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# BLOOD SERUM ELECTROLYTES IN A COLORADO MULE DEER POPULATION*

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*Abstract:* Means (± SD) of serum electrolytes sampled from 21-32 male and 32-65 female Rocky Mountain mule deer *(Odocoileus hemionus hemionus)* 18 months and older collected yearlong were: sodium, 148.5 ± 19.0 and 148.8 ± 17.8 meq/liter; potassium, 8.88 ± 2.12 and 8.74 ± 2.13 meq/liter; calcium, 6.44 ± 1.58 and 6.13 ± 1.31 meq/liter; magnesium, 3.11 ± 0.95 and 3.34 ± 1.14 meq/liter; and inorganic phosphorus, 7.27 ± 1.03 and 7.82 ± 2.70 mg/100 cc, respectively. Significant ($P < 0.05$) between-sex differences were limited to higher mean calcium values in 6-11 month old females. Significant age class differences occurred only in mean potassium and inorganic phosphorus among males and mean calcium among females wherein younger deer had the larger values. Significantly larger seasonal means occurred in potassium of mature females during the spring and summer and in inorganic phosphorus of mature females during the summer. Over a three-year period of decreasing precipitation and browse yields, annual means of sodium and calcium increased in mature deer of both sexes but decreased for inorganic phosphorus in mature females.

## INTRODUCTION

Meir[15] described the functions of electrolytes and pointed out that routine determinations of electrolyte levels in blood samples are potentially useful in assessing the "metabolic effects of various disease states on electrolyte balance in animals." Apparently there are no published base-level values of blood serum electrolytes in a free-ranging Rocky Mountain mule deer population. Such values may be useful in the design and execution of metabolic-disease experiments.

This report provides a statistical description of blood serum sodium, potassium, calcium, magnesium, and inorganic phosphorus by sex, age class, season, and year sampled yearlong from a Rocky Mountain mule deer population.

All deer were collected from a 528-mile[2] (137,000 ha) portion of the Cache la Poudre River drainage which trends easterly through the Front Range within the Roosevelt National Forest in north-central Colorado. This is a generally rugged to precipitous, plutonic, and largely forested region characterized by dendritic drainage patterns and massive rock outcrops. Elevations range from about 5,500 ft (1680 m) to over 12,000 ft (3660 m).

The mule deer population is largely migratory and the 8,500 ft contour line is a useful division between the "winter" (October - May) and "summer" (June - September) ranges of approximately equal area. Deer population levels for the entire sampled area were unknown, 1961-65, but indirect estimates of average

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wintering deer densities on representative portions of the winter range ranged from about 28 to 62 deer/mile,[2] (259 ha), 1961-65.

## MATERIALS AND METHODS

An attempt was made to collect one immature and one mature deer of each sex each month from their seasonal ranges; above about 2600 m elevation from June through September and below this elevation during the remainder of the year. The elevations of deer collection sites ranged from about 1680 m to 3320 m and averaged about 2440 m. Most deer were shot through the spine in the thoracic or cervical region. Mean (± SD) times of death were 9:15 ± 5:35 hr for males and 8:32 ± 3.39 hr for females. Immediately after shooting, about 100 ml of blood was aspirated from the heart and flushed into two 60 ml centrifuge tubes. The mean (± SD) number of minutes which elapsed between death and blood sampling was 4.7 ± 4.1 for males and 4.8 ± 3.7 for females. The samples were transported to the laboratory in an insulated container and refrigerated in an upright position until a clot formed leaving the serum in separate phase. The serum was decanted, centrifuged on the day of death until clear, and stored in a freezer until analyzed by a commercial laboratory. The dates of analyses for serum sodium, potassium, magnesium, and calcium were not recorded for 13 male and 24 female deer. For the remaining deer, the mean (± SD) number of days from death to analysis of these electrolytes were 32.7 ± 29.3 for 43 male and 33.1 ± 28.7 for 56 female deer. Analysis of serum inorganic phosphorus occurred 42.5 ± 26.5 days and 43.6 ± 25.0 days following the deaths of 33 male and 41 female deer, respectively. Values from hemolyzed samples are excluded herein. Sampling periods were April 13, 1961 to April 27, 1965 for serum sodium, potassium, and magnesium; April 27, 1962 and April 27, 1965 for serum calcium; and January 2, 1963 to April 27, 1965 for serum inorganic phosphorus. Serum sodium and potassium were estimated by flame photometry,[5] serum calcium and magnesium by titrametric procedures,[10] and serum inorganic phosphorus by a colorimetric procedure.[9]

