ENDOGENOUS FAT AS AN INDICATOR OF PHYSICAL CONDITION OF SOUTHEASTERN WHITE-TAILED DEER[1]

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Abstract: Data were collected from 440 white-tailed deer (*Odocoileus virginianus*) throughout much of the southeastern United States in order to determine relationships between specific fat indices and overall physical condition. Specific criteria were presented for evaluating physical condition of white-tailed deer. An improved method for measuring the amount of bone marrow fat was described. The employment of various fat reserves as indicators of physical condition indicated that kidney fat was superior to other indices. Heart and pericardial fat were found to be nearly as favorable as kidney fat in all seasons except winter. Limited data showed tail fat to be a favorable indicator of physical condition for winter and spring. Femur marrow fat content, by itself, was not a reliable indicator of physical condition.

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A number of investigators have used fat deposits in evaluating physical condition of wild ruminants. Cheatum (1949) described visual criteria for estimating bone marrow fat which he utilized as an index for physical condition of winter-killed deer in the Adirondack region of New York. His hypothesis that bone marrow fat accurately reflected physical condition was widely accepted and was expanded to include seasons other than late winter and early spring. Technique development progressed to include quantitative measurements of bone marrow fat (Greer 1968, Neiland 1970, Verme and Holland 1973). The misuse and limitations of bone marrow analyses led to the examination of other endogenous fat centers. While some techniques continued to be of a qualitative nature (Harris 1945, Riney 1955), others were quantitative (Riney 1955, Ransom 1965, Bear 1971).

Harris (1945) and Riney (1955) postulated the following order of fat utilization in deer: first the rump fat; followed by subcutaneous fat; fat around the kidneys, intestines, stomach, and heart, in that order; and finally, bone marrow fat. Deposition of fat was in the reverse order of absorption (Harris 1945, Riney 1955). Cheatum (1949) reported that bone marrow fat content in white-tailed deer of the Adirondacks did not fall below 50% until fat within the body proper was utilized.

Cheatum's (1949) visual technique involved a series of color and consistency levels to assess the amount of fat in femur marrow. Bischoff (1954) noted limitations of Cheatum's technique when assessing physical condition of black-tailed deer (*Odocoileus hemionus columbianus*). He concluded that only consistency of femur marrow fat could adequately be used to determine physical condition under the prevailing conditions. Since visual

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descriptions of bone marrow were subject to varying evaluations among different observers, Greer (1968) developed a compression method to indicate fat content in elk (*Cervus canadensis*). Femur fat levels determined by the compression method were highly correlated with levels determined by the ether-extract technique when marrow fat content exceeded 50%. Bear (1971) observed a possible correlation between bone marrow consistency and percentage fat content, whereas the relationship between color and percentage marrow fat was very poor. Riney (1955) found visual estimates of both color and consistency of bone marrow to be highly correlated with chemical analyses of bone marrow fat in red deer (*Cervus elaphus*). He also found that bone marrow fat was correlated with other fat indices including kidney, back, and abdominal fat. Riney (1955) and Ransom (1965) determined that while several fat deposits within the body proper were decreasing, the bone marrow fat content remained relatively constant until these other fat deposits decreased to a low level.

Riney (1955) and Bear (1971) evaluated indices such as kidney fat, back fat, thoracic fat, visceral fat, and heart girth in addition to bone marrow fat to determine the relative efficacy of these potential measurements. Of the indices examined, kidney fat appeared to be the most useful index.

Since evaluation of physical condition in deer has been the subject of much conjecture, this study was undertaken to determine the most reliable and feasible method of judging physical condition of white-tailed deer in the Southeast. Specific objectives were to: (1) evaluate the accuracy of a commercial fat extractor for measuring the percentage fat in femur marrow; (2) evaluate a visual approach for estimating the amount of femur marrow fat; (3) determine whether endogenous fat deposits vary with season or sex or age of the animal; and (4) evaluate the use of endogenous fat indices as a reflection of overall physical condition.

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MATERIALS AND METHODS

Collection Sites and Procedures

From the spring of 1968 to the spring of 1973, 440 white-tailed deer from 45 localities in 12 southeastern states collected for evaluation of parasitism and disease entities were assessed for endogenous fat deposits and physical condition (Table 1). In most instances, sex or age discrimination was not made during collections. All animals were obtained by shooting. Usually 5 randomly selected animals constituted a sample, although in some cases fewer or more animals were collected. Most areas were sampled only once; however, 6 areas were evaluated repeatedly for all seasons for at least 1 year.

