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# HEMATOLOGICAL AND SERUM CHEMISTRY NORMS FOR SANDHILL AND WHOOPING CRANES

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***Abstract:*** The normal values used as a diagnostic tool and for comparison of cranes were established in the early 1970's. In that early study, no effort was made to look at factors such as age, sex, or subspecies. In addition, during the early study disease problems (primarily disseminated visceral coccidiosis) and nutritional problems were undiagnosed and uncontrolled. For 2 years during the annual health examinations of cranes at the USGS Patuxent Wildlife Research Center (Patuxent), we collected blood from healthy cranes for analysis. We found significant differences between the values reported from the 1970's and the values seen in this study for 8 blood parameters for Florida sandhill cranes (*Grus canadensis pratensis*), 6 blood parameters for greater sandhill cranes (*G. c. tabida*), and 6 blood parameters for whooping cranes (*Grus americana*). In addition, there were significant differences for some hematology and serum chemistry values based on the age of the cranes.

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**Key words:** blood counts, clinical pathology, cranes, *Grus americana, Grus canadensis,* hematology, serum chemistry.

The current program to breed endangered cranes at Patuxent was established by the Bureau of Sport Fisheries and Wildlife expressly for the scientific study and propagation of species "whose survival could not be assured by existing methods" (Erickson 1968). The program currently houses 40 endangered whooping cranes for breeding purposes plus approximately 25–30 juveniles awaiting release to the wild. In addition, 80–90 Florida sandhill cranes and a similar number of greater sandhill cranes are housed at the research center for use in various scientific studies to benefit the endangered whooping crane population.

The normal clinical pathology values (hematology and serum chemistries) used for comparison today are based on values obtained in 1973–75 at Patuxent by Gee et al. (1981). The results from that study were based on only 15 whooping cranes and 15–20 sandhill cranes (but no effort was made to identify or separate the subspecies of sandhill cranes). Although the cranes used in the 1973–75 study appeared to be in relatively good health, we now know that there were serious disease problems (primarily disseminated visceral coccidiosis, Carpenter et al. 1979, 1980, 1984) and nutritional problems (Serafin 1982) in the captive cranes at that time. Since 1975, several diseases present in the captive cranes have been identified and controlled (Carpenter et al. 1979, 1980, 1984, Olsen and Carpenter 1997). In addition, a major nutritional study conducted in the late 1970's (Serafin 1982) identified dietary problems that have since been corrected. Also, since 1975, many advancements have been made in developing more precise methods for measuring clinical serum chemistry values. All of these factors led to this 2-year study to identify new standard values for blood parameters in captive cranes.

Several additional hematological and serum chemistry tabulations have been done since 1975. A study completed by Carpenter (1986) reported several important species differences between whooping cranes and sandhill cranes. A second compilation of blood parameters (Olsen et al. 1996) produced a table of normal hematologic and serum chemistry values for healthy cranes of 6 different species and pediatric values for sandhill cranes, all held in captivity at Patuxent or the International Crane Foundation, Baraboo, Wisconsin, USA. Other than looking at pediatric values, no study has focused on age-related differences in cranes, yet we now have a population ranging in age from 0–37. Age-related differences could be important in diagnosing and monitoring disease conditions in cranes of varying ages.

## METHODS

Standard methods (Dein 1984, Olsen et al. 1996) were used to collect blood samples from clinically healthy cranes during the annual health examinations conducted at Patuxent during September through November, 1996 and 1997, and from healthy young whooping cranes being tested for release (October 1996 through January 1997 and October 1997 through January 1998). Blood samples were collected from

