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BLOOD AND URINARY PROFILES OF FREE-RANGING DESERT MULE DEER IN ARIZONA

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ABSTRACT: As a corollary to a more comprehensive study on their ecology, we documented blood and urinary profiles for 10 free-ranging desert mule deer (*Odocoileus hemionus crooki*) (five males, five females) captured by net-gun shot from a helicopter during February 1988 in Saguaro National Monument, Arizona. Pursuit with the helicopter for netting deer ranged from 3 to 15 min. Blood profiles included seven hematological characteristics and 12 serum chemistries, electrolytes, hormones and enzymes. Urine samples were assayed for urea nitrogen, creatinine, sodium, potassium, calcium and phosphorus. Urinary data were compared as ratios to creatinine. Serum cholesterol was greater ($P < 0.05$) in males than females. Pursuit time was correlated with serum non-esterified fatty acids ($r = 0.67$, $P < 0.05$) and influenced urinary specific gravity ($r^2 = 0.77$, $P < 0.004$), urea nitrogen : creatinine ($r^2 = 0.79$, $P < 0.005$), and potassium : creatinine ($r^2 = 0.42$, $P = 0.08$) ratios. Increasing specific gravity was related to urinary creatinine concentration ($r^2 = 0.72$, $P < 0.008$). All deer exhibited acute adrenal stimulation, accompanied by elevated serum creatine phosphokinase and urinary potassium : creatinine ratios, which were indicative of acute excitement and muscle trauma associated with the capture process. We demonstrated that urinary data are a valuable supplement to serum data in demonstrating effects of intense physical exertion, and both forms of data emphasize the need to assess capture-related excitability as a source of variation in blood and urine characteristics of free-ranging desert mule deer.

Key words: Desert mule deer, *Odocoileus hemionus crooki*, blood and urinary profiles, net-gun capture, serum chemistry, intense physical exertion, capture-related excitability, field study.

INTRODUCTION

Blood analysis is a common means of assessing the nutritional, disease, and reproductive status of free-ranging deer (*Odocoileus* spp.) (Kitchen and Pritchard, 1962; Seal et al., 1981; Waid and Warren, 1984; Wood et al., 1986) and other ungulates (Seal and Hoskinson, 1978; Hawley and Peden, 1982; Weber et al., 1984; Houston et al., 1986). Multiple sources of variation (e.g., nutrition, condition, season, physical excitement and chemicals used for immobilization) have made it imperative that "reference values" be established for blood characteristics of ungulates occurring in various geographical locations and captured and immobilized by various protocols. Such values are essential to accurate interpretations of physiological data and for valid comparisons of data among studies (Franzmann, 1972; LeResche et al., 1974; Seal et al., 1981; Waid and Warren, 1984; DelGiudice et al., 1987a; Kock et al., 1987a).

Urinalysis also has potential as a means of examining the metabolic response of ungulates to their environment (Hove and Jacobsen, 1975; Keith et al., 1981; Warren et al., 1982; Waid and Warren, 1984; DelGiudice et al., 1987b, 1988b, 1989b); thus, reference values for urinary characteristics also need to be documented.

There has been no documentation of reference values for blood or urinary characteristics in desert mule deer (*O. hemionus crooki*). Our objectives were to report blood and urinary profiles for free-ranging desert mule deer in Arizona and to identify potential effects of capture-related stress on these constituents. These objectives were actually secondary to those of a more comprehensive study of potential effects of human development on seasonal home ranges and habitat relation-

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ships of free-ranging desert mule deer in Arizona. That study required capturing deer by net-gun for radio-collaring. We viewed this as an opportunity to test chemical immobilization and reversal agents (DelGiudice et al., 1989a) and to collect physiological data.

STUDY AREA

Our study area was within the Rincon Mountain District of Saguaro National Monument (Tucson, Arizona, USA; 32°12'N, 110°41'W). The Rincon Mountain District is located on the eastern edge of Tucson; it is bordered on the east, north and south by the Coronado National Forest. The western portion is bordered by residential developments. The entire area is in the Sonoran Desert, characterized by desert scrub habitat (<1,000 m) and dominated by saguaro (*Carnegiea gigantea*) and palo-verde (*Cercidium microphyllum*). Mean maximum monthly temperature in February 1988 was 21 C.