Ages of deer were determined by tooth eruption and attrition (Severinghaus 1949). All deer from 6 months to 1 year of age were grouped as young deer, whereas deer over 1 year were grouped as adults.

All animals were necropsied within 24 hours and endogenous fat levels recorded. Specific measurements taken included: (1) a visual appraisal of color and consistency of femur marrow; (2) the percentage femur marrow fat as determined by use of a commercial fat extractor;[1] and (3) an estimate of the amount of kidney, heart, pericardial, and tail fat.

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[1]Hobart Fat Percentage Indicator for ground beef, Model F101, Hobart Manufacturing Company, Troy, Ohio.

Qualitative estimates of endogenous fat deposits were categorized as zero, low, moderate, or high, whereas percentage femur marrow fat was recorded as a quantitative value.

Table 1. Collection sites for white-tailed deer in 12 Southeastern states, 1968-73.

County and State	*Season of Collection*	*Number of Deer*
Mountain Areas		
Allegany Co., Maryland	Spring, Summer	10
Garrett Co., Maryland	Summer	4
Doddridge Co., West Virginia	Winter	5
Hampshire Co., West Virginia	Winter	5
Hardy Co., West Virginia	Summer	10
Caldwell Co., North Carolina	Fall, Winter, Spring, Summer	20
Stone Co., Arkansas	Winter	10
Cleburne Co., Alabama	Fall, Winter, Spring, Summer	40
Yancey Co., Alabama	Spring	5
Low Plateau Area		
Edmonson Co., Kentucky	Summer	5
Piedmont Areas		
Caroline Co., Virginia	Fall, Winter, Spring, Summer	40
McCormick Co., South Carolina	Fall, Winter, Spring, Summer	40
Floyd Co., Georgia	Winter	5
Coastal Plain Areas		
Worcester Co., Maryland	Spring	5
Dorchester Co., Maryland	Fall	5
Kent Co., Maryland	Fall	5
Prince Georges Co., Maryland	Winter, Spring	20
Harford Co., Maryland	Spring	5
Craven Co., North Carolina	Spring	5
Stafford Co., Virginia	Spring	5
Beaufort Co., South Carolina	Winter	5
Berkeley Co., South Carolina	Winter	5
Hampton Co., South Carolina	Summer	5
Chatham Co., Georgia	Fall, Winter	10
Liberty Co., Georgia	Fall, Winter, Spring, Summer	40
Clay Co., Florida	Fall	5
Collier Co., Florida	Fall	5
Duval Co., Florida	Summer	5
Gadston Co., Florida	Spring	8
Walton Co., Florida	Fall, Winter, Spring, Summer	20
Baldwin Co., Alabama	Fall	5
Barbour Co., Alabama	Spring	5
Marengo Co., Alabama	Fall	5
Lincoln Par., Louisiana	Summer	5
Winn Par., Louisiana	Spring	13
Charleston Co., South Carolina	Winter	5
Mississippi Delta Areas		
Madison Par., Louisiana	Spring	3
Assumption Par., Louisiana	Winter	3
Concordia Par., Louisiana	Summer	5
Desha Co., Arkansas	Summer	5

Table 1. (Continued)

County	*Season of Collection*	*Number of Deer*
Coahoma Co., Mississippi	Summer	5
Issaquena Co., Mississippi	Fall	5
Laflore Co., Mississippi	Summer	10
Warren Co., Mississippi	Winter	4
Wilkinson Co., Mississippi	Summer	5
Total		440

Femur Marrow Fat Procedures

The femur marrow was exposed by striking the shaft of the bone with a hammer midway between the epiphyses. The entire marrow including that at the epiphyses was removed and examined. Utilizing a classification adopted from Cheatum (1949), femur marrow was categorized by color and consistency.

Following visual evaluation, the marrow from both femurs was macerated in a mortar to obtain a homogeneous mixture. A 10cc sample of this mixture was placed on the Hobart fat extractor plate and exposed to heat for 22 minutes. Liquids, including fats and water, were collected in a funnel which was inserted into a 10ml graduated cylinder beneath the heating unit. The funnel and sides of the cylinder were heated periodically to ensure that fat did not solidify on these surfaces. Since fluids other than lipids were present, water was added and the cylinder heated. From the resultant biphasic mixture, the true quantity of fat could then be visualized. The volume (ml) of fat recovered was divided by 10 (volume of initial sample) and the result recorded as percent femur marrow fat.