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the right jugular vein using sterile techniques and were stored until processed in Becton Dickinson vacutainers (models 6510-6A901, 6385-5B155, or 6388-5C011, Becton Dickinson VACUTAINER Systems, Franklin Lakes, New Jersey, 07417-1885, USA). Blood smears for "differentials" were made using the 2-cover-slip technique (Dein 1984) and stained with Diff Quick (Jorgensen Laboratories, Loveland, Colorado 80538, USA). White blood cell counts were calculated from a heterophyll/eosinophil count performed using a Becton Dickinson Eosinopil Unopette (#5877, Becton Dickinson) and corrected with the results from the differential count. Serum chemistry values were run on a Dupont Chemistry Analyzer (Dupont, Medical Products Department, Wilmington, Delaware, 09898, USA) or were run by an outside commercial laboratory (Antech Diagnostics, Farmingdale, New York, 11735, USA). Some samples were divided in half and serum chemistry was performed both at Patuxent and by the commercial laboratory to check for accuracy.

Significant differences among the 3 crane groups were detected using Tukey's studentized range test under the general linear model procedure of SAS (SAS Institute, Inc. 1988). To compare the means from the 1973–75 study (Gee et al. 1981) with the results from this study, a Student's t-test was used. Age related differences were detected using a

**Table 1. Means and standard deviations of blood parameters for captive Florida sandhill cranes, greater sandhill cranes, and whooping cranes at USGS Patuxent Wildlife Research Center with a comparison of values among the 3 crane groups (Tukey test, see footnote).**

| Variable | Florida Sandhill Cranes | | | Greater Sandhill Cranes | | | Whooping Cranes | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | *n* | Mean | SD | *n* | Mean | SD | *n* |
| Heterophils ( %) | 66.4[a] | 11.0 | 50 | 64.1[a] | 5.2 | 33 | 63.7[a] | 11.7 | 40 |
| Lymphocytes (%) | 31.1[a] | 11.1 | 50 | 34.2[a] | 5.1 | 33 | 32.3[a] | 9.3 | 40 |
| Monocytes (%) | 1.0[a] | 1.2 | 50 | 0.5[a] | 0.6 | 33 | 1.2[a] | 1.8 | 40 |
| Eosinophils (%) | 1.3[a] | 1.0 | 50 | 1.2[a] | 1.1 | 33 | 2.6[a] | 3.5 | 40 |
| H/E count (No./mm$^3$) | 8185[a] | 3185 | 50 | 6262[a] | 1893 | 30 | 9467[b] | 2570 | 40 |
| White blood cells (No./mm$^3$) | 11968[a] | 3705 | 50 | 9610[a] | 2863 | 30 | 14472[b] | 4114 | 40 |
| Hematocrit (%) | 36.9[a] | 6.4 | 50 | 39.1[a] | 3.6 | 30 | 39.6[a] | 3.5 | 40 |
| Total solids (g/dl) | 3.9[a] | 0.5 | 50 | 4.1[a] | 0.5 | 30 | 4.2[a] | 0.4 | 40 |
| Glucose (mg/dl) | 252[a] | 24 | 50 | 248[a] | 34 | 33 | 241[a] | 29 | 40 |
| Total protein (g/dl) | 3.0[a] | 0.4 | 50 | 3.0[a] | 0.4 | 33 | 3.3[b] | 0.4 | 40 |
| Albumin (g/dl) | 1.4[a] | 0.2 | 50 | 1.4[a] | 0.1 | 33 | 1.5[b] | 0.2 | 40 |
| Globulin (g/dl) | 1.7[a] | 0.3 | 50 | 1.6[a] | 0.3 | 33 | 1.8[a] | 0.3 | 40 |
| Albumin/globulin | 0.85[a] | 0.20 | 50 | 0.94[a] | 0.16 | 33 | 0.89[a] | 0.18 | 40 |
| Alkaline phosphatase (IU/l) | 479[a] | 334 | 50 | 371[a] | 190 | 33 | 169[b] | 78 | 40 |
| Lactic dehydrogenase (IU/l) | 537[a] | 341 | 43 | 234[b] | 83 | 28 | 374[a] | 123 | 33 |
| Creatine kinase (IU/l) | 1784[a] | 2171 | 49 | 284[b] | 129 | 30 | 375[b] | 250 | 39 |
| Aspartase aminotransferase (IU/l) | 196[a] | 53 | 50 | 195[a] | 39 | 33 | 294[b] | 68 | 39 |
| Calcium (mg/dl) | 9.96[a] | 0.91 | 50 | 9.19[a] | 0.73 | 33 | 9.17[a] | 0.53 | 40 |
| Phosphorus (mg/dl) | 4.12[a] | 1.52 | 50 | 3.65[a] | 1.68 | 33 | 3.52[a] | 1.33 | 39 |
| Uric acid (mg/dl) | 9.49[a] | 3.13 | 50 | 6.13[b] | 2.58 | 33 | 5.68[b] | 2.24 | 40 |

