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SEASONAL VARIATIONS IN PHYSIOLOGICAL INDICES OF ADULT FEMALE WHITE-TAILED DEER IN TEXAS

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ABSTRACT: Seasonal variations in blood chemistry, urine chemistry, fat reserves, and crude protein levels of rumen contents were determined for free-ranging adult female white-tailed deer (*Odocoileus virginianus* Zimmermann) in central Texas. Seasonal variations ($P < 0.05$) existed for serum total protein, albumin, globulin, albumin/globulin ratios, blood urea nitrogen (BUN), cholesterol, alkaline phosphatase, creatinine, phosphorus, and sodium; and urinary urea/creatinine (U/C) ratios, rumen crude protein, the kidney fat index (KFI), femur marrow fat (FMF), and dressed weights. Variations in BUN, urinary U/C ratios, dressed weights, KFI, and FMF were attributed partially to the nutritional demands of late gestation and lactation.

INTRODUCTION

A number of studies have been conducted on the physiology and nutrition of white-tailed deer. However, most studies have been conducted with captive deer, and of these, few have examined normal seasonal patterns of variation. Knowledge of normal seasonal variations in these physiological parameters from free-ranging populations is needed before baseline data for this species can be established.

Seal et al. (1978) observed seasonal variations in four blood parameters of free-ranging white-tailed deer from Minnesota, but they combined males and females in their analyses. Seasonal variations in blood and urine parameters of white-tailed deer in Virginia were determined for adult males by Warren et al. (1981) and for male and female fawns by Warren et al. (1982), but their studies were conducted with captive deer.

Few data are available on physiological indices of white-tailed deer in more arid habitats (i.e., southern and western United States). Blood values of free-ranging white-tailed deer in southern Texas have been examined by White and Cook (1974) and Blankenship and Varner (1977), but these studies provided no data on seasonal variations. Kie et al. (1983) presented data on seasonal variations in blood and fat indices of white-tailed deer from the Texas Gulf Prairies, but this region is much more humid than other parts of Texas. In addition, no literature has been published in which corollary changes in blood chemistry, urine chemistry, fat reserves, and nutrient analysis of rumen contents were examined in the same study. The objective of our study was to determine seasonal variations in these physiological indices for white-tailed deer from the Texas Edwards Plateau.

MATERIALS AND METHODS

The study was conducted on the YO Ranch in Kerr County, Texas. The 22,400-ha ranch is surrounded by a 2.3-m deer-proof fence. Rolling topography and shallow rocky soils of limestone origin characterize the area. Precipitation averages 63.5 cm annually, occurring primarily in May and September. Woody plant communities of this area are mixtures of juniper (*Juniperus* sp.), liveoak (*Quercus virginiana* Miller), Spanish oak (*Q. texana* Buckley), postoak (*Q. stellata* Wangenheim), blackjack oak (*Q. marilandica* Muenchhausen), white shinoak (*Q. breviloba* Sargent), and mesquite (*Prosopis glandulosa* Torrey). The ranch is managed for exotic big game, native game, and domestic livestock. White-tailed deer densities average one deer per 5 ha.

To standardize variations due to age and sex, only adult female white-tailed deer were collected. Deer were killed by a rifle shot to the neck. Hours of collection were between 1700

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and 2400 hr. We attempted to collect 15 does about every 2 mo from August 1981 to August 1982. During each collection period, deer were collected over a 3-day period to minimize diurnal variation in the physiological indices to be examined.

Blood was collected within 5 min of death (Wesson et al., 1979). Blood for serum was drawn from the jugular vein using 15-ml evacuated blood tubes and 20-gauge, 38-mm needles. Urine samples were obtained from the bladder in similar tubes. Blood and urine were stored on wet ice in the field. Blood was allowed to clot, centrifuged in a clinical centrifuge for 20 min, and serum extracted. Severely hemolyzed serum samples were discarded because of their potential for biasing results (Blankenship and Varner, 1977; Frank et al., 1978; Dorner et al., 1981). Serum and urine were frozen until analysis. Serum samples were analyzed for glucose, urea nitrogen, creatinine, sodium, potassium, chloride, calcium, phosphorus (P), alkaline phosphatase (ALP) (EC 3.1.3.1), total protein, albumin, globulin, serum glutamic oxaloacetic transaminase (SGOT) (EC 2.6.1.1), lactic dehydrogenase (LDH) (EC 1.1.1.27), and cholesterol. Urine samples were analyzed for urea nitrogen (U) and creatinine (C), and were expressed as a urinary U/C ratio as described by Warren et al. (1981, 1982). All analyses were conducted on an automated clinical chemistry analyzer by Medical Diagnostic Laboratories, Lubbock, Texas 79410, USA.