The age of each deer was estimated to the nearest month by molariform tooth replacement chronology for deer with temporary dentition[16] and by counting dental cementum annuli in stained, transverse sections of the first incisor[6] for deer with permanent dentition. A June birth date was assumed for this population.[1] Deer were segregated into four age classes; 1-5, 6-11, 12-17, and 18 or more months of age based on the "growth stanzas" of this race[21] and reproductive phenology. A mature deer herein is about 18 months and older.

An autopsy, which included a cursory qualitative search for parasites, dissection of organs and glands, and examination of the skeleton, was performed on each carcass. Obvious lesions were recorded and materials submitted to the College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, for diagnosis.

Means of two variables were tested for significant differences with the *t*-test for unequal variances with the degrees of freedom computed and rounded to the nearest integer.[11] Regression analysis was used to investigate the separate effects of (1) estimated age (X) and (2) time elapsed between death and blood sampling (X) on each serum electrolyte (Y). Tests of significance are at $P < 0.05$ unless otherwise stated.

## RESULTS

### Sex and age class variation

Statistical descriptions and the results of significance tests for the five blood serum electrolytes are summarized by sex and age class in Table 1. Significant differences between the means of males and females occurred only for serum calcium in deer about 6-11 months old. Significant differences between age classes occurred for serum potassium and inorganic phosphorus among males and for serum calcium among females. In general, the younger age classes had

TABLE 1. Sex and age class variation in 5 blood serum electrolytes sampled yearlong from mule deer, 1961-65.

| Electrolyte | Age Class (months) | Male N | Male Mean | Male SD | Male Range | Female N | Female Mean | Female SD | Female Range |
|---|---|---|---|---|---|---|---|---|---|
| Sodium | 1-5 | 4 | 146.2 | 16.5 | 135-170 | 4 | 158.8 | 25.0 | 125-185 |
| (meq/liter) | 6-11 | 9 | 147.1 | 23.1 | 130-190 | 5 | 155.0 | 9.4 | 140-165 |
| | 12-17 | 11 | 146.7 | 14.7 | 130-175 | 6 | 140.0 | 18.9 | 120-170 |
| | 18+ | 32 | 148.5 | 19.0 | 109-180 | 65 | 148.8 | 17.8 | 116-190 |
| Potassium | 1-5 | 4 | 10.00 | 3.33 | 6.8-14.6 | 4 | 12.78 | 4.84 | 9.8-20.0 |
| (meq/liter) | 6-11 | 9 | 9.78[a] | 2.13 | 6.6-12.9 | 5 | 8.78 | 1.30 | 7.4-10.3 |
| | 12-17 | 11 | 7.38 | 1.44 | 3.9-9.2 | 6 | 8.28 | 1.94 | 4.6-9.7 |
| | 18+ | 32 | 8.88[a] | 2.12 | 4.4-15.7 | 65 | 8.74 | 2.13 | 3.6-13.3 |
| Calcium | 1-5 | 3 | 6.67 | 0.32 | 6.3-6.9 | 3 | 6.63 | 0.59 | 6.2-7.3 |
| (meq/liter) | 6-11 | 7 | 6.14 | 1.45 | 4.0-7.8 | 5 | 7.76[b,c] | 0.42 | 7.3-8.4 |
| | 12-17 | 8 | 6.20 | 1.44 | 3.8-7.8 | 5 | 6.36 | 1.20 | 5.1-7.8 |
| | 18+ | 25 | 6.44 | 1.58 | 3.4-8.4 | 45 | 6.13 | 1.31 | 3.6-8.1 |
| Magnesium | 1-5 | 4 | 2.85 | 0.73 | 2.3-3.9 | 4 | 3.25 | 1.38 | 2.4-5.3 |
| (meq/liter) | 6-11 | 9 | 3.61 | 1.78 | 2.2-7.9 | 5 | 3.04 | 0.79 | 2.2-4.0 |
| | 12-17 | 11 | 3.26 | 0.69 | 2.5-4.2 | 6 | 2.92 | 1.22 | 1.9-5.3 |
| | 18+ | 32 | 3.11 | 0.95 | 0.9-5.4 | 65 | 3.34 | 1.14 | 1.5-7.2 |
| Inorganic | 1-5 | 3 | 9.40[d] | 1.01 | 8.5-10.5 | 3 | 6.83 | 0.35 | 6.5-7.2 |
| Phosphorus | 6-11 | 5 | 8.26 | 1.61 | 7.0-10.8 | 5 | 7.92 | 0.98 | 6.7-9.0 |
| (mg/100 cc) | 12-17 | 4 | 8.48 | 1.07 | 7.5-9.5 | 3 | 7.77 | 1.11 | 6.6-8.8 |
| | 18+ | 21 | 7.27 | 1.03 | 6.1-10.4 | 32 | 7.82 | 2.70 | 4.7-20.2 |

