Evaluating Nutritional Status of White-Tailed Deer Using Fat Indices

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Abstract: Femurs, mandibles, and kidneys with attached perirenal fat were collected from white-tailed deer (*Odocoileus virginianus*) in controlled and field studies to examine the use of fat indices for assessing nutritional status. Eleven fawns were fed formulated rations differing in energy content for 4 weeks. The kidney fat index (KFI) was significantly lower for fawns fed low energy (LE) diets compared to high energy (HE) diets. Femur marrow (FMF) and mandibular marrow fat (MMF) levels were unaffected by diet. In another experiment, 9 fawns were fed diets differing in energy and protein content for 13 weeks. In this experiment, all fat indices were lower in fawns on LE diets than on HE diets. Protein intake had no effect on the fat indices. Samples also were collected from 98 captive and wild deer to examine correlations among the fat indices. A significant correlation ($r = 0.44$) was observed between FMF and MMF. Significant correlations of FMF with KFI ($r = 0.78$) and MMF with KFI ($r = 0.53$) when plotted revealed an inverse quadratic relationship. Thus, kidney fat reserves appeared to be used at an early stage of malnutrition and were almost depleted before FMF and MMF reserves were mobilized.

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Numerous techniques have been studied as physiological indices for the assessment of nutritional status in white-tailed deer. Harris (1945) and Cheatum (1949) originally proposed the use of FMF as an index of malnutrition in white-tailed deer. Riney (1955) developed the KFI in order to esti-

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mate nutritional status of red deer (*Cervus elaphus*). Baker and Lueth (1966) determined that MMF also indicated nutritional status in white-tailed deer.

Subsequent research on fat indices examined seasonal and area patterns of variation as well as correlations with other physiological indices. However, there are no investigations of a controlled and quantitative nature. Before fat indices can be applied reliably and accurately in the field, controlled experiments are needed. The objectives of this project were to determine the responsiveness of white-tailed deer femur, mandibular, and kidney fat indices to controlled diets and to examine correlations between these indices in field-collected deer.

Methods

Pen Studies

Controlled experiments were conducted at the V.P.I. & S.U. deer pen facility. The facility consists of 22 covered pens, each measuring 3.65 × 7.30 m. All deer were born in captivity and were left with their dams until 85 days of age, at which time they were weaned and fed pelleted deer feed (Warren et al. 1981).

At 6–7 months of age, the fawns were weighed and assigned randomly to treatments. Fawns in the same dietary group were penned 2 or 3 per pen. Feed was offered in 2 buckets to increase accessibility. Feed consumption was monitored daily and regulated based on the amount consumed by fawns fed HE diets to insure approximately equal feed intake for all experimental groups.

Upon termination of an experiment, deer were sacrificed, weighed, and dissected. The right femur, mandible, and both kidneys with attached perirenal fat were removed and frozen. The KFI was determined as described by Riney (1955). Femur marrow fat and MMF were determined as described by Warren and Kirkpatrick (1978) and Kirkpatrick (1980).

In the first experiment, 11 fawns (5 males and 6 females) were placed on HE (2,938 kcal DE/kg) and LE (2,336 kcal DE/kg) unpelleted rations for 4 weeks. Protein intake between groups was equal and of sufficient quantity (13.7% crude protein) to prevent nitrogen deficiencies. Complete ration formulations and nutrient calculations are presented by Warren (1979). Data in this experiment were analyzed (Barr et al. 1976) using a 2 × 2 factorial arrangement of treatments with energy and sex as factors.

In the second controlled experiment, 9 female fawns were fed 1 of 4 unpelleted rations (Warren 1979), containing 2 levels each of energy and protein for 13 weeks. High energy diets averaged 3,029 kcal DE/kg, compared to 2,425 kcal DE/kg for LE diets. High protein (HP) diets averaged 16.2% crude protein, compared to 8.7% for low protein (LP) diets. Data in this experiment were analyzed using a 2 × 2 factorial arrangement of treatments with energy and protein as factors.

Field Collections

In order to examine age patterns of variation and correlations among the fat indices, samples were taken from deer sacrificed at the V.P.I. & S.U. deer pen facility, from wild deer collected at the Radford Army Ammunition Plants located at Dublin and Radford, Virginia, and from wild deer collected throughout Virginia in cooperation with personnel from the Virginia Commission of Game and Inland Fisheries during a 4-year period (1975–79). A total of 98 deer was collected. Mandibles were not collected the first year, thus resulting in a smaller sample size for MMF. These samples permitted examination of fat indices from deer over a wide range of nutritional states. Data were analyzed to determine Spearman rank correlation coefficients. Fawns and adults were analyzed separately followed by a combined analysis of both age classes.