Since the Hobart technique for determining percentage fat in tissue other than ground beef had not been verified, femur marrow samples from 35 deer were evaluated simultaneously by the modified Hobart method and the Folch procedure. The Folch technique, used routinely for recovering total lipids from many tissue types (Folch et al. 1951, Sperry and Brand 1955, Folch et al. 1957), is considered to be a highly accurate, standard method for lipid analyses.

Other Endogenous Fat Procedures

Visual appraisals of the kidney, heart, and pericardial fat depots were made. A manual appraisal of the amount of tail fat was determined by palpating the base of the tail prior to skinning.

Kidney Fat Index

LIGHT—At least 75% of the kidney visible; obvious fat laid in a few thin streaks or narrow layers.

MODERATE—Thick layer of fat covering about 50-70% of the kidney surface.

HEAVY—Kidney completely encapsulated within a thick layer of fat.

Heart Fat Index

LIGHT—Trace of fat on basal region with or without a trace of fat on coronary groove.

MODERATE—Moderate deposit of fat on basal region, extending slightly down coronary groove.

HEAVY—Thick deposit of fat on basal region, extending well along coronary groove.

Pericardial Fat Index

LIGHT—Traces of fat at basal area; possibly light streaks extending to apex.

MODERATE—Zones of moderate amounts of fat at basal area; linear streaks of fat extending from base to apex.

HEAVY—Zones of fat up to 7mm thick at basal area; obvious linear streaks of fat extending from base to apex.

Tail Fat Index

BONY—No palpable fat between skin and coccyx.

LIGHTLY PADDED—Light amount of fat present; coccyx vertebrae could be felt; sharp points padded.

PADDED—Heavy deposit of fat present; unable to feel the coccyx vertebrae.

Determination of Overall Physical Condition

Excluding femur marrow, all of the above endogenous fat deposits in addition to factors presented below were used to assess the overall condition of each animal. Physical condition ratings were categorized in four levels:

Poor – No trace of fat on the kidney, heart, pericardium, omentum, or intestines. Carcass approaching emaciation. Tail bony and backbone very prominent before skinning. Gelatinous material may be present on the heart and omentum where fat was mobilized.

Fair – Zero or light fat on kidney, heart, and pericardium. Tail bony. Adequate skeletal muscle. Light deposit of fat on the omentum which may be pink in color.

Good – Moderate kidney fat, light to moderate heart and pericardial fat, lightly padded or padded tail, and fibrous material in omental fat. Fawns classified in good condition did not necessarily have any fat deposits provided the animals were not obviously in poor health.

Excellent – Heavy kidney fat, moderate to heavy heart and pericardial fat, padded tail, heavy subcutaneous fat, back fat extending from the tail into the lumbar region, which may be as much as 12 to 25 mm thick at the last sacral vertebrae.

Statistical Studies

Coded values for estimated endogenous fat deposits and physical condition, actual values for percent femur marrow fat, and other pertinent data were placed on computer cards. Analysis of variance, standard correlation, Spearman rank-order correlation, and regression analysis as available for Statistical Analysis System (Service 1972) were utilized for statistical analyses.

RESULTS

Comparison of Hobart and Folch Techniques

Values of percentage femur marrow fat obtained by the Hobart technique generally were consistent with values obtained by the Folch technique ($Y = 3.723 + 0.896X$). At levels above 10% the Hobart technique always yielded values within 5% of the Folch technique. When the marrow fat was below 10% by the Folch technique, the Hobart technique tended to yield values slightly below those of the Folch technique.

Femur Marrow Fat Studies

The color and consistency of femur marrow near the epiphyses often were different from that at the center of the femur. A white or light color indicated marrow with a high fat content. As the color deepened to pink, light red, and finally dark red or brown, fat content decreased in that order. Similarily, the graduation in texture varied from firm, dry, waxy consistency in marrow having a high fat content to a gelatinous, soft, or watery consistency in marrow having a low fat content.

A regression analysis on bone marrow color showed that 43% (r = 0.42456) of the variability in percentage femur marrow fat was related to marrow color. A regression analysis on marrow consistency showed that 59% (r = 0.58642) of the variability in percentage femur marrow fat was related to consistency. A regression analysis incorporating both color and consistency showed that 66% (r = 0.66079) of the variability in percentage femur marrow fat could be accounted for by combination of these 2 factors.

Average femur marrow fat levels varied considerably between seasons. Average femur marrow fat content was highest during the winter, while lower values were observed during the spring and summer. Variability among samples was great, and there was not a significant difference ($P > 0.05$) between sexes (Tables 2 and 3). Deer 1-year-old or younger had considerably less marrow fat than adults during the spring and summer months. Adult males had the highest marrow fat levels during the fall.