[a] Significantly ($P < 0.02$) greater than the mean of 12-17 month old males.
[b] Significantly ($P < 0.01$) greater than the mean of 18 month and older females.
[c] Significantly ($P < 0.05$) greater than the mean of 6-11 month males.
[d] Significantly ($P < 0.05$) greater than the mean of 18 month and older males.

higher mean levels of these electrolytes but regression analysis did not reveal significant correlations (r) of estimated age (X) with any serum electrolyte (Y). This is probably due to the occurrence of a few extreme values over the entire range of ages. No information has been found on age-serum electrolyte relationships in *Odocoileus* spp. In three breeds of domestic sheep, serum magnesium increased with age, but serum potassium, calcium, and phosphorus decreased in sheep which had reached maturity, and serum sodium was unaffected by age.[12]

In confined and malnourished male white-tailed deer fawns *(Odocoileus virginianus)* sampled February through March, mean serum calcium and inorganic phosphorus values approximated 4.8 meq/liter and 3.6 mg/100 ml, respectively,[19] values well below those from Cache la Poudre mule deer fawns (Table 1). Conversely, the blood plasma of eight male and two female, mainly adult white-tailed deer shot on November 13 from a free-ranging population, averaged higher in inorganic phosphate (9.2 mg/100 cc), sodium (174 meq/liter), and potassium (10.4 meq/liter)[20] than did the serum of adult, Cache la Poudre mule deer during the autumn period (Table 2).

#### Seasonal variation

Analyses of seasonal variation are limited to mature deer because age and season were confounded in the three youngest age classes. Significant differences between seasonal means occurred only in the serum potassium and inorganic phosphorus of females (Table 2). Means of serum potassium were highest during spring and summer. Mean serum inorganic phosphorus was highest during the summer.

Since mean levels of both serum potassium and inorganic phosphorus have been associated with dietary intake in ruminants,[15,18] we examined seasonal variation detected during 1961 in these ions in nine Cache la Poudre forage species.[17] Mean levels of potassium in most forage species were high during the spring but all species peaked during the summer with lows during the autumn and winter. Mean levels of phosphorus were highest in most plant species during the spring or summer and lowest during the autumn and winter. Thus, mean potassium and phosphorus levels in serum and forage appeared to be fairly synchronous. Mean sodium, calcium, and magnesium fluctuated seasonally in forage samples[17] but not in serum samples (Table 2).

Because metabolic requirements for inorganic salts might be expected to increase during antlerogenesis, the apparent lack of significant seasonal variation in the mean levels of any serum electrolyte in mature male mule deer is surprising. Results of experimental studies of plasma calcium in white-tailed and fallow deer *(Dama dama)* are in conflict. Significant seasonal variation in mean plasma calcium did not occur in male white-tailed and fallow deer[8] but did occur in white-tailed deer of both sexes.[14] The former authors postulate that the relative stability of plasma calcium levels may represent a compensatory function of the parathyroid system.

In 30 range cows sampled at 28-day intervals over a 5 year period, there was no consistent seasonal variation in mean plasma calcium.[13] Low levels of mean plasma magnesium in these cows occurred during one of the spring months each year and mean plasma phosphorus peaked during May, June, and July, and reached minimal values during the winter.[13] These authors reported that the winter drop in mean plasma phosphorus was reduced by feeding hay.