Results

Caloric intake in the 4-week pen study (Table 1) differed by 1,726 kcal DE/deer/day between HE and LE diets. Fawns fed LE diets gained less weight than fawns on HE diets (Table 1). On HE diets, males gained more weight than females, but on LE diets, males gained less weight than females. This disparity resulted in an Energy × Sex interaction. Femur marrow fat and MMF did not vary significantly between diets or sexes (Table 1). However, fawns fed LE diets averaged lower KFI's than those on HE diets (Table 1).

Caloric intake in the 13-week pen study (Table 2) was recorded for the first 7 weeks in this experiment, and revealed an average difference of 457 kcal DE/deer/day between HE and LE diets. Caloric intake differed by 209 kcal DE/deer/day between HP and LP diets. No consistent or significant effects of energy or protein intake on body weight change (Table 2) were observed. Fawns on LE diets tended to have lower FMF, MMF and KFI's than fawns on HE diets (Table 2), but the small sample sizes and high variability incurred prohibited significant differences from being detected.

In the field collections, body weight (BW) covaried with FMF, but to a much greater degree in fawns than adults (Table 3). The correlation coefficient for BW and MMF was similar, regardless of age. Body weight also was correlated with the KFI. Femur marrow fat covaried with MMF (Table 3). These data are presented graphically (Fig. 1) to show the distribution of points. Femur marrow fat varied over a wide range with little change in MMF being evident. Femur marrow fat and the KFI also were correlated

Table 1. Caloric Intake (CI), Final Body Weights (BW), Weight Changes (WC), Femur Marrow Fat (FMF), Mandibular Marrow Fat (MMF), and Kidney Fat Indices (KFI) of White-Tailed Deer Fawns in a 4-Week Pen Study

			CI (kcal/deer/day)	BW (kg)		WC[b,c] (kg)		FMF (%)		MMF[d,e] (%)		KFI[f] (%)	
Diet[a]	Sex	N	$\bar{X}$	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
HE	F	3	4,113	33.3	0.9	5.3	0.7	93.7	3.0	90.0	1.9	140.7	18.6
	M	2	4,407	34.0	3.0	7.5	0.5	93.5	3.6	92.5	1.5	97.5	20.5
LE	F	3	2,453	29.7	0.7	3.7	1.5	94.5	2.1	90.0	1.3	32.7	7.7
	M	3	2,616	30.0	2.0	1.0	0.9	92.0	3.0	83.1	3.1	34.0	13.4

[a] HE = high energy ration; LE = low energy ration.
[b] $P < 0.01$, F-test (HE vs. LE).
[c] $P < 0.05$, F-test (Energy X Sex Interaction).
[d] $P = 0.099$, F-test (HE vs. LE).
[e] $P = 0.058$, F-test (Energy X Sex Interaction).
[f] $P < 0.001$, F-test (HE vs. LE).

Table 2. Caloric Intake (CI), Final Body Weights (BW), Weight Changes (WC), Femur Marrow Fat (FMF), Mandibular Marrow Fat (MMF), and Kidney Fat Indices (KFI) of White-Tailed Deer Fawns in a 13-Week Pen Study

		CI[b] (kcal/deer/day)	BW (kg)		WC (kg)		FMF (%)		MMF (%)		KFI[c] (%)	
Diet[a]	N	$\overline{X}$	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE
HEHP	2	3,848	33.0	1.0	4.0	1.0	99.1	0.4	95.0	0.8	119.0	12.0
HELP	3	4,268	33.0	3.1	3.7	0.9	98.0	0.4	93.5	2.0	108.0	33.6
LEHP	2	3,602	29.5	8.5	—0.5	2.5	73.9	21.7	88.1	4.5	20.5	11.5
LELP	2	3,600	35.5	3.5	3.5	1.5	83.3	14.5	65.6	29.0	59.0	54.0

[a] HEHP = high energy, high protein; HELP = high energy, low protein; LEHP = low energy, high protein; LELP = low energy, low protein.
[b] Recorded for the first 7 weeks only.
[c] $P = 0.087$, F-test (HE vs. LE).