[a,b,c] Means with the same letter superscript in any row are not significantly different (alpha = 0.05).

**Table 2. A comparison of blood parameters for Florida sandhill cranes between current and historic values at USGS Patuxent Wildlife Research Center using t-tests to compare means.**

| Variable | Current Values | | Historic Values[a] | | t[b] |
|---|---|---|---|---|---|
| | Mean | *n* | Mean | *n* | |
| Hematocrit (%) | 39.0 | 30 | 44.0 | 20 | 5.93[c] |
| Glucose (mg/dl) | 255 | 27 | 229 | 18 | -2.67[c] |
| Total protein (g/dl) | 3.06 | 27 | 3.90 | 17 | 7.09[c] |
| Albumin (g/dl) | 1.39 | 27 | 1.40 | 18 | 0.19 |
| Alkaline phosphatase (IU/l) | 248.2 | 26 | 184.0 | 18 | -1.67 |
| Lactic dehydrogenase (IU/l) | 267.3 | 26 | 257.0 | 18 | 0.38 |
| Calcium (mg/dl) | 9.23 | 27 | 9.80 | 18 | 3.64[c] |
| Phosphorus (mg/dl) | 3.62 | 27 | 3.60 | 18 | 0.01 |
| Globulin (g/dl) | 1.67 | 27 | 2.30 | 18 | -8.09[c] |
| Albumin/globulin | 0.85 | 27 | 0.56 | 18 | 8.49[c] |
| Uric acid (mg/dl) | 7.83 | 27 | 9.70 | 16 | 4.29[c] |

[a] Historic Values are from Gee et al. (1981).
[b] t = student's t value.
[c] Significance was assumed if $P < 0.05$.

**Table 3. A comparison of blood parameters for greater sandhill cranes between current and historic values at USGS Patuxent Wildlife Research Center using t-tests to compare means.**

| Variable | Current Values | | Historic Values[a] | | t[b] |
|---|---|---|---|---|---|
| | Mean | *n* | Mean | *n* | |
| Hematocrit (%) | 38.0 | 30 | 41.0 | 18 | 2.46[c] |
| Glucose (mg/dl) | 246 | 28 | 264 | 20 | 1.49 |
| Total protein (g/dl) | 2.95 | 28 | 3.90 | 20 | 4.29[c] |
| Albumin (g/dl) | 1.43 | 28 | 1.4 | 20 | 1.25 |
| Alkaline phosphatase (IU/l) | 410.8 | 27 | 146.0 | 20 | -1.14 |
| Lactic dehydrogenase (IU/l) | 239 | 28 | 296 | 20 | 2.34[c] |
| Calcium (mg/dl) | 9.3 | 28 | 9.6 | 20 | 1.95 |
| Phosphorus (mg/dl) | 3.77 | 28 | 3.70 | 20 | 0.05 |
| Globulin (g/dl) | 1.51 | 28 | 2.30 | 20 | -5.06[c] |
| Albumin/globulin | 0.96 | 28 | 0.69 | 20 | 8.21[c] |
| Uric acid (mg/dl) | 5.98 | 28 | 9.70 | 19 | 1.74[c] |

[a] Historic values from Gee et al. (1981).
[b] t = student's t value.
[c] Significance was assumed if $P < 0.05$.