#### Annual variation

As inferred from non-overlapping 95% confidence intervals calculated about annual means, serum sodium and calcium of both sexes increased from 1962 to 1964 whereas serum inorganic phosphorus in females decreased from 1963 to 1964 (Table 3). From 1961 to 1964, total annual precipitation within the Cache la Poudre drainage decreased 40-50% accompanied by a 3-to-5-fold reduction in mean yields (primarily linear annual twig growth) of two of three major winter range browse species.[2] The annual increase in serum sodium is in-

TABLE 2. Seasonal variation in 5 blood serum electrolytes sampled from mule deer about 18 months old and older, 1961-65.

| | | Autumn (Sept. 23 - Dec. 22) | | | Winter (Dec. 23 - March 21) | | | Spring (March 22 - June 21) | | | Summer (June 22 - Sept. 22) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electrolytes | Sex | N | Mean | SD | N | Mean | SD | N | Mean | SD | N | Mean | SD |
| Sodium | M | 5 | 147.2 | 13.8 | 11 | 147.9 | 18.0 | 12 | 151.7 | 20.4 | 4 | 142.0 | 27.8 |
| (meq/liter) | F | 10 | 147.4 | 16.5 | 18 | 153.2 | 14.7 | 20 | 148.8 | 17.8 | 17 | 144.8 | 21.5 |
| Potassium | M | 5 | 7.12 | 2.33 | 11 | 9.35 | 2.43 | 12 | 8.98 | 1.55 | 4 | 9.42 | 2.05 |
| (meq/liter) | F | 10 | 7.19 | 1.96 | 18 | 8.18 | 2.72 | 20 | 9.52[a] | 1.07 | 17 | 9.33[b] | 1.94 |
| Calcium | M | 4 | 6.72 | 2.02 | 9 | 6.31 | 1.86 | 9 | 6.91 | 1.01 | 3 | 5.00 | 1.31 |
| (meq/liter) | F | 8 | 5.99 | 0.94 | 13 | 6.16 | 1.36 | 12 | 6.42 | 1.49 | 12 | 5.91 | 1.38 |
| Magnesium | M | 5 | 3.36 | 0.59 | 11 | 3.15 | 1.28 | 12 | 2.95 | 0.63 | 4 | 3.12 | 1.35 |
| (meq/liter) | F | 10 | 3.44 | 1.21 | 18 | 3.36 | 1.04 | 20 | 3.44 | 1.33 | 17 | 3.16 | 1.03 |
| Inorganic | M | 3 | 6.83 | 0.64 | 9 | 7.60 | 0.74 | 8 | 7.18 | 1.39 | 1 | 6.40 | 0.00 |
| Phosphorus (mg/100 cc) | F | 4 | 6.68 | 1.55 | 12 | 8.95 | 4.02 | 10 | 6.81 | 0.82 | 6 | 8.03[c] | 0.89 |

a Significantly ($P < 0.01$) greater than the autumn mean of females.

b Significantly ($P < 0.02$) greater than the autumn mean of females.

c Significantly ($P < 0.05$) greater than the spring mean of females.

TABLE 3. Annual variation in 5 blood serum electrolytes sampled yearlong from mule deer about 18 months of age and older.