MATERIALS AND METHODS

During 15 to 17 February 1988, we captured 10 adult desert mule deer (five males, five females) with a net-gun (Coda Enterprises, Mesa, Arizona 85203, USA) shot from a Bell Jet Ranger helicopter; mean pursuit time was 6.1 ± 1.2 min (range = 3 to 15 min) (DelGiudice et al., 1989a). Reproductive status of the females was unknown. When deer were physically restrained in the net, we injected them intramuscularly with 100 mg xylazine hydrochloride (HCl) (Rompun, Haver-Lockhart Laboratories, Shawnee, Kansas 66201, USA) and 300 to 400 mg ketamine HCl (Ketaset, Bristol Laboratories, Syracuse, New York 13201, USA) (DelGiudice et al., 1989a).

We recorded rectal temperatures, heart and respiratory rates, body weights and morphological measurements (DelGiudice et al., 1989a); collected blood and urine samples; fitted all animals with radio collars; and reversed immobilizations with an intravenous injection of 2.0 to 3.0 mg of tolazoline HCl (Sigma Chemical Co., St. Louis, Missouri 63178, USA) (DelGiudice et al., 1989a). Heart and respiratory rates were recorded before and after chemical immobilization (DelGiudice et al., 1989a).

We collected blood samples by jugular venipuncture into 5-ml ethylenediamine tetraacetic acid vials for hematological analysis and into 10-ml serum tubes for chemistry and hormone assays. Mean time between induction of anesthesia and blood collection was 11.8 ± 2.1 min. Blood samples were stored on ice for 7 ± 1 hr before serum separation in the laboratory. Hematology methods and serum chemistry and hormone assays have been described by Seal et al. (1967, 1972a, b, 1975, 1978b).

We collected urine from female deer by catheterization with polypropylene catheters. We obtained urine from male deer by cystocentesis or by collecting voided urine once the diuretic effect of xylazine HCl occurred (Kreeger et al., 1986). Time between induction and urine collection was 23 ± 4 min. Urine samples were stored at −20 C. We analyzed thawed samples for urea nitrogen (U), creatinine (C), sodium (Na), potassium (K), calcium (Ca), and phosphorus (P); urinary characteristics are presented as ratios to C (DelGiudice et al., 1987b). We multiplied Na:C and K:C by 100 and Ca:C and P:C by 1,000 for comparison of data within this study and with reference values presented in other deer studies (DelGiudice et al., 1987b, 1989b). We measured specific gravity of urine samples with a refractometer (TS Meter Model 10406, American Optical Scientific Instruments, Buffalo, New York 14215, USA).

We conducted a separate study of three juvenile (two males, one female) and two adult (one male, one female) captive desert mule deer maintained in an outdoor enclosure in Tucson, Arizona, and fed alfalfa hay and hog-breeder chow. We provided water ad libitum. Juveniles were born in captivity and adults had been maintained in captivity for ≥3 yr. During March 1988, we chemically immobilized these deer with 50–100 mg xylazine HCl and 200 to 300 mg ketamine HCl by intramuscular injection with a pole syringe. We collected blood and urine samples and handled them according to the same protocols used for the free-ranging deer. Because these deer were not subjected to the acute excitement and physical exertion associated with helicopter pursuit and capture by net-gun, we present their data for select blood and urine constituents for comparison with values influenced by capture-related excitement in the free-ranging deer.

We analyzed data by one-way analysis of covariance to test for an effect of sex. Pursuit time required for successful netting of each deer was used as the covariate. When indicated, we $\log_e$ transformed urine data to stabilize the variance before analysis. Data are presented as means and standard error of the means.