2-way analysis of variance test (ANOVA). Cranes were grouped by age to increase the sample sizes in each category. The 5 age groups were young-of-the-year, 1-year-old, 2–5-years-old, 6–15-years-old, and >15-years-old. The oldest cranes in this study were 35 years old. The age groups were chosen to mirror the life histories of the cranes. Young-of-the-year show juvenile features. One-year-old cranes or yearlings still have some juvenile characteristics but are mature in size, although not sexually mature. Cranes are mature sexually when 2–6 years of age. Cranes 7–15-years-old are the mature breeding cranes generally, and cranes older than 15 years, while still active breeders, may show evidence of aging.

## RESULTS

When comparing the mean results of our study, there were significant differences between whooping cranes and sandhill cranes (either the Florida or greater subspecies) for white blood cell count, total protein, albumin, lactic dehydrogenase, and aspertase aminotransferase (Table 1).

There were significant differences between whooping cranes and greater sandhill cranes for globulin and alkaline phosphatase. Whooping cranes and Florida sandhill cranes had significantly different mean values for uric acid. Finally, Florida and greater sandhill cranes had significantly different values for alkaline phosphatase, creatinine phosphokinase, and uric acid.

Florida sandhill cranes were found to have significantly different values in this study as compared to the Gee et al. (1981) study for hematocrit, glucose, total protein, calcium, globulin, albumin/globulin ratio, and uric acid (Table 2). Greater sandhill cranes showed a similar pattern of differences between this study and Gee et al.(1981). Differences were seen with hematocrit, total protein, lactic dehydrogenase, globulin, albumin/globulin ratio, and uric acid (Table 3).

Whooping crane blood values also significantly varied between this study and the Gee et al. (1981) study. Significant differences were seen in values for hematocrit, total protein, alkaline phosphatase, globulin, albumin/globulin ratio, and uric acid (Table 4).

Examining differences between cranes of various ages, we found significant differences ($P < 0.05$) for hematocrit, alkaline phosphatase, aspartate aminotransferase, calcium, uric acid, lactic dehydrogenase, and creatinine kinase for

Florida sandhill cranes (Table 5). Similar age-related differences were seen for greater sandhill cranes for hematocrit, glucose, aspartate aminotransferase, calcium, phosphorus, albumin/globulin ratio, globulin, and creatine kinase (Table 6). Whooping cranes showed the least number of differences in hematology and serum chemistry based on age, with only hematocrit and alkaline phosphatase having significant differences ($P < 0.05$) based on age (Table 7).

## DISCUSSION

It is no surprise that there are differences among the 3 crane species/subspecies kept at Patuxent. The results point to the uniqueness of each group and to the value of identifying normal blood values for each species or subspecies.

Historically, hematology and serum chemistry values seen in cranes have changed, thus necessitating establishing new standards. Total protein, globulin, albumin/globulin ratio, and uric acid values were all significantly different from the historic normal values reported from the 1970's by Gee et al. (1981). Total protein values are subject to variance depending on the method used. Total protein obtained from plasma can be up to 1.0 g/l higher than that obtained from serum due to the presence of fibrinogen (Lumeij 1987). Furthermore, there is a difference in methodology with readings of serum or plasma taken using a refractometer being consistently higher than those obtained by the biuret method (Lumeij 1987). Indeed, today we refer to the refractometer method as giving us a reading in total solids, not total protein. Even when using the refractometer method to measure serum or plasma total solids, it is now known that it is important to use a temperature compensated refractometer (Fudge 1997).