| | | Male | | | | Female | | | |
|---|---|---|---|---|---|---|---|---|---|
| Electrolyte | Year | N | Mean | SD | 95% Confidence Interval | N | Mean | SD | 95% Confidence Interval |
| Sodium | 1962 | 7 | 140.0 | 9.7 | 130.3 - 149.7 | 19 | 143.5 | 8.6 | 139.2 - 147.7 |
| (meq/liter) | 1963 | 10 | 155.2 | 22.5 | 138.3 - 172.1 | 15 | 155.7 | 17.2 | 145.8 - 165.5 |
| | 1964 | 9 | 160.6 | 12.1 | 150.7 - 170.4 | 12 | 164.2 | 20.3 | 150.7 - 177.7 |
| Potassium | 1962 | 6 | 8.43 | 4.01 | 4.22- 12.64 | 19 | 7.42 | 2.36 | 6.28- 8.56 |
| (meq/liter) | 1963 | 10 | 9.45 | 1.30 | 8.52- 10.38 | 16 | 9.04 | 2.24 | 7.85- 10.23 |
| | 1964 | 9 | 9.27 | 1.30 | 8.27- 10.27 | 12 | 9.95 | 1.33 | 9.10- 10.80 |
| Calcium | 1962 | 5 | 4.22 | 0.41 | 3.65- 4.79 | 13 | 4.66 | 0.62 | 4.27- 5.05 |
| (meq/liter) | 1963 | 10 | 5.96 | 1.51 | 4.82- 7.10 | 15 | 6.19 | 1.10 | 5.56- 6.83 |
| | 1964 | 9 | 7.64 | 0.35 | 7.36- 7.93 | 12 | 7.38 | 0.46 | 7.08- 7.69 |
| Magnesium | 1962 | 7 | 3.09 | 0.86 | 2.23- 3.95 | 19 | 3.42 | 1.27 | 2.79- 4.05 |
| (meq/liter) | 1963 | 10 | 2.52 | 0.78 | 1.93- 3.11 | 15 | 2.93 | 0.66 | 2.56- 3.31 |
| | 1964 | 9 | 3.17 | 0.95 | 2.39- 3.94 | 11 | 2.76 | 0.51 | 2.41- 3.12 |
| Inorganic | 1963 | 10 | 7.09 | 3.14 | 4.84- 9.34 | 16 | 8.29 | 3.68 | 8.09- 8.49 |
| Phosphorus (mg/100 cc) | 1964 | 9 | 7.09 | 0.45 | 6.74- 7.44 | 12 | 7.28 | 1.01 | 6.64- 7.92 |

explicable. There is little information on the nutritional aspects of sodium but it is the chief cation of extracellular water and of intestinal secretions.[15] Since calcium was found to be relatively high in the leaves of Cache la Poudre forage species, particularly willow *(Salix* spp.),[17] we speculate that the annual increases of leaves of willow and other important forage species observed in the inferred diet (stomach content samples) may have increased the annual levels of serum calcium,[18] 1962-64. Reduced precipitation has been associated with reduced levels of plasma phosphorus in range cows.[13]

#### Pathological variation

In individual animals, serum changes of the order of 3 or 4 meq/liter calcium may result in symptoms of tetany and 2 or 3 meq/liter potassium may be fatal.[8] The extreme ranges of the serum electrolytes in Table 1 suggests the possibility of pathological variation. Inspection of the autopsy records from deer with extreme serum electrolyte values, however, did not reveal lesions which could be related to these extreme values. Unfortunately, autopsy procedures did not include histochemical studies of target organs as reported for sika deer *(Cervus nippon)*.[4]

## DISCUSSION

As tabulated by Benjamin,[3] mean values of serum electrolytes of cattle and domestic sheep compare to those from adult mule deer as follows: sodium — deer higher than cattle but no mean value cited for sheep; potassium — deer higher than both cattle and sheep; magnesium — deer lower than cattle and sheep; inorganic phosphorus — deer slightly higher than cattle and sheep. Extreme values of serum electrolytes in Cache la Poudre mule deer encompassed the extreme values cited by this author for the serum electrolytes of cattle and sheep. In addition to the possible influence of unidentified disease, several other factors unique to migratory mule deer and our collection method probably contribute to the observed variation in serum electrolytes, such as: *dietary differences*—while some Cache la Poudre deer are yearlong residents at lower elevations, most deer migrate to upper elevations and thus the two subpopulations exist on seasonally different dietary regimes; *shock* — resulting from gunshot may increase potassium and phosphorus;[20] *excitement* — prior to death may also increase potassium and phosphorus;[7] *elapsed time between death and blood sampling* — in this study was found by regression analysis to be significantly ($P < 0.05$) related ($r = -0.32$) only to inorganic phosphorus in males. Thus, the means, standard deviations, and tests of significance presented for serum potassium and inorganic phosphorus are likely to be less reliable than those for serum sodium, calcium, and magnesium. Experimental studies with captive deer are needed to assess the effects of the above four factors on serum electrolyte values. Because of our small sample sizes and the many uncontrolled variables inherent in sampling serum electrolytes from migratory mule deer, additional field studies are recommended.

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