RESULTS

There were no differences in hematologic values between free-ranging male and female desert mule deer (Table 1). Within

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TABLE 1. Blood profiles of free-ranging desert mule deer, Saguaro National Monument, Arizona, February 1988.[a]

Blood characteristics	n	$\bar{x}$	SE	Range
Hematology				
Hemoglobin (g/dl)	10	18.2	0.5	15.2–19.4
Red blood cells ($10^6/\mu l$)	10	13.0	0.3	11.5–14.0
White blood cells ($10^3/\mu l$)	10	3.9	0.5	1.8–7.6
Packed cell volume (%)	10	48.0	1.2	40.0–51.0
MCV (fl)[b]	10	37.0	0.5	34.0–39.0
MCHC (g/d)[b]	10	37.7	0.2	37.0–39.0
MCH (pg)[b]	10	14.0	0.2	13.0–15.0
Serum				
Creatine phosphokinase (IU/liter)	10	258	29	117–414
Urea nitrogen (mg/dl)	10	28.6	1.3	21.7–35.1
Sodium (mEq/liter)	9	149	2.1	136–158
Potassium (mEq/liter)	9	5.7	0.3	4.5–7.0
Calcium (mg/dl)[c]	10	10.1	0.2	9.1–11.6
Phosphorus (mg/dl)	10	7.3	0.3	5.7–8.4
Cholesterol (mg/dl)[d]	10	45.3	1.4	37–52
NEFA (μEq/liter)[b,e]	10	240	24	161–411
Triiodothyronine (ng/dl)	10	97.1	5.9	70–135
Thyroxine (μg/dl)	10	10.2	0.4	8.3–12.5
Cortisol (μg/dl)	10	10.6	0.2	10.0–12.0
Insulin (μIU/ml)	10	13.5	1.3	8.0–20.0

[a] Deer were captured by net-gun shot from a Bell Jet Ranger 205 helicopter, then were chemically immobilized with xylazine and ketamine.

[b] MCV = mean corpuscular volume, MCHC = mean corpuscular hemoglobin concentration, MCH = mean corpuscular hemoglobin, NEFA = non-esterified fatty acids.

[c] Difference ($P = 0.07$) between females (9.7 ± 0.3 mg/dl) and males (10.6 ± 0.3 mg/dl).

[d] Difference ($P < 0.05$) between females (42.2 ± 0.7 mg/dl) and males (48.4 ± 1.0 mg/dl).

[e] Pursuit time had a significant ($P < 0.05$) effect on non-esterified fatty acids. (See text.)

our range of pursuit times (3 to 15 min), chase was not a significant ($P > 0.05$) source of variability in hematologic values.

Serum cholesterol was greater ($P < 0.05$) in males than females (Table 1). Non-esterified fatty acid (NEFA) concentrations were directly correlated ($Y = 157.27 + 13.480x$, $r = 0.67$, $P < 0.05$) with pursuit time. Pursuit had an apparent effect on serum P as a covariate ($P = 0.12$). Serum cortisol was not correlated with pursuit time, but was elevated in all free-ranging deer (Table 1).

Mean urinary P:C tended to be greater ($P < 0.08$) in males (23.9 ± 4.9) than females (18.7 ± 0.7) (Table 2). Duration of pursuit significantly affected urinary specific gravity ($Y = 1.0045 + 6.2273e - 3x$, $r^2 = 0.77$, $P < 0.004$), U:C ($Y = 13.891 - 1.236x$, $r^2 = 0.79$, $P < 0.005$), and K:C ratios ($Y = 591.05 - 29.654x$, $r^2 = 0.42$, $P = 0.08$). As pursuit time was increased, specific gravity increased, and U:C and K:C decreased. Increased specific gravity was directly related ($Y = -1,446.4 + 1,471.7x$, $r^2 = 0.72$, $P < 0.008$) to urinary C concentration (77.7 ± 10.9 mg/dl, range = 44.8–141.3 mg/dl).

Mean hemoglobin (Hb, 14.0 ± 0.3 g/dl), red blood cell (RBC) count (11.2 ± 0.6 $10^6/\mu l$), and packed cell volume (PCV, 37.6 ± 1.0%) in the captive mule deer were lower ($P < 0.005$) than in the free-ranging deer. Captive deer exhibited serum NEFA, creatine phosphokinase (CPK), and cortisol values of 326 ± 65.8 μEq/liter, 165 ± 45 mIU/ml, and 4.4 ± 0.7 μg/dl, respectively; urinary specific gravity and K:C were 1.010 ± 0.003 and 170 ± 23, respectively. Serum CPK ($P < 0.05$) and cortisol ($P < 0.001$) and urinary specific gravity ($P < 0.02$) and K:C ($P < 0.001$)

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TABLE 2. Urinary profiles of free-ranging desert mule deer, Saguaro National Monument, Arizona, February 1988.[a]

Urinary characteristics[b]	$\bar{x}$	SE	Range	n
Specific gravity	1.036	0.006	1.014–1.060	8
U:C[c]	7.7	1.23	0.5–10.4	8
Na:C ×100	15.8	8.5	0.2–62.4	8
K:C ×100	443	41	256–621	8
P:C ×1,000[d]	20.6	1.9	16.9–33.7	8
Ca:C ×1,000	180	55	25–494	8

[a] Deer were captured by net-gun shot from a Bell Jet Ranger 205 helicopter, then were chemically immobilized with xylazine and ketamine.