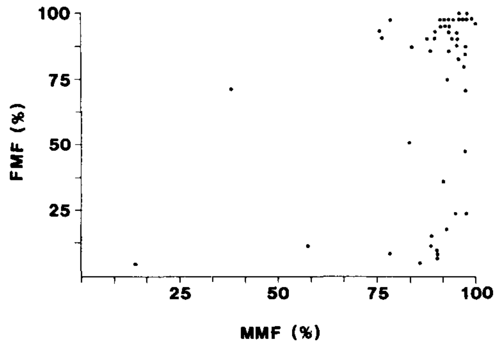

Figure 1. Relationship between femur marrow fat (FMF) and mandibular marrow fat (MMF) observed in fawn and adult white-tailed deer collected during a 4-year period in Virginia ($r = 0.44$; $P < 0.001$).

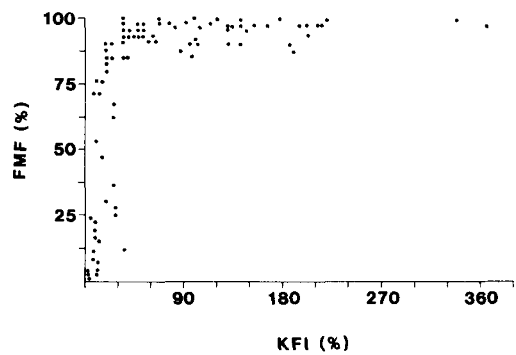

Figure 2. Relationship between femur marrow fat (FMF) and the kidney fat index (KFI) observed in fawn and adult white-tailed deer collected during a 4-year period in Virginia ($r = 0.78$; $P < 0.001$).

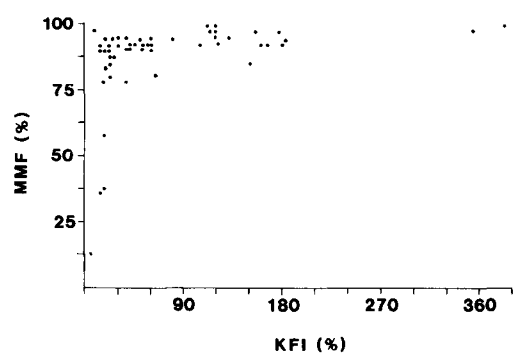

Figure 3. Relationship between mandibular marrow fat (MMF) and the kidney fat index (KFI) observed in fawn and adult white-tailed deer collected during a 4-year period in Virginia ($r = 0.53$; $P < 0.001$).

Table 3. Spearman Rank Correlation Coefficients (r) for Fawn and Adult Deer Collected from 1975–1979 Throughout Virginia

Data Analyzed		Nutritional Indices Correlated[a]					
		BW/FMF	BW/MMF	BW/KFI	FMF/MMF	FMF/KFI	MMF/KFI
Fawns Only	r	0.80[b]	0.50[c]	0.80[b]	0.64[b]	0.81[b]	0.57[b]
	N	44	24	44	24	44	24
Adults Only	r	0.64[b]	0.58[b]	0.73[b]	0.55[d]	0.77[b]	0.57[b]
	N	54	33	54	32	53	33
Fawns and Adults	r	0.39[b]	0.53[b]	0.48[b]	0.44[b]	0.78[b]	0.53[b]
	N	98	57	98	56	97	57

[a] BW = body weight; FMF = femur marrow fat; MMF = mandibular marrow fat; KFI = kidney fat index.
[b] $P < 0.001$.
[c] $P < 0.05$.
[d] $P < 0.01$.

(Table 3). When plotted (Fig. 2), these data depict an inverse quadratic relationship rather than a simple linear correlation. Mandibular marrow fat covaried with the KFI (Table 3). However, when plotted (Fig. 3), these data also demonstrate an inverse quadratic correlation.