Ages of animals were determined by tooth eruption and wear (Severinghaus, 1949). Body weights were recorded before and after evisceration. Rumen contents were thoroughly mixed, sampled, and frozen for crude protein (CP) analysis. Crude protein was determined by micro-kjeldahl techniques (AOAC, 1970), using a 0.10-g sample. The KFI was determined using the method developed by Riney (1955). The right femur was removed, frozen, and later analyzed for femur marrow fat by ether extraction (Warren and Kirkpatrick, 1978).

Results of field and laboratory analyses were sorted by animal and month of collection. A completely randomized design analysis of variance with a split-plot arrangement was used to test for seasonal effects. The general linear model (GLM) procedure of the Statistical Analysis System (Barr et al., 1976) was used for data analysis. Duncan's New Multiple Range Test (Steel and Torrie, 1980) was used to separate means, at $P < 0.05$ level of significance. Product moment correlations (Steel and Torrie, 1980) were calculated for all variables. Significant or significantly refer to statistical significance at $P < 0.05$.

TABLE 1. Serum chemistry parameters that did not vary seasonally in adult female white-tailed deer from central Texas.

Serum parameter[a]	n	$\bar{x}$	SE
Glucose, mg/dl	80	109.8	5.0
Potassium, mEq/liter	74	7.7	0.2
Chloride, mEq/liter	81	102.5	0.8
Calcium, mg/dl	80	9.6	0.1
SGOT, IU/liter	81	114.2	6.9
LDH, IU/liter	81	544.5	21.1

[a] Data presented are means pooled over all collection months.

RESULTS

Eighty-six deer were collected during the study. Ages of the deer ranged from 15 to 87+ mo. No significant differences in ages were detected among collection months. Small sample sizes in most of the age groups prohibited analysis of the variables examined by specific ages. However, a comparison of age with all other variables produced significant, but weak correlations ($r < 0.40$) for five variables (BUN, ALP, P, cholesterol, and kidney weight).

Of the serum chemistry variables examined, six did not demonstrate significant seasonal variation (Table 1). Serum variables for which significant monthly differences were observed are listed in Tables 2 and 3. Although 86 deer were collected, hemolysis and inadequate volumes of sera resulted in unequal sample sizes.

Total protein and albumin began increasing in October, peaked in June and decreased in August (Table 2). Globulin varied significantly, but no consistent seasonal trends were evident. The A/G ratio peaked suddenly in January and decreased gradually thereafter. Concentrations of BUN were greater in August 1981 than for all other collection months. Cholesterol varied inconsistently, but was greater in October than in other months.

Alkaline phosphatase levels were lowest in August 1981 and highest in June; however, levels in August 1982 were greater

TABLE 2. Seasonal variation in serum values for total protein (TP), albumin, globulin, albumin/globulin (A/G) ratio, blood urea nitrogen (BUN), and cholesterol for adult female white-tailed deer from central Texas.

Collection month	n	TP, g/dl		Albumin, g/dl		Globulin, g/dl		A/G ratio		BUN, mg/dl		Cholesterol, mg/dl	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Aug 1981	15	6.1^{bc}	0.1	1.91^{c}	0.06	4.2^{a}	0.1	0.46^{c}	0.02	21.5^{a}	1.7	62.3^{b}	2.9
Oct 1981	10	5.9^{c}	0.2	2.11^{cz}	0.20	3.8^{abz}	0.2	0.56^{cz}	0.06	8.8^{bz}	1.9	75.7^{a}	3.5
Jan 1982	13	6.0^{bc}	0.1	3.10^{ab}	0.10	2.9^{c}	0.1	1.07^{a}	0.07	9.1^{b}	1.5	58.9^{b}	2.1
Mar 1982	13	6.4^{bc}	0.1	3.10^{ab}	0.05	3.3^{c}	0.1	0.94^{a}	0.03	11.4^{bz}	1.4	58.9^{b}	2.5
Jun 1982	15	7.2^{a}	0.2	3.13^{a}	0.07	4.1^{ab}	0.2	0.80^{b}	0.04	14.9^{b}	1.5	62.5^{b}	4.3
Aug 1982	15	6.5^{b}	0.2	2.80^{b}	0.07	3.7^{b}	0.2	0.76^{b}	0.03	12.4^{b}	2.6	58.8^{b}	3.6

^{a,b,c} Means in the same column with the same superscript are similar ($P > 0.05$).
^{z} n = 1 less than indicated.