The uric acid levels in our study were significantly lower in all 3 crane groups as compared to the historic values from Gee et al. (1981). High values for uric acid may be a result of the technique used to obtain the sample or may represent kidney disease (Fudge 1997). In addition, uric acid is synthesized in the kidney (Lumeij 1987). The historic blood samples were collected in the period before disseminated visceral coccidiosis (DVC) was recognized as an important disease in the crane population at Patuxent. Focal granulomatous nodules caused by the causative organisms (*Eimeria gruis* or *E. reichenowi*) form in a number of tissues including the heart, liver, spleen, and kidney (Carpenter 1980, 1984). This may also account for the significant difference seen in greater sandhill cranes between the historic data and current values. Liver or heart damage can lead to elevated levels of lactic dehydrogenase, and these organs are both affected by DVC. For the past 2 decades DVC has been controlled at Patuxent by using coccidiostatic medicines as feed additives (Olsen and Carpenter 1997).

**Table 4. A comparison of blood parameters for whooping cranes between current and historic values at USGS Patuxent Wildlife Research Center using t-tests to compare means.**

| Variable | Current Values | | Historic Values[a] | | t[b] |
|---|---|---|---|---|---|
| | Mean | *n* | Mean | *n* | |
| Hematocrit (%) | 40.0 | 29 | 42.0 | 15 | 1.84[c] |
| Glucose (mg/dl) | 236 | 29 | 232 | 16 | 0.45 |
| Total protein (g/dl) | 3.31 | 29 | 3.80 | 16 | 4.06[c] |
| Albumin (g/dl) | 1.55 | 29 | 1.50 | 16 | -1.06 |
| Alkaline phosphatase (IU/l) | 170.4 | 29 | 46.0 | 16 | 6.17[c] |
| Lactic dehydrogenase (IU/l) | 348.5 | 29 | 440.0 | 16 | 1.59 |
| Calcium (mg/dl) | 8.99 | 29 | 9.10 | 16 | 0.61 |
| Phosphorus (mg/dl) | 3.44 | 29 | 2.80 | 16 | 1.59 |
| Globulin (g/dl) | 1.76 | 29 | 2.30 | 16 | -9.55[c] |
| Albumin/globulin | 0.87 | 29 | 0.65 | 16 | 7.64[c] |
| Uric acid (mg/dl) | 5.95 | 29 | 8.10 | 16 | 2.98[c] |

[a] Historic values from Gee et al. (1981).
[b] t = student's t value.
[c] Significance was assumed if $P < 0.05$.

The results reported in this study should provide a new benchmark to measure the health of the captive crane populations at Patuxent. The results should also be applicable to other institutions keeping these crane species under similar conditions. Because of the large size of the crane flock at Patuxent, we were able to obtain large sample sizes for this study. The methodologies used are well established and standardized at this point in time. Of course, we make these statements on the assumption that the crane population at Patuxent is healthy and that there are no serious unknown diseases at this time. Some of the indicators of the health of the crane population at Patuxent are the record number of eggs and young produced each year and the ages of some of the cranes in the population, with a few of the cranes being 35 years old at the time of the study.

In summary, both a healthier crane population and improvements in sampling techniques have apparently altered the hematological and serum chemistry norms in the Patuxent colony. New standards (as presented herein) need to be used and updated as needed.

**Table 5. Means and standard deviations of blood parameters for captive Florida sandhill cranes at USGS Patuxent Wildlife Research Center by age group (young-of-the-year [0], 1-year-old, 2–5 years-old, 6–15-years-old, and >15-years-old).[a]**