[b] U:C = urea nitrogen : creatinine, Na : C = sodium : creatinine, K:C = potassium : creatinine, P : C = phosphorus : creatinine, and Ca : C = calcium : creatinine.

[c] Pursuit time had a significant ($P < 0.005$) effect on U : C. (See text.)

[d] Difference ($P < 0.08$) between females (18.7 ± 0.7) and males (23.9 ± 4.9).

were also lower in the captive deer compared to the free-ranging deer.

DISCUSSION

Absence of any differences in hematologic values between male and female desert mule deer agrees with findings for free-ranging white-tailed deer (*Odocoileus virginianus*) in southern Texas (White and Cook, 1974) and with the contention of those authors that few differences solely related to sex have been documented for deer. Mean values for these characteristics were within the range reported for free-ranging white-tailed and Rocky Mountain mule deer (*O. hemionus hemionus*) (Rosen and Bischoff, 1952; Seal and Erickson, 1969; White and Cook 1974; Seal et al., 1978a; Kie et al., 1983). Although time of pursuit by helicopter was not a significant ($P > 0.05$) source of variation in hematological values of desert mule deer within our range of times (3 to 15 min), Hb, RBC, and PCV were generally elevated (Table 1) compared to values for free-ranging deer elsewhere at this time of year. Deer in this study were highly excited from the capture process as evidenced by elevated rectal temperatures ($\bar{x}$ = 41.4 C, range = 40.2 to 43.2 C) and heart and respiratory rates ($\bar{x}$ = 108 beats/min and 75 breaths/min, respectively) (Seal and Bush, 1987; DelGiudice et al., 1989a). Hemoglobin, RBC, and PCV were lower in the five captive desert mule deer not chased and less excited, but chemically immobilized and handled according to the same protocol. Elevations of Hb, RBC, and PCV are often attributable to hemoconcentration which commonly accompanies physical excitement (Franzmann, 1972; Seal et al., 1972a, 1978a; Seal and Hoskinson, 1978; Wesson et al., 1979a; Benjamin, 1981; Seal and Bush, 1987). Dehydration associated with undernutrition may also have a hemoconcentrating effect (Seal et al., 1972b; Jacobsen, 1978; DelGiudice et al., 1987a), but is unlikely in these mule deer because February is a period of increased precipitation and enhanced quality of vegetation (P.R. Krausman, unpubl. data).

Greater cholesterol concentrations in males than females were most likely ascribable to longer pursuits of males (8.0 ± 2.1 min versus 4.7 ± 0.7 min) (DelGiudice et al., 1989a) and greater stress (Franzmann, 1972; Bryant et al., 1986); however, a consistent trend was not observed. Although cholesterol may be influenced by nutrition (Seal et al., 1972b, 1978a, b; Card et al., 1985; DelGiudice et al., 1987a), there was little additional evidence from blood and urine profiles suggesting nutritional differences between males and females.

The influence of pursuit and acute excitement on variation in NEFA concentrations in desert mule deer is consistent with previously reported findings (Newsholme and Leeche, 1983; Seal and Bush, 1987). The maximum NEFA concentration (411 μEq/liter) was measured in the deer with the longest pursuit time (15 min) and the highest rectal temperature (43.2 C). Individual variation in physical stress and the behavioral and physiological response to a given pursuit time must be considered in evaluating stress effects on blood constituents. One deer (No. 4716) only required 3 min to be successfully netted; however, this deer was ranked as high-

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ly excited during the pursuit, indicated by continuous and rapid movements throughout this period. This stress was reflected by the highest NEFA concentration (301 μEq/liter) in deer pursued for <15 min. Deleting this deer's data from the regression analysis (pursuit time versus NEFA concentrations) raised the correlation coefficient (R) from 0.67 to 0.81 ($P < 0.008$). Elevated NEFA's may have been attributable to increased cortisol values via their stimulating effect on lipolysis (Newsholme and Leeche, 1983).