TABLE 3. Seasonal variation in serum values for alkaline phosphatase (ALP), creatinine, phosphorus (P), and sodium (Na), and rumen crude protein (CP) and urinary urea/creatinine (U/C) ratio for adult female white-tailed deer from central Texas.

Collection month	n	ALP, IU/liter		Creatinine, mg/dl		P, mg/dl		Na, mEq/liter		CP, %		Urinary U/C ratio	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Aug 1981	15	19.7^{c}	2.6	1.61^{d}	0.04	7.9^{a}	0.4	148.5^{a}	1.1	13.1^{b}	0.6	3.39^{bu}	0.73
Oct 1981	10	62.0^{bc}	11.3	1.44^{e}	0.06	7.2^{ab}	0.4	142.7^{cdu}	0.5	10.8^{cz}	0.3	0.48^{cw}	0.30
Jan 1982	13	61.7^{bc}	7.7	1.69^{cd}	0.06	6.3^{bu}	0.5	147.5^{abu}	1.1	10.2^{c}	0.2	0.40^{cv}	0.23
Mar 1982	13	68.2^{bc}	9.3	2.12^{a}	0.07	6.4^{bu}	0.3	148.6^{ax}	1.0	12.0^{by}	0.2	0.72^{cv}	0.18
Jun 1982	15	135.3^{a}	18.0	1.80^{bc}	0.07	7.8^{aw}	0.5	140.6^{d}	0.7	17.0^{a}	0.3	6.51^{av}	1.56
Aug 1982	15	114.7^{ab}	26.8	1.89^{b}	0.05	7.5^{ab}	0.4	144.8^{bc}	1.1	12.8^{b}	0.4	2.07^{bcw}	0.88

^{a,b,c,d,e} Means in the same column with the same superscript are similar ($P > 0.05$).
^{u} n = 1 less than indicated.
^{v} n = 2 less than indicated.
^{w} n = 3 less than indicated.
^{x} n = 4 less than indicated.
^{y} n = 1 more than indicated.
^{z} n = 4 more than indicated.

TABLE 4. Seasonal variations in values for whole body weight (WBW), dressed weight (DW), kidney fat index (KFI), and femur marrow fat (FMF) for adult female white-tailed deer from central Texas.

Collection month	n	WBW, kg		DW, kg		KFI, %		FMF, % dry weight	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Aug 1981	15	35.0[b]	1.2	22.4[b]	0.8	7.0[d]	1.0	56.1[c]	6.0
Oct 1981	14	39.7[a]	1.0	26.9[a]	0.7	34.4[c]	6.7	73.9[b]	4.7
Jan 1982	13	40.3[a]	1.0	28.7[a]	0.8	108.3[a]	13.0	90.5[a]	2.0
Mar 1982	14	38.1[a]	0.8	26.7[a]	0.6	59.7[b]	8.0	90.5[a]	1.7
Jun 1982	15	41.1[a]	1.2	27.3[a]	0.8	13.4[d]	2.8	55.2[c]	6.1
Aug 1982	15	33.8[b]	1.5	21.8[b]	0.9	5.6[d]	0.6	36.2[d]	4.8

[a,b,c,d] Means in the same column with the same superscript are similar ($P > 0.05$).

than in August 1981 (Table 3). Creatinine varied significantly over the collection months, but no consistent seasonal trends were evident. Phosphorus concentrations were lower in January and March than in other months. Levels of sodium varied erratically over the collection months.

Rumen CP values were significantly different among months. Peak levels occurred in June, with lowest levels in January (Table 3). Rumen CP correlated significantly with urinary U/C ratios ($r = 0.49$).