| Variable | 0 (22) | | 1 (4) | | 2–5 (5) | | 6–15 (15) | | >15 (4) | | *P* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | |
| Heterophils (%) | 72.3 | 11.1 | 49.3 | 15.9 | 62.8 | 4.8 | 63.9 | 5.2 | 64.5 | 5.4 | 0.2481 |
| Lymphocytes (%) | 24.3 | 10.6 | 46.8 | 16.5 | 36.2 | 4.8 | 34.7 | 5.2 | 33.8 | 5.1 | 0.1042 |
| Monocytes (%) | 1.5 | 1.3 | 2.5 | 1.3 | 0.4 | 0.5 | 0.2 | 0.4 | 0.8 | 1.0 | 0.0049 |
| Eosinophils (%) | 1.7 | 1.2 | 1.5 | 1.9 | 0.6 | 0.5 | 1.2 | 0.6 | 1.0 | 0 | 0.1553 |
| H/E count (No./mm$^3$) | 9400 | 3690 | 5620 | 1540 | 7380 | 3550 | 7680 | 3485 | 6960 | 1585 | 0.2768 |
| White blood cells (No./mm$^3$) | 12600 | 4310 | 11185 | 1445 | 11485 | 4890 | 11790 | 3290 | 10560 | 1660 | 0.5467 |
| Hematocrit (%) | 33.0 | 7.0 | 44.0 | 3.5 | 38.4 | 1.9 | 39.1 | 0.3 | 40.8 | 6.1 | 0.0058 |
| Total solids (g/dl) | 3.6 | 0.5 | 4.2 | 0.6 | 4.0 | 0.3 | 4.1 | 0.4 | 4.4 | 0.2 | 0.0011 |
| Glucose (mg/dl) | 250 | 23 | 257 | 9 | 249 | 17 | 256 | 30 | 256 | 34 | 0.4792 |
| Total protein (g/dl) | 3.0 | 0.4 | 3.2 | 0.6 | 2.9 | 0.5 | 3.1 | 0.3 | 3.4 | 0.2 | 0.0577 |
| Albumin (g/dl) | 1.3 | 0.1 | 1.5 | 0.4 | 1.3 | 0.1 | 1.4 | 0.1 | 1.6 | 0.1 | 0.0630 |
| Alkaline phosphatase (IU/l) | 759 | 222 | 459 | 513 | 223 | 219 | 231 | 102 | 207 | 95 | 0.0001 |
| Aspartase aminotransferase (IU/l) | 228 | 48 | 232 | 53 | 145 | 26 | 166 | 38 | 160 | 14 | 0.0006 |
| Lactic dehydrogenase (IU/l) | 861 | 247 | -- | -- | 259 | 65 | 290 | 106 | 271 | 115 | 0.0001 |
| Calcium (mg/dl) | 10.7 | 0.7 | 10.0 | 0.5 | 9.2 | 0.2 | 9.2 | 0.5 | 9.4 | 0.4 | 0.0001 |
| Phosphorus (mg/dl) | 4.4 | 1.7 | 4.9 | 0.9 | 4.2 | 2.7 | 3.6 | 1.0 | 3.8 | 0.2 | 0.1459 |
| Albumin/globulin | 0.84 | 0.27 | 0.90 | 0.18 | 0.88 | 0.19 | 0.83 | 0.12 | 0.88 | 0.15 | 0.8053 |
| Globulin (g/dl) | 1.6 | 0.3 | 1.7 | 0.3 | 1.5 | 0.4 | 1.7 | 0.2 | 1.8 | 0.2 | 0.1397 |
| Creatine kinase (IU/l) | 3520 | 2243 | 356 | 174 | 384 | 70 | 368 | 115 | 380 | 133 | 0.0001 |
| Uric acid (mg/dl) | 11.1 | 3.3 | 9.6 | 2.8 | 10.2 | 1.5 | 7.4 | 2.4 | 7.9 | 2.1 | 0.0025 |

[a] Numbers in parenthesis are sample sizes.