Serum cortisol values and CPK were not affected by sex, and variability of these characteristics did not appear to be influenced over our range of pursuit times; however, elevated concentrations (Table 1) were indicative of acute adrenal stimulation and muscle trauma (Wesson et al., 1979b; Benjamin, 1981; Seal et al., 1981; Kock et al., 1987a; Seal and Bush, 1987). Lower cortisol and CPK in the captive desert mule deer indicated less intense physical exertion prior to collection of blood. Mean cortisol values in our free-ranging deer (Table 1) were greater than concentrations associated with acute excitement of manual restraint (5.7 ± 0.5 μg/dl) of white-tailed deer without helicopter pursuit prior to blood-sampling (Wesson et al., 1979b; Seal and Bush, 1987). Kock et al. (1987a) reported capture-related elevations of serum cortisol in bighorn sheep (*Ovis canadensis*) and suggested concentrations >5.0 μg/dl were indicative of stress.

The moderate elevations of CPK in the blood samples procured immediately after chemical immobilization of the free-ranging deer were conservative indicators of muscle damage incurred by these animals; CPK continues to increase dramatically for 24 hr following handling (Seal et al., 1972a).

Increased urinary specific gravity in response to pursuit in free-ranging deer was probably related to the accompanying hyperventilation and dehydration and an increase in C concentration (Benjamin, 1981; DelGiudice et al., 1989a). Mean specific gravity was considerably lower in captive mule deer compared to the free-ranging deer. Urinary U:C has exhibited potential as a useful nutritional index in deer (Warren et al., 1982; Waid and Warren, 1984; DelGiudice et al., 1987b, 1989b); however, our data showed that the strenuous physical exertion associated with capture by net-gun can decrease U:C values.

Although serum K values were maintained homeostatically, the effect of pursuit time on urinary K:C ratios and the extreme elevation of mean K:C in free-ranging mule deer (Table 2) compared to that in the captive desert mule deer were noteworthy. As with elevated serum CPK concentrations, the high K:C ratios further indicated muscle damage (Harthoorn, 1982; Spraker, 1982; Kock et al., 1987a). The inverse relationship between pursuit time and K:C and U:C ratios reflected the increase in specific gravity and urinary C excretion.

During February, free-ranging white-tailed deer in Minnesota, supplementally fed a high quality commercial diet, yielded K:C values (130 ± 15) lower than in free-ranging desert mule deer, but comparable to ratios in the captive desert mule deer (DelGiudice et al., 1989b). These ratio values were measured in fresh urine samples collected from snow (DelGiudice et al., 1988a), so there were no biases related to pursuit, chemical immobilization, or handling. Even in spring, captive white-tailed deer in Minnesota fed a high quality pelleted diet ad libitum had urinary K:C ratios <160 (DelGiudice et al., 1987b).

Pursuit of free-ranging desert mule deer and other ungulates by helicopter and capture by net-gun, albeit stressful, is considered an acceptable, relatively safe and efficient means of capturing animals in desert areas for tagging and radio-collaring (Krausman et al., 1985; Kock et al., 1987a, b). The combined use of this capture method and chemical immobilization in our study exhibited serious limitations with regard to animal safety and resulted in a 20% capture-related mortality (DelGiudice et al., 1989a).

Collection of physiological data often

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requires chemical restraint (e.g., urine-sampling) (DelGiudice et al., 1989a). Biases associated with different capture, immobilization, and handling techniques must be considered when comparing blood and urine values for deer from different studies (Franzmann, 1972; Seal et al., 1972a, 1981; Kock et al., 1987a). Our study provides reference values for numerous hematological, serum, and urinary characteristics of desert mule deer captured by net-gun and chemically immobilized with xylazine HCl and ketamine HCl. Equally as important, we documented effects of strenuous physical exertion and acute excitement on blood and urinary constituents in mule deer captured by this technique. Urinary specific gravity, C, and U:C exhibited the most consistent responses to prolonged pursuit. Excitability and physical exertion must be assessed for individuals within a study to permit valid data comparison.

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