumin, and globulin concentrations increased with age. Similarly, there were significant changes in serum lipid profiles with age; cholesterol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) concentrations decreased, whereas triglycerides concentration increased as a function of age.

Table 16. Serum biochemical analytes for adult males

			Central tendency		Reference values			Variability	
Analyte	S	N	Mean	**Median**	**5%tile**	**95%tile**	**Reference interval (S.I. units)**	S.D.	Interquartile range
Total bilirubin (mg/dl)	219	27	0.37	**0.36**	**0.23**	**0.61**	**3.93–10.43** μmol/L	0.11	0.13
AST (U/L)	341	27	35.79	**34.46**	**22.28**	**56.21**	**0.37–0.94** μkat/L	10.87	12.96
ALT (U/L)	342	27	37.13	**35.00**	**28.57**	**61.63**	**0.48–1.03** μkat/L	8.74	7.24
Alkaline phosphatase (U/L)	341	27	85.22	**81.75**	**56.04**	**146.07**	**0.93–2.43** μkat/L	24.83	24.52
Glucose (mg/dl)	227	27	85.14	**85.75**	**68.62**	**106.17**	**3.81–5.89** mmol/L	11.44	15.03
BUN (mg/dl)	341	27	13.59	**13.57**	**10.62**	**17.83**	**3.79–6.37** mmol/L	2.21	2.62
Creatinine (mg/dl)	223	27	1.09	**1.10**	**0.90**	**1.26**	**79.56–111.38** μmol/L	0.11	0.15
Total protein (g/dl)	358	27	7.80	**7.88**	**7.29**	**8.35**	**72.90–83.50** g/L	0.37	0.52
Albumin (g/dl)	357	27	3.78	**3.85**	**3.25**	**4.13**	**32.50–41.30** g/L	0.27	0.32
Globulin (g/dl)	357	27	4.06	**3.91**	**3.53**	**4.82**	**35.30–48.20** g/L	0.44	0.67
Calcium (mg/dl)	22	14	9.23	**9.40**	**7.80**	**10.00**	**1.95–2.50** mmol/L	0.65	1.00
Phosphorus (mg/dl)	21	13	3.09	**3.00**	**1.80**	**4.90**	**0.58–1.58** mmol/L	0.80	0.83
Chloride (mmol/L)	19	11	104.30	**103.00**	**92.33**	**116.00**	**92.33–116.00** mmol/L	8.01	11.25
Sodium (mmol/L)	29	15	143.54	**143.00**	**139.00**	**150.00**	**139.00–150.00** mmol/L	3.70	6.37
Potassium (mmol/L)	29	15	3.73	**3.60**	**3.20**	**4.70**	**3.20–4.70** mmol/L	0.44	0.77
Cholesterol (mg/dl)	93	22	206.73	**205.58**	**167.20**	**253.76**	**4.32–6.56** mmol/L	26.82	44.75
HDL (mg/dl)	65	21	49.81	**48.33**	**33.72**	**67.75**	**0.87–1.75** mmol/L	11.74	22.13
LDL (mg/dl)	65	21	143.61	**146.00**	**101.71**	**193.12**	**2.63–4.99** mmol/L	26.63	33.29
Triglycerides (mg/dl)	84	22	93.67	**91.91**	**55.60**	**141.55**	**0.63–1.60** mmol/L	25.75	41.00
CK (U/L)	23	14	568.49	**443.40**	**173.00**	**1347.50**	**2.88–22.46** μkat/L	371.00	539.00
LD (U/L)	52	16	347.10	**317.70**	**259.00**	**618.50**	**4.32–10.31** μkat/L	92.76	112.26
Uric acid (mg/dl)	16	11	2.81	**2.80**	**1.60**	**6.00**	**95.17–356.88** μmol/L	1.17	0.75

See Table 15 for key.