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**Table 6. Means and standard deviations of blood parameters for captive greater sandhill cranes at USGS Patuxent Wildlife Research Center by age group (young-of-the-year [0], 1-year-old, 2–5-years-old, 6–15-years-old, and >16-years-old).[a]**

| Variable | 0 (4) | | 1 (1) | | 2–5 (9) | | 6–15 (12) | | >15 (7) | | *P* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | |
| Heterophils (%) | 64.8 | 7.6 | 65.0 | 0 | 63.6 | 5.1 | 62.5 | 5.5 | 67.1 | 3.0 | 0.1764 |
| Lymphocytes (%) | 34.0 | 7.4 | 33.0 | 0 | 35.2 | 5.0 | 35.6 | 5.2 | 30.7 | 2.9 | 0.1453 |
| Monocytes (%) | 0.3 | 0.5 | 0 | 0 | 0.4 | 0.5 | 0.7 | 0.5 | 0.7 | 0.8 | 0.2481 |
| Eosinophils (%) | 1.0 | 0 | 2.0 | 0 | 0.8 | 0.4 | 1.3 | 1.5 | 1.3 | 1.4 | 0.6022 |
| H/E count (No./mm$^3$) | 6340 | 1320 | 1985 | 0 | 6000 | 2060 | 6290 | 1580 | 7460 | 1850 | 0.0651 |
| White blood cells (No./mm$^3$) | 9575 | 1010 | 2961 | 0 | 9385 | 3390 | 9840 | 2280 | 10860 | 2410 | 0.1383 |
| Hematocrit (%) | 41.5 | 0.6 | 42.0 | 0 | 40.9 | 2.8 | 37.7 | 3.6 | 36.6 | 3.9 | 0.0018 |
| Total solids (g/dl) | 3.5 | 0.1 | 3.8 | 0 | 4.3 | 0.4 | 4.2 | 0.5 | 3.9 | 0.5 | 0.8371 |
| Glucose (mg/dl) | 249 | 12 | 295 | 0 | 221 | 39 | 250 | 29 | 272 | 20 | 0.0367 |
| Total protein (g/dl) | 2.4 | 0.1 | 2.8 | 0 | 3.1 | 0.2 | 3.1 | 0.2 | 3.1 | 0.5 | 0.1800 |
| Albumin (g/dl) | 1.3 | 0.1 | 1.4 | 0 | 1.5 | 0.1 | 1.5 | 0.1 | 1.4 | 0.1 | 0.4636 |
| Alkaline phosphatase (IU/l) | 558 | 97 | 242 | 0 | 377 | 116 | 319 | 248 | 364 | 162 | 0.6611 |
| Aspartase aminotransferase (IU/l) | 223 | 19 | 150 | 0 | 199 | 30 | 202 | 49 | 168 | 21 | 0.0106 |
| Lactic dehydrogenase (IU/l) | 364 | 93 | 257 | 0 | 207 | 32 | 222 | 83 | 194 | 42 | 0.0635 |
| Calcium (mg/dl) | 9.7 | 0.4 | 9.1 | 0 | 9.5 | 1.0 | 9.0 | 0.6 | 8.8 | 0.5 | 0.0558 |
| Phosphorus (mg/dl) | 5.1 | 1.4 | 2.8 | 0 | 4.5 | 2.4 | 3.0 | 0.7 | 2.9 | 1.0 | 0.0341 |
| Albumin/globulin | 1.15 | 0.06 | 0.5 | 0 | 0.96 | 0.15 | 0.91 | 0.12 | 0.84 | 0.20 | 0.0069 |
| Globulin (g/dl) | 1.1 | 0.1 | 1.4 | 0 | 1.6 | 0.2 | 1.6 | 0.2 | 1.7 | 0.4 | 0.0125 |
| Creatine kinase (IU/l) | 336 | 0 | 550 | 0 | 343 | 167 | 260 | 97 | 207 | 31 | 0.0381 |
| Uric acid (mg/dl) | 5.3 | 1.5 | 7.1 | 0 | 8.2 | 3.6 | 5.2 | 1.5 | 5.3 | 1.8 | 0.1511 |

[a] Numbers in parenthesis are sample sizes.