Urinary U/C ratios were significantly different across months (Table 3). Urinary U/C ratios also correlated significantly with BUN ($r = 0.67$). Urine samples were unequal in number because some deer had micturated prior to being collected.

Mean values for whole body weight, dressed weight, KFI, and FMF (Table 4) displayed significant seasonal effects. Monthly trends observed for these variables varied from lowest mean values in August to peak values in January.

DISCUSSION

Serum, urine, and rumen indices

Globulin and albumin are the two major protein fractions making up total protein. LeResche et al. (1974) suggested that seasonal changes in total protein may reflect dietary protein levels. In our study, total protein values were not correlated with albumin, but were correlated with globulin ($r = 0.64$) and CP ($r = 0.52$).

Albumin levels may be depressed as a result of starvation or protein malnourishment (Bell et al., 1965; LeResche et al., 1974). Albumin synthesis also may decrease in response to increases in the globulin fractions of the serum (Rothschild and Oratz, 1976). Lowest levels of albumin occurred in August 1981 (Table 2). Mean rumen CP in that month (Table 3) was similar to values found in March and August 1982, when significantly higher albumin levels were observed. This seems to discount protein available for assimilation as the factor producing the low albumin level. If globulin levels also are examined (Table 2), the highest mean value was found in August 1981. Thus, depressed albumin levels could be explained, in part, by the effect of globulin levels on albumin synthesis.

Kie et al. (1983) observed less variation seasonally in total serum protein and albumin of adult deer from the Texas Gulf Prairies than we observed; however, they combined male and female deer in their data. Warren et al. (1981) observed no seasonal variation in albumin of adult male deer fed controlled diets in Virginia.

We used rumen CP to estimate the level of dietary protein, which may be two or three times less than rumen CP (Klein, 1962). This discrepancy is due mainly to

large amounts of microbial protein present in the rumen. However, Klein (1962) found that levels of CP in the rumen of mule deer (*Odocoileus hemionus* Rafinesque) reflected protein levels in forages from ranges of different nutritional quality. The seasonal differences in rumen CP observed (Table 3) were similar to, but lower in absolute value than, those reported by Kirkpatrick et al. (1969) for white-tailed deer in the southeastern United States.

In our study, rumen CP levels were highest in June, a period when low rainfall and high temperatures normally dry up forbs, and cause a shift in deer diets primarily to browse (Bryant et al., 1979). Bryant et al. (1980) found a decline in forage CP levels associated with such a dietary shift. However, we found an increase in rumen CP values in June (Table 3), which may reflect the high level of forb intake by deer in our study at that time (Waid et al., 1984). Higher than normal levels of precipitation were received in 1981 and through May of 1982, which may have extended the period of forb growth and palatability (Waid et al., 1984), thus elevating rumen CP levels.

We used BUN and urinary U/C ratios to detect changes in dietary protein levels (Warren et al., 1981, 1982). Urinary U/C ratios and rumen CP were significantly correlated; however, BUN was only weakly correlated with CP ($r = 0.24$). Additionally, similar trends were observed for CP, BUN, and urinary U/C ratios (Tables 2, 3). The high value for BUN in August 1981, however, cannot be explained in terms of the rumen CP level for that month.

Kie et al. (1983) also observed seasonal variations for BUN in deer from the Texas Gulf Prairies, but no consistent trends were evident, which is similar to the conclusion Warren et al. (1981) reached for adult male deer in Virginia. Bahnak et al. (1979) found distinct seasonal variations for BUN in pregnant does on "low" diets (6.6% crude protein, 2,520 cal/g metabolizable energy) in Michigan, but not in those on "high" diets (16.2% crude protein, 2,800 cal/g metabolizable energy).

In the only other published data available on urinary U/C ratios in adult deer, Warren et al. (1981) observed no significant seasonal variation in males fed controlled diets in Virginia. The drastic seasonal differences we observed in urinary U/C ratios may have resulted because we studied free-ranging, pregnant females in a different geographic location.

Of the remaining serum values demonstrating significant seasonal variations, ALP and cholesterol were reported by LeResche et al. (1974) as possible indicators of nutritional stress. However, they can be influenced by stressors such as excitement, trauma, and tissue damage (LeResche et al., 1974).

Pregnancy may have been an important factor in causing the seasonal variation in blood parameters observed. Of the 13 does collected in January, 11 were pregnant; all of the 14 does collected in March were pregnant. In June, 14 of the 15 does collected were or had been pregnant (12 does had recently given birth). Levels of total protein, albumin, BUN, ALP, and the urinary U/C ratio (Tables 2, 3) increased during gestation (January to June 1982) and decreased after parturition (August 1982). Bahnak et al. (1979) also observed lowest levels of total protein in summer months, and attributed this to the nutritional stress of lactation. Seal et al. (1972) also reported increasing total protein and albumin concentrations during late gestation in white-tailed deer in Michigan. However, their data on BUN do not agree with ours. We observed a rise in BUN near term, whereas Seal et al. (1972) reported a significant decline. Bahnak et al. (1979) observed declining levels of BUN during late gestation in does on "low" diets, compared to slight increases in does on "high" diets near term. Our data on urinary U/C ratios support the

rise in BUN concentrations during late gestation with the concomitant increase in urea excretion. Although, nutritional stress of dietary origin may reverse this trend (Bahnak et al., 1979) by causing deer to conserve (recycle) nitrogen (urea). Our data on increasing ALP concentrations in late gestation are supported by LeResche et al. (1974). Kie et al. (1983) also reported greater serum albumin and ALP concentrations in pregnant versus nonpregnant does.

Fat indices

Use of KFI to assess animal condition across seasons has been questioned by Batcheler and Clarke (1970) and Dauphine (1975). Seasonal fluctuations in kidney weights may distort the KFI. Warren and Kirkpatrick (1982) suggested using absolute perirenal fat values, instead of KFI, to determine nutritional status. In our study, KFI correlated with perirenal fat ($r = 0.97$), making it as accurate as absolute fat for predicting nutritional status.

From highest levels in January, KFI dropped drastically until August 1982 (Table 4). Femur marrow fat also peaked in January, but it maintained that level through March before dropping to a low in August. Deer diets in this region of Texas have been reported to be lowest in digestible energy during late summer and early fall (Bryant et al., 1980), a time during which deer in our study were increasing fat stores. This apparent contradiction in results may indicate that reduced energy needs for lactation during late summer and early fall, and perhaps increased food intake (especially mast in October), permitted the does in our study to deposit fat despite low digestible energy in the forage. In addition, Verme and Ozoga (1980a, b) determined that lipogenesis in deer during the fall is an obligatory physiological event that will occur, although at a reduced rate, despite food shortages.

The delay in mobilization of FMF compared to kidney fat suggests that kidney fat levels are lowered before FMF is drawn upon extensively. Both fat stores are then used simultaneously. This supports the findings of Ransom (1965), Dauphine (1971), and Warren and Kirkpatrick (1982).

Few published data on seasonal variations in fat reserves of white-tailed deer are available. Mautz (1978) discussed the annual fat cycle in deer, and indicated that highest seasonal fat reserves occurred in late fall, prior to the winter stress period. This conclusion seems to be applicable to deer in northern and southeastern states, since it is supported by data for mule deer in Oregon (Kistner et al., 1980) and for white-tailed deer in the southeastern United States (Stockle et al., 1978; Finger et al., 1981). The annual fat cycle in Texas deer seems to be much different. Kie et al. (1983) observed less variation seasonally in fat reserves than has been reported for the areas previously discussed. In addition, our data demonstrated an entirely different fat cycle, with highest reserves in January, and lowest in August (Table 4).

Levels for KFI and FMF reflected the periods of nutritional stress resulting from high energy demands during the third trimester of gestation and lactation (Table 4). In addition, high levels of BUN (Table 2) and urinary U/C ratios (Table 3) during June and August, and low dressed weights (Table 4) during August may indicate tissue catabolism at that time for the does to meet the nutritional demands of lactation.

In conclusion, information obtained on physiological indices from a representative sample of a deer herd can aid biologists in predicting herd responses to a variety of ecological factors, if normal seasonal variations are known. Significant monthly variations were well demonstrated in several physiological indices examined. Some of these variations were different than those that have been reported for deer in other areas of the United States,

thus possibly indicating local adaptations to prevailing ecological conditions. Several of the physiological indices examined varied between years (i.e., August 1981 vs. August 1982), thereby indicating that even longer term data may be required before true baseline data will be available.

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