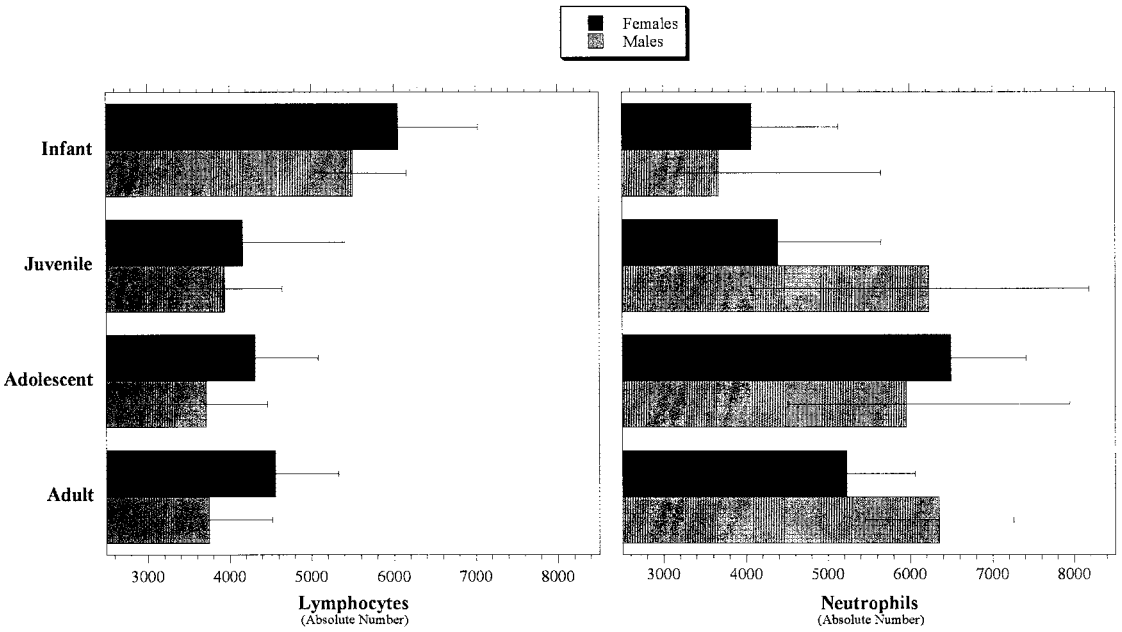

Figure 1: Distribution of white blood cells types as a function of age and gender. The lengths of the bars represent the median estimated cell counts and the error bars represent their respective nonparametric two-sided 95% confidence intervals.

Discussion

The data reported here provide a more complete and nuanced set of hematologic and serum biochemical values than has previously been available to the general scientific and clinical communities. Such detail is important because we consistently observed significant main effects of age and sex, as well as interactions among a number of variables, such as the lymphocytes and neutrophils depicted in Fig. 1. For example, infants have significantly more lymphocytes than does any other age group. If a single overall reference range is used to evaluate the test results from an infant chimpanzee, the lymphocyte count may appear to fall outside the normal range, even though it is within normal limits for this age group. If true, this infant could conceivably be misclassified as a sick animal and treated needlessly. The reference ranges for several variables were found to be similarly age and sex specific. Consequently, it is now clear that "normal" values for the chimpanzee are strongly influenced by sex and age and that these two factors must be taken into account when interpreting biochemical profiles in the assessment of general health.

One potential criticism of the study reported here is that use of different anesthetic agents for chemical restraint may have undermined the usefulness of the tabled values to practitioners in the field. Our choice of anesthetic agents, however, belies this concern. Ketamine and Telazol, both phencyclidines, are the two principal anesthetic agents used by primate clinicians and were the only two agents used in this study. Although Huser found that phencyclidines had a significant effect on a number of hematologic parameters in chimpanzees, he concluded that the most likely explanation for such effect was reduced stress in anesthetized relative to unanesthetized animals (12).

Our hematologic results are roughly comparable to those reported in earlier studies. Such comparisons are indeterminate, however, because the data from animals in previous studies are only partially stratified (3, 5). For example, it was reported that males and females differ in the RBC-related analytes (3-5). We

discovered, however, that this difference is more pronounced in, and principally a function of, the sex difference in older animals—an effect undetectable when interaction of sex and age is not evaluated. Likewise, it had been reported that infants appear to have higher lymphoctye counts than do other age groups (5). We replicated the finding, but also discovered that lymphocytes actually make up a greater percentage of the total WBC count than do neutrophils for this age category (Fig.1). Furthermore, because age and sex were evaluated factorially, we were able to discover that adult females have significantly higher lymphocyte count and significantly lower neutrophil count than do adult males—findings that, to the authors' knowledge, have not been reported.

Our serum biochemical results also are roughly comparable to those reported in earlier studies. As with our hematologic results, however, such comparisons are inconclusive because the data from animals in most previous studies were only partially stratified. Generally, when the data were categorized, it was done either by sex or age, but not by both (3, 4). As a result, sex differences in the liver and renal function-related analytes began to emerge in those studies, but the combined data masked important distinctions that were clearly evident in this study. For example, the 40 chimpanzees sampled in the study conducted by Hainsey and his colleagues (3) comprised 20 males and 20 females that ranged in age from 5 to 33 years. Although those data were analyzed on the basis of sex, there were no analyses performed on the basis of age. Mean serum creatinine concentration was higher in males (0.5 to1.3 mg/dl) than females (0.3 to 1.1 mg/dl), though not significantly so. In this study, there was a significant sex difference, though only among adult males and females ($P < 0.0001$). Likewise, although mean serum AST values were higher in males than females of the Hainsey study, no distinction was made on the basis of age, and again the differences were not significant, as they were among adult males and females in our study ($P < 0.0001$). One exception to incomplete stratification was Hodson and co-workers, who documented sex and age interactions in their 1968 chimpanzee study (10). Their analyses, however, were limited to six analytes: BUN; serum protein, sodium, potassium, and total CO_2; and pH. Our results for BUN and total protein are comparable to those of Hodson and co-workers. An exact comparison cannot be made, however, because the Hodson data were reported in one-year intervals rather than classified into the broader age categories used by us.

These findings underscore the need for clearly defined and stratified reference intervals. The reference tables provided represent the next stage in the continuing evolution of the scientifically valid, clinically relevant, and readily accessible information needed by clinicians responsible for long-term care and treatment of chimpanzees.

Acknowledgment

Supported in part by NIH grant U42-RR03589 to MEK and in part by an NSF Presidential Faculty Fellowship to LGT.

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