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**Table 7. Means and standard deviations of blood parameters for captive whooping cranes at USGS Patuxent Wildlife Research Center by age group (young-of-the-year [0], 1-year-old, 2–5-years-old, 6–15-years-old, and 16-years-old).[a]**

| Variable | 0 (13) | | 1 (3) | | 2–5 (8) | | 6–15 (15) | | >15 (1) | | *P* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | |
| Heterophils (%) | 61.5 | 8.3 | 65.7 | 1.5 | 67.0 | 7.4 | 63.3 | 16.7 | 67.0 | 0 | 0.3762 |
| Lymphocytes (%) | 33.7 | 7.8 | 33.0 | 1.7 | 29.5 | 9.3 | 32.5 | 11.7 | 31.0 | 0 | 0.5568 |
| Monocytes (%) | 1.7 | 2.3 | 0.3 | 0.6 | 1.0 | 1.4 | 1.1 | 1.7 | 7 | 0 | 0.2571 |
| Eosinophils (%) | 2.6 | 3.0 | 2.4 | 1.0 | 3.0 | 3.0 | 2.9 | 4.6 | 2.0 | 0 | 0.9321 |
| H/E count (No./mm$^3$) | 8270 | 2685 | 8115 | 735 | 11690 | 2030 | 9720 | 2285 | 7520 | 0 | 0.1771 |
| White blood bells (No./mm$^3$) | 12950 | 4340 | 12165 | 910 | 16910 | 2480 | 15195 | 4435 | 10900 | 0 | 0.2953 |
| Hematocrit (%) | 41.8 | 3.2 | 42.0 | 2.0 | 38.4 | 2.9 | 37.7 | 3.2 | 42.0 | 0 | 0.0107 |
| Total solids (g/dl) | 4.2 | 0.4 | 3.9 | 0.6 | 4.3 | 0.5 | 4.2 | 0.3 | 3.5 | 0 | 0.8189 |
| Glucose (mg/dl) | 248 | 20 | 240 | 58 | 241 | 33 | 236 | 28 | 211 | 0 | 0.1769 |
| Total protein (g/dl) | 3.2 | 0.4 | 3.4 | 0.2 | 3.4 | 0.5 | 3.5 | 0.3 | 3.6 | 0 | 0.4665 |
| Albumin (g/dl) | 1.5 | 0.1 | 1.5 | 0.2 | 1.5 | 0.2 | 1.6 | 0.1 | 1.7 | 0 | 0.7706 |
| Alkaline phosphatase (IU/l) | 238 | 92 | 183 | 15 | 125 | 38 | 133 | 43 | 105 | 0 | 0.0012 |
| Aspartase aminotransferase (IU/l) | 331 | 80 | 266 | 78 | 282 | 67 | 277 | 52 | 271 | 0 | 0.1476 |
| Lactic dehydrogenase (IU/l) | 334 | 89 | 354 | 77 | 437 | 175 | 345 | 89 | 612 | 0 | 0.4128 |
| Calcium (mg/dl) | 9.3 | 0.4 | 8.9 | 0.2 | 9.3 | 0.8 | 9.0 | 0.5 | 9.4 | 0 | 0.3995 |
| Phosphorus (mg/dl) | 3.7 | 1.1 | 3.0 | 1.2 | 3.7 | 1.3 | 3.4 | 1.7 | 3.0 | 0 | 0.6263 |
| Albumin/globulin | 0.96 | 0.28 | 0.83 | 0.06 | 0.83 | 0.09 | 0.87 | 0.10 | 0.90 | 0 | 0.4294 |
| Globulin (g/dl) | 1.7 | 0.3 | 1.83 | 0.06 | 1.9 | 0.3 | 1.8 | 0.2 | 1.9 | 0 | 0.3295 |
| Creatine kinase (IU/l) | 585 | 266 | 359 | 180 | 285 | 129 | 227 | 138 | 844 | 0 | 0.0553 |
| Uric acid (mg/dl) | 6.3 | 3.0 | 6.0 | 2.0 | 5.3 | 1.3 | 5.0 | 1.6 | 10.1 | 0 | 0.8017 |

[a] Numbers in parenthesis are sample sizes.

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