Table 2. Mean fat levels for male deer collected in Southeastern United States, 1968-73.

Season	*Age Class*	*N*	*Percent Marrow Fat*	*Standard Deviation*	*Kidney Fat Index*	*Standard Deviation*	*Heart Fat Index*	*Standard Deviation*	*Pericardial Fat Index*	*Standard Deviation*
Winter	< 1 yr	14	36	20.56	2.42	0.669	3.00	1.000	2.55	0.882
	> 1 yr	23	23	18.86	2.52	0.730	2.52	0.665	2.58	0.768
	All	37	28	20.30	2.49	0.702	2.67	0.806	2.57	0.790
Spring	< 1 yr	24	9	9.96	1.78	0.422	1.91	0.515	2.00	0.000
	> 1 yr	7	17	23.78	2.00	0.000	2.17	0.408	2.33	0.577
	All	31	11	14.19	1.83	0.384	1.96	0.499	2.08	0.288
Summer	< 1 yr	30	8	16.42	2.36	0.621	2.55	0.572	2.45	0.595
	> 1 yr	15	17	18.92	2.76	0.725	3.20	0.774	3.18	0.751
	All	45	11	17.64	2.49	0.675	2.77	0.711	2.70	0.728
Fall	< 1 yr	13	19	22.72	2.36	0.809	3.00	0.774	2.88	0.927
	> 1 yr	20	26	20.27	2.94	0.929	3.56	0.814	3.27	0.961
	All	33	24	21.22	2.70	0.912	3.33	0.832	3.12	0.947

Table 3. Mean fat levels for female deer collected in Southeastern United States, 1968-73.

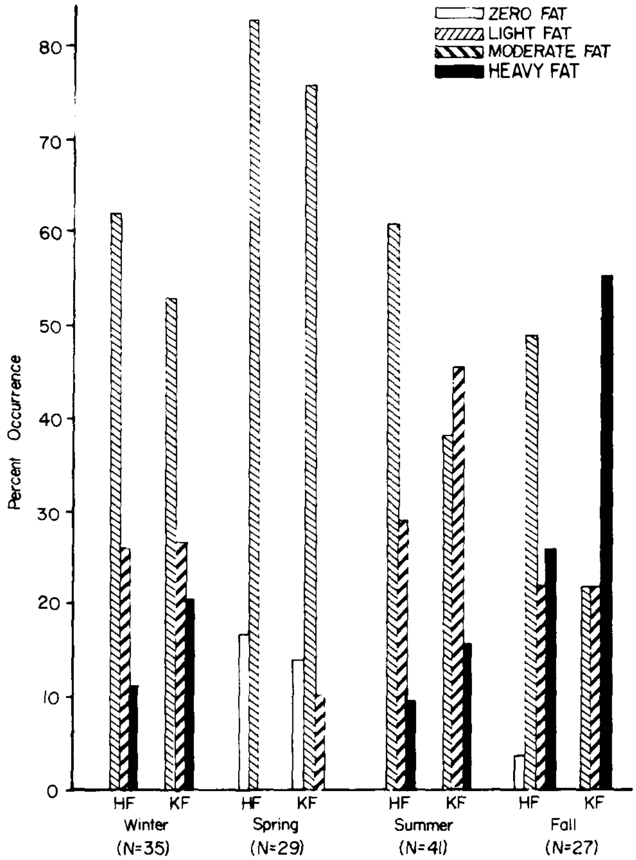
Season	*Age Class*	*N*	*Percent Marrow Fat*	*Standard Deviation*	*Kidney Fat Index*	*Standard Deviation*	*Heart Fat Index*	*Standard Deviation*	*Pericardial Fat Index*	*Standard Deviation*
Winter	< 1 yr	21	32	18.05	2.33	0.483	2.76	0.889	2.46	0.519
	> 1 yr	54	45	18.07	3.14	0.783	3.31	0.706	3.15	0.792
	All	75	41	18.94	2.90	0.795	3.15	0.799	2.98	0.789
Spring	< 1 yr	23	9	10.69	2.09	0.668	2.30	0.703	1.75	0.707
	> 1 yr	65	20	21.07	2.36	0.753	2.52	0.784	2.39	0.728
	All	88	18	19.43	2.29	0.737	2.46	0.765	2.27	0.758
Summer	< 1 yr	19	13	16.99	2.50	0.923	2.36	0.761	2.38	0.961
	> 1 yr	55	18	22.09	2.41	0.687	2.66	0.700	2.77	0.684
	All	74	17	20.89	2.43	0.747	2.59	0.723	2.68	0.765
Fall	< 1 yr	14	19	20.48	3.07	0.475	3.29	0.611	3.17	0.577
	> 1 yr	44	30	20.50	3.18	0.756	3.38	0.740	3.44	0.694
	All	58	27	20.86	3.15	0.690	3.35	0.705	3.38	0.672

