Blood parameters of the wild chacma baboon, *Papio ursinus*

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Serum chemical and haematological data are presented for 63 wild chacma baboons, *Papio ursinus*, living in the Okavango Swamp, Botswana. Most values are similar to those which have been found previously for captive baboons, although some differences are noted, particularly in serum lipid levels. The effects on blood assays of 16 environmental, physiological and behavioural variables are examined. Female reproductive state, especially pregnancy, and the age and size of individuals were the variables which had the most significant effects on blood assays, whereas the presence of blood parasites and the dominance status of an individual had no effect. The importance of defining boundary conditions when describing normal blood values is emphasized.

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Chemiese en hematologiese serumgegewens van 63 wilde bobbejane, *Papio ursinus*, in die Okavango-moerasse van Botswana word verskaf. Die meeste waardes stem ooreen met dié wat reeds gevind is by bobbejane in gevangeskap, maar daar is tog verskille, veral in die serumvetvlakke. Die uitwerking van 16 omgewings-, fisiologiese en gedragsveranderlikes op bloedtoetse is ondersoek. Voortplantingstoestand van wyfies, veral dragtigheid, en die ouderdom en grootte van indiwidue was die veranderlikes wat die grootste uitwerking gehad het, terwyl die teenwoordigheid van bloedparasiete en die dominansie-status van 'n indiwidu geen uitwerking gehad het nie. Die belangrikheid van die uitstip van grenskenmerke wanneer normale bloedwaardes beskryf word, word beklemtoon.

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Most published blood profiles for *Papio* species come from laboratory populations (e.g. De La Pena, Matthijssen & Goldzieher 1970; Weber, Brede, Retief, Retief & Melby 1971; Steyn, Hamilton-Bruce, Zuurmond & Pharo 1975), although occasionally one or two blood parameters have been measured in a recently caught or shot sample of wild baboons (McGill, Strong, Holman & Werthessen 1960; van der Watt, Kotze, Kempff, du Plessis & Laubscher 1973). This paper presents blood data from two troops of wild chacma baboons (*P. ursinus*) which have been under behavioural observation for several years. The purpose of this study is two-fold. First, it provides baseline data for a wide range of whole blood and serum constituents from baboons feeding on a natural diet, which can be compared to similar statistics from captive animals. While the precise nutritional composition of any natural diet of *P. ursinus* has not been established, it has been shown that the animal protein component at least is considerably lower than that provided for captive baboons (Hamilton & Busse 1978, National Academy of Sciences 1978).

The second aim of this study is to investigate the effects of several environmental, physiological and behavioural variables on blood vlaues. Of particular interest, in view of the concurrent behavioural observations, is the relationship between dominance status and physiological profile. Recent detailed studies on food intake in wild baboon populations, including the one sampled here, have suggested that dominance status may affect both the quality and quantity of food eaten, and consequently be positively related to an individual's nutritional status (Hamilton & Busse 1978; Post 1978; Hamilton & Busse pers. comm.).

Methods

The baboons sampled belonged to two troops living in the Okavango Swamp, Botswana, southern Africa. Both troops have had a stable population during the seven years in which they have been under observation (Busse pers. comm.). Sixty-three baboons were immobilized from August 1979 to March 1980 using a blow-dart system with the drug ketamine hydrochloride (Vetalar; Parke-Davis, Detroit, U.S.A.) or phencyclidine hydrochloride (Sernylan; Bio-Ceutic Laboratories Inc., St. Joseph, U.S.A.) (Melton 1980). All were captured as early in the morning as possible to standardize blood data.

As soon as an individual was immobilized and moved out of sight of the other members of the troop, a 10-ml blood sample was taken from the femoral vein. Two blood slides were prepared immediately, and the remainder of the blood was divided between an ordinary glass tube and one containing the anticoagulant EDTA for later analysis in the field laboratory.

Other data collected from the immobilized animal were as follows. Tooth eruption was examined to estimate age up to six years (Freedman 1962; Reed 1965, 1967). Tooth impressions were taken of the upper molariform teeth using dental alginate and a specially made series of metal tooth trays. An index of relative age from tooth wear was later calculated by summing the anterior and posterior occlusal breadths of molars M_1 and M_2 measured to 0,1 mm with calipers on the positive dental stone caste.

Each baboon was weighed to the nearest 0,1 kg by suspending it on a canvas sling from a 50 kg scale. The reproductive state of females was described as immature, cycling, pregnant or lactating. Testicular volume of males was calculated from the minimum (a) and maximum (b) diameters to be $4\pi a^2 b$ assuming an approximate spheroid shape.

All serum and haematological analyses were carried out within four hours of collection. Serum was collected by centrifugation. Serum chemical analyses, and haemoglobin, were performed with the Bio-Dynamics Unitest System (Bio-Dynamics, Indianapolis, U.S.A.) using a Unimeter 300 and prescribed colorimetric methods. Packed cell volume (PCV) was determined by the microhaematocrit method (Dacie & Lewis 1975). Red and white cell counts were made using the Unopette system (Becton-Dickinson, Rutherford, U.S.A.) and a Brite-Line manual haemocytometer at $\times 400$ and $\times 100$ magnification respectively. Blood slides were fixed in 100% methanol and kept for later examination of blood parasites.

Data on relative dominance rank of males and females was provided by Busse (pers. comm.) based on feeding displacement observations. In order to quantify the effects of variables on blood assays, all blood data were analysed by stepwise multiple linear regression using the Statistical Package for the Social Sciences (SPSS) program Regression (Draper & Smith 1966). This statistical method has been used previously by Huser (1970) for the analysis of multispecies primate blood data. The general form of the regression is:

$$Y' = A + B_1X_1 + \ldots . B_kX_k$$

where Y' represents the estimated value of Y (a blood parameter), A is the Y intercept and the B_i are partial regression coefficients. A partial regression coefficient, say B_1 above, stands for the expected change in Y with a change of one unit in X_1 when all other X_i are held constant. Variables were added to the equation in order of decreasing significance until an F value denoting $P > 0,05$ was reached for a single additional independent variable. Thus the formulae include only those variables believed to exert a significant effect on blood values. It is stressed, though, that different combinations of variables produce different F values, so the results given are not unique for this set of data. The results could also be further modified by the inclusion of additional 'X' parameters not measured.

Direct examination of scatter-plots of residuals indicated that a linear model was acceptable for all regression analyses.

Results and Discussion

Mean values for serum and whole blood constituents

The mean values, standard deviations and ranges of serum and whole blood constituents for all animals sampled are given in Table 1. These data allow for a general comparison with results from previous studies; the effects of boundary conditions on blood values are examined later.

Table 1 Mean values, standard deviations and ranges for whole blood and serum constituents for 63 baboons (*P. ursinus*) sampled from August 1979 to March 1980, in the Okavango Swamp, Botswana

Blood parameter	Mean	Standard deviation	Range
Haemoglobin (g/dl)	11,4	1,2	7,9 – 15,8
PCV (%)	39,1	3,4	30 – 49
RBC ($\times 10^6$/ml)	5,4	0,6	4,26 – 6,97
MCV (fl)	72,7	5,6	59,9 – 88,7
MCH (pg)	21,3	1,9	16,8 – 25,6
MCHC (%)	29,3	1,5	26,3 – 35,6
WBC ($\times 10^3$/ml)	9,6	2,4	5,2 – 16,1
Total protein (g/dl)	6,6	0,5	4,6 – 7,4
Albumin (g/dl)	3,7	0,5	2,4 – 4,4
Globulin (g/dl)	2,9	0,5	1,6 – 4,2
Albumin:Globulin	1,3	0,3	0,5 – 1,9
Blood urea nitrogen (g/dl)	11,9	5,6	2,3 – 24,9
Cholesterol (mg/dl)	71,2	18,3	31 – 150
Total lipids (mg/dl)	349,3	44,0	153 – 460
Glucose (mg/dl)	74,5	22,4	45 – 188
Phosphorus (mg/dl)	4,9	1,4	2,4 – 8,1
Calcium (mg/dl)	8,1	0,8	6,1 – 10,9
Alkaline phosphatase (King-Armstrong Units)	29,9	14,6	12,6 – 70,1

The sample consisted of 31 females including 27 adults, three 3 – 4 year-olds and one less than one year, and 32 males, including 15 adults, eight 5 – 6 year-olds, seven 3 – 4 year-olds and two less than one year. For the females four were classed as immature, eight were cycling, five were pregnant and fourteen lactating. Individual weights ranged from 1,4 kg for an infant male to 30,4 kg for the largest adult male.

Most values are similar to those which have been found for laboratory populations of *P. ursinus* (Van Zyl & Kerrich 1955; Weber *et al.* 1971; Steyn 1975; Steyn *et al.* 1975). The mean blood urea nitrogen (BUN) value of 11,9 mg/dl, however, is much lower than mean values of 38 – 48 mg/dl reported by Weber *et al.* (1971) and Steyn *et al.* (1975). The latter authors suggested that these high BUN values might be characteristic of the chacma baboon, but it is apparent that in the wild, BUN values of *P. ursinus* are comparable to the lower values which have been found for East African *Papio* species (De La Pena & Goldzieher 1967; De La Pena *et al.* 1970; McCraw & Sim 1972). As BUN is positively correlated to the amount of

protein in the diet (Eggum 1974) these differences may be dietary in origin.

Cholesterol levels, although considerably lower than those of 100 mg/dl and higher reported for captive *P. ursinus*, are similar to values obtained for both newly captured *P. ursinus* (85 mg/dl, Van der Watt *et al.* 1973) and wild East African *Papio* sp. (78 mg/dl, McGill *et al.* 1960). Total lipid values are lower than those found for any age group of *P. ursinus* by Van Zyl & Kerrich (1955) but are similar to those from captive East African *Papio* sp. (De La Pena & Goldzieher 1967; De La Pena *et al.* 1970). Again, these differences between captive and wild populations seem most likely to be dietary in origin. Although the relationship between dietary and serum lipids is controversial and some genetic component is probably also involved, several studies have produced elevated cholesterol levels in baboons by altering the amount and composition of dietary fat (e.g. Savage & Goldstone 1965; Mott, McMahan & McGill 1978).

Albumin values are slightly higher, and calcium and glucose levels slightly lower, than have been found in laboratory populations of *P. ursinus*. The low glucose levels suggest that the early-morning sampling procedure did approximate a fasting sample, and in addition indicate an absence of stress-related alterations in blood chemistry resulting from the capture method (Steyn *et al.* 1975).

Both haemoglobin and mean corpuscular haemoglobin (MCH) values are lower than those in captive *P. ursinus*; De La Pena & Goldzieher (1967) and Huser, Rieber, Sheehy & Berman (1967) found similar low haemoglobin levels in East African *Papio* species. Foy, Kondi & Mbaya (1965) found lower haemoglobin values in recently caught baboons than in those which had been in captivity for 1 – 3 years.

The differences found here between blood values from wild and captive baboons could all result from differences in diet, in particular to the lower amount of fat and protein from animal sources found in natural diets. The overall similarity of blood profiles between these two groups, however, indicates that the baboons studied here are not suffering from a nutritionally inadequate diet, as suggested by Foy *et al.* (1965) for wild East African *Papio* species. This is in agreement with van der Watt *et al.* (1973) who observed that recently caught *P. ursinus* showed no signs of any dietary deficiencies.

Effects of physiological, environmental and behavioural variables on blood assays

A list of the variables examined for their effect on blood assays is given in Table 2. The regressions for all blood parameters are given in Table 3 and a summary of the importance of the different variables in affecting blood values is given in Table 4.

Variables which affected blood assays

Five variables frequently affected blood values; these were FPREG, AGE, SEX, WATE and SEAS (see Table 2). Of these pregnancy had the most marked effect on blood values, resulting in significantly lower values for nine of the 18 parameters measured: haemoglobin, PCV, RBC, total protein, albumin, albumin:globulin ratio, cholesterol, total lipids and calcium. Pregnancy in captive baboons has previously been associated with a decrease in haemoglobin, PCV and RBC (Berchelmann & Kalter 1973) as well as cholesterol (Van Zyl 1955; McGill, Mott & Bramblett 1976).

Increasing age as quantified by age class was related to reductions in five blood parameters: mean corpuscular

Table 2 Variables examined for their effects on blood assays

Variable types	Specific variable	Code name	Continuous or discontinous	Units
Food intake effects	Time of day	TIME	Cont.	h
	Month	SEAS	Dis.	1 – 8 (months Aug. – March)
Immobilizing drugs	Elapsed time from darting to sampling	STIM	Cont.	min
	Vetalar total dose	KDRUG	Cont.	mg/kg
	Sernylan total dose	SDRUG	Cont.	mg/kg
Age	Age by tooth eruption	AGE	Dis.	1 – 6+ yr
	Age by tooth wear (occlusal widths)	TAGE	Cont.	mm
	Weight	WATE	Cont.	kg
Reproduction	Sex	SEX	Dis.	male or female
	Female sexually immature	FIMM	Dis.	yes or no
	Female cycling	FCYC	Dis.	yes or no
	Female pregnant	FPREG	Dis.	yes or no
	Female lactating	FLAC	Dis.	yes or no
	Male sexual maturity index (testis volume)	REPM	Cont.	ml
Behaviour	Dominance status	DOM	Dis.	1 – *n*
Disease	Presence of blood parasites	BDIS	Dis.	yes or no

Table 3 Regression formulae for eighteen blood parameters

Regression[a]	df regression	df residual	F	Overall sig.
Hgb(g/dl) = 11,2 − (1,6×FPREG[c]) + (0,8×male[c])	2	60	11,4	$P<0,005$
PCV(%) = 38,4 − (4,4×FPREG[c]) + (2,1×male[d])	2	60	12,4	$P<0,005$
RBC(×10^6/ml) = 5,45 − (0,7×FPREG[d])	1	61	7,4	$P<0,01$
MCV(fl) = 67,6 + (0,3×WATE[c])	1	62	9,4	$P<0,005$
MCH(pg) = 21,1 + (0,03×REPM[c]) − (1,0×SDRUG[c])	2	60	6,8	$P<0,005$
MCHC(%) = 25,9 + (0,4×SEAS[c]) + (0,4×TIME[c]) − (0,3×AGE[c])	3	59	13,8	$P<0,005$
WBC(×10^3/ml) = 8,2 + (0,02×STIM[c]) + (1,9×FCYC[c])	2	60	4,4	$P<0,05$
TP(g/dl) = 6,3 − (1,1×FPREG[c]) + (0,01×TAGE[d])	2	60	21,7	$P<0,005$
Alb(g/dl) = 4,3 − (1,0×FPREG[c]) + (0,3×FLAC[c]) − (0,1×AGE[c])	3	59	23,7	$P<0,005$
Glob(g/dl) = 2,7 − (0,6×FIMM[c]) + (0,7×SEAS[d])	2	60	9,5	$P<0,005$
A:G(ratio) = 2,0 − (1,0×AGE[c]) − (0,4×FPREG[c]) − (0,05 × SEAS[d])	3	59	9,5	$P<0,005$
BUN(g/dl) = 10,6 + (5,9×FLAC[c])	1	61	14,6	$P<0,005$
CHOL(mg/dl) = 77,7 − (30,8×FPREG[c]) + (0,9×KDRUG[c]) + (9,9×SDRUG[d]) − (1,0×WATE[d])	4	58	21,4	$P<0,005$
TL(mg/dl) = 403,6 − (2,9×WATE[c]) − (62,3×FPREG[c])	2	60	12,9	$P<0,005$
Phos(mg/dl) = 6,3 − (0,3×AGE[c]) + (0,7×male[c])	2	60	6,8	$P<0,005$
Gluc(mg/dl) = 74,5[b]	No significant variables			
Ca(mg/dl) = 9,0 − (1,5×FPREG[c]) − (0,05×WATE[c])	2	62	18,5	$P<0,005$
Alk. Phos. (King-Armstrong Units) = 66,8 − (7,7×AGE[c]) + (13,2×male[c]) − (0,1×REPM[c])	3	59	77,1	$P<0,005$

[a]See Table 2 for code name explanations.
[b]Mean value given.
[c]Significance for individual variable $P<0,005$.
[d]Significance for individual variable $P<0,01$.
[e]Significance for individual variable $P<0,05$.

Table 4 Variables classified by their observed effects on blood assays[a]

Variables which frequently affected blood assays	Variables which occasionally affected blood assays	Variables which did not affect blood assays
FPREG (9)[b]	FLAC (2)	BDIS
AGE (5)	REPM (2)	DOM
SEX (4)	SDRUG (2)	
WATE (4)	STIM (1)	
SEAS (3)	TIME (1)	
	KDRUG (1)	
	TAGE (1)	
	FIMM (1)	
	FCYC (1)	

[a]See Table 2 for code name explanations.
[b]Number of times variable found significant (at least $P<0,05$).

haemoglobin concentration (MCHC), albumin, albumin: globulin ratio, phosphorus and alkaline phosphatase. Alkaline phosphatase levels are elevated during periods of active growth in man and other animals (Latner 1975) and the inverse relationship between age class and alkaline phosphatase activity found here confirms previous observations made on captive baboons (McCraw & Sim 1972). Berchelmann & Kalter (1973) reported elevated haematological values in neonatal baboons; the only very young (2 months old) baboon sampled here also had relatively high haemoglobin (12,8 g/dl), PCV (44) and RBC (6,97 × 10^6) values. Several workers (Van Zyl & Kerrich 1955; Baeder 1965; McGill *et al.* 1976) have also reported higher cholesterol and total lipid values in infant baboons than in adults. Although no significant relationship between age class and either of these chemicals was obtained here, this is probably due to the small sample size of young baboons. Only three baboons less than one year were sampled; their values for both cholesterol (125; 108; 150 mg/dl) and total lipids (375; 460; 410 mg/dl) were considerably above the mean values for all baboons.

Males were found to have significantly higher haemoglobin, PCV, phosphorus and alkaline phosphatase than females. Previous workers have also found these values to be higher in captive male baboons (Weber *et al.* 1971; McCraw & Sim 1972; De La Pena *et al.* 1970; Steyn *et al.* 1975). In addition, several other sex differences have been noted in various studies; these include elevated albumin, albumin:globulin ratio, BUN and RBC values, and lower cholesterol and glucose levels in males (De La Pena *et al.* 1970; Steyn *et al.* 1975).

Changes in blood chemistry related to weight are intimately bound to sex differences, age effects and the effect of increasing sexual maturity. Here increasing weight by itself was associated with significantly lower cholesterol, total lipids and calcium, and higher mean corpuscular volume (MCV). Van der Watt *et al.* (1973) recorded lowered cholesterol in newly captured *P. ursinus* > 10 kg *cf.* < 10 kg.

As the season of sampling changed from winter through spring to summer there was a significant increase in MCHC and globulin and a decrease in the albumin: globulin ratio. Huser *et al.* (1967) found MCHC, along with several other haematological parameters, to decrease in iron-deficient *Papio* species; the lower value in winter could be due to this or another dietary cause. Haematological values in primates may also be affected by protein deficiency (Worthington & Alvares 1978), and variations in a number of dietary constituents have been shown to produce altered serum chemical levels in captive baboons (Foy, Kondi & Mbaya 1964; Buss & Reed 1970; Mott *et al.* 1978). The few seasonal differences in blood values found for this population give no evidence of nutritional stress at any time of the year.

The above results emphasize the necessity of defining boundary conditions when describing normal blood values. For this study population, reproductive state, particularly pregnancy, and the age and size of individuals are the variables which had the most significant effects on blood assays.

Nine variables occasionally affected blood assays significantly.

Lactation was associated with increased BUN and albumin. Elevated cholesterol and total lipids have been found previously in lactating baboons in captivity (Van Zyl 1955).

Increased amounts of Sernylan used per kg were associated with increased cholesterol and lowered MCH, while increasing the Vetalar dose resulted in increased cholesterol. Any possible causal relation of these findings remains unclear; phencyclidine anaesthesia has previously been associated with haemodilution (Steyn 1975) and hence would be expected to result in lowered serum chemical values.

The elapsed time between darting and taking blood was only just significantly related to increased WBC. Steyn (1975) showed significant decreases in several haematological and serum parameters with increased time between Sernylan administration and sampling. The consistent capture procedure used in this study probably resulted in too little variation in the elapsed time to detect any comparable effects on blood assays.

As stated above, baboons were immobilized as early in the morning as possible. Time of day of sampling was only just significantly related in increased MCHC. The lack of association of any of the assays, particularly glucose and BUN, with a later time of day suggests that even for the later sampled baboons food intake that day had no effect on blood values.

Total protein increased with age determined from tooth wear. It has been described above how globulin increased with age class while albumin decreased. These findings could result from higher infection rates in very old baboons with worn teeth, causing both increased globulin and total protein levels; however no correlation was found between age and infection with *Hepatocystis* sp., the only blood parasite found in these baboons.

Immature females showed lower globulin values whereas cycling females had increased white blood cell counts. Finally testis volume, the index of male sexual maturity, was positively related to lowered alkaline phosphatase and increased MCH.

Variables which did not affect blood assays

Neither the presence of blood parasites nor the dominance ranking of an individual was found to affect blood assays.

Forty-eight percent of animals sampled were infected with *Hepatocystis* sp. gametocytes. This parasite is particularly common in baboons (Foy *et al.* 1965; Huser *et al.* 1967; Berchelmann & Kalter 1973). Huser *et al.* (1967) observed lower haematological values in an infected baboon compared to non-infected baboons. Berchelmann & Kalter (1973) found increased *Hepatocystis* infection rates to result in a drop in haemoglobin and an increase in total WBC counts, although they observed no obvious clinical symptoms in infected baboons. The carrier levels found here were presumably not detrimental to the baboons' health.

The lack of significance of dominance status of both males and females in affecting blood assays suggests that at the time of this study supplanting at food sites had no appreciable effect on nutrient intake and animal condition, even during winter. This interpretation is in agreement with the absence of seasonal effects on blood values. Nonetheless, it is still possible that under severe environmental conditions dominance status could be important in the acquisition of an adequate diet and concommitant good health. In addition to an absence of long-term dietary effects, there is no evidence of short-term changes in blood chemistry due to nervousness or excitement (for example glucose elevation, as suggested by Steyn *et al.* 1975) in baboons of low social status.

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