Discussion

Femur Marrow Fat and Mandibular Marrow Fat

Femur marrow fat and MMF levels tended to be lower in fawns on LE diets compared to HE diets in the 13-week pen study, whereas no changes were evident in the 4-week pen-study. It is likely that longer-term energy deficiencies are required to result in significant changes in FMF or MMF. Baker and Lueth (1966), and Nichols and Pelton (1974) found that MMF separated deer into more distinguishable nutritional classes (i.e., over a wider range) than FMF. However, Nichols and Pelton (1974) found substantially greater levels of fat in FMF than in MMF, whereas Baker and Lueth (1966) reported greater levels of fat in MMF than in FMF. This disparity may be related to the different seasons in which their samples were collected. Nichols and Pelton (1974) obtained their samples primarily during the hunting season (early winter), whereas Baker and Lueth (1966) sampled deer from February through August. Fat reserves (FMF) of white-tailed deer in the southeastern United States are known to be at their lowest in spring and summer and at their highest in fall and winter (Stockle et al. 1978). Deer obtained by Baker and Lueth (1966) in spring and summer exhibited lower fat levels in both MMF and FMF, with FMF being the lowest of the two, compared to deer obtained by Nichols and Pelton (1974) in winter, which exhibited higher fat levels in both MMF and FMF, but with MMF being the lowest of the two. It is possible that the differences between these 2 studies may actually indicate that FMF varied more seasonally (i.e., nutritionally) than MMF. Data in the current study indicate that FMF varied over a wider range than MMF. There was no evidence in our study to indicate MMF is utilized prior to FMF, as stated by Nichols and Pelton (1974), or that MMF would be a better nutritional index than FMF, except for the obvious fact that mandibles are easier to collect from hunter-killed deer than femurs.

Baker and Lueth (1966) and Nichols and Pelton (1974) also found low and nonsignificant correlations between FMF and body weight. In their studies, correlations between MMF and BW were much higher and significant. Correlations for fawns in our study were much greater between FMF and BW than between MMF and BW. Obviously, more controlled research on FMF and MMF is needed if they are to be used as sensitive and reliable indices of nutritional status in white-tailed deer.

Although the effect of age on FMF and MMF was not examined in controlled experiments, obvious differences in correlation coefficients between fawns and adults were observed in the field collections. The primary function of bone marrow in young mammals is red blood cell production, not fat storage. The rapid growth rates and concomitant energy and protein demands of younger deer require them to invest all available nutrition into growth, thereby allowing only minimal fat storage in bone marrow.

Femur marrow fat was correlated with BW to a much greater degree in fawns than in adults. Fawns of younger age would weigh less than older fawns and would be expected to have very little fat stored in their femur bone marrow. But, as age and BW in fawns increased, more fat would be stored in the marrow, thus resulting in a significant linear correlation. Nichols and Pelton (1972) observed increasing MMF levels in fawns up to and including the 3- to 4-year age class.

Differences in FMF or MMF due to sex were not observed. Sex-related nutritional deficiencies would seem to be the most logical sources of variation. Nichols and Pelton (1972) observed lower MMF levels in bucks compared to does.

Kidney Fat Index

The KFI results are suggestive of the sequential, but simultaneous utilization of fat reserves that has been reported previously in Cervids (Harris 1945, Riney 1955, Dauphine 1971). Kidney fat reserves appear to be utilized before bone marrow fat is mobilized. However, rarely would 1 fat reserve be depleted entirely before utilization of another begins. In our study, kidney fat reserves were similar between experiments, but FMF and MMF were lowered only in the experiment of longer duration. Cheatum (1949) states that

FMF would not be expected to drop below 50% until subcutaneous and visceral fat reserves had been depleted.

The inverse quadratic relationships between FMF and the KFI, and MMF and the KFI, also supports this conclusion regarding fat dynamics. The KFI may decrease as a result of early stages of fat reserve utilization. Once having reached low amounts of kidney fat, the FMF and MMF reserves then appear to be mobilized and may reflect long-term utilization of fat reserves. This inverse quadratic relationship between the KFI and FMF is identical to that reported by Ransom (1965) for white-tailed deer and by Brooks et al. (1977) for 3 species of African ungulates.

Age effects on the KFI were not tested experimentally. However, correlation of the KFI with other variables indicated distinct differences between fawns and adults. The kidney fat reserve develops early and supposedly is a reliable nutritional index in deer above 6 months of age (Riney 1955, Stockle et al. 1978).

Differenecs in the KFI between sexes were not detected, but have been indicated by Riney (1955) to be related to differing seasonal physiological demands in each sex.

Seasonal considerations are perhaps most important in applying the KFI. Batcheler and Clarke (1970) and Dauphine (1975) have reported distortions in the KFI due to seasonal changes in kidney weight, upon which the KFI is based. Thus, absolute comparisons of nutritional status in deer between seasons using the KFI are invalid. In cases where deer are of approximately the same age and weight, comparisons between seasons should be made with absolute weight of the kidney (perirenal) fat.

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