Other Endogenous Fat Studies

Kidney, heart, and pericardial fat deposits exhibited similar patterns for seasons, sexes, and age groups. These organs attained the highest mean fat levels in the fall and lowest during the spring. Males and females exhibited similar patterns in all seasons except summer, when mean fat levels were noticeably higher for adult males than for adult females. A similar pattern occurred in deer 1-year-old and less but was not as pronounced. Adult females exhibited a slow deposition of kidney fat in the summer while females 1-year-old and less displayed more rapid deposition.

A larger proportion of females attained moderate or heavy kidney and heart fat reserves than did males in all seasons except summer (Figs. 1 and 2). In all seasons, both sexes exhibited higher kidney fat levels than heart fat (Figs. 1 and 2).

Fig. 1. Seasonal occurrence of heart fat (HF) and kidney fat (KF) levels in male deer of all ages.



The level of tail fat averaged higher in females than in males and in both sexes was higher in winter (females = 1.8; males = 1.6) than in spring (females = 1.6; males = 1.0).

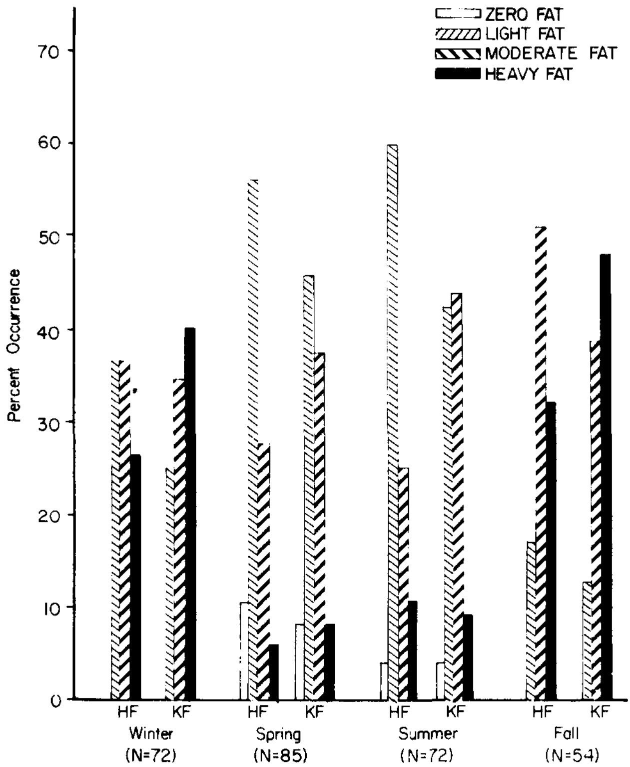
Correlation Between Fat Indices and Overall Physical Condition

Correlations between fat indices and overall physical condition are tabulated in Table 4. Kidney fat had the highest correlation for all seasons. Within seasons for which data were available, tail fat also was highly correlated. Compared to other fat indices tested, percent femur marrow fat had the lowest correlation values with overall physical condition.

DISCUSSION

The Hobart technique quantified the percentage fat by volume in bone marrow with a relatively high degree of accuracy (± 5%) but underestimated the amount of fat at levels

Fig. 2. Seasonal occurrence of heart fat (HF) and kidney fat (KF) levels in female deer of all ages.



less than 10% fat content as determined by the Folch technique. The degree of underestimation was inconsistent but exhibited a greater margin of error as the percentage fat approached zero. This discrepancy was attributed to the tendency of small quantities of fat to cling to the extractor plate and funnel despite periodic heating. At low fat levels the tissue also charred more easily thus providing a substrate to which fat adhered. Care therefore should be taken to enhance fat flow into the cylinder without applying excessive heat. The small margin of error encountered with this technique indicated that it was an acceptable method which required little training and equipment.

Regression analyses of visual estimates and percentage femur marrow fat (Hobart technique) indicated that consistency was a better indicator of marrow fat levels than color if only a single parameter was utilized. Combination of both color and consistency increased the accuracy of visual techniques. Since deer studied had marrow fat ranging between 0 and 90%, these visual techniques used in combination were considered to be reasonably reliable for estimating percentage femur marrow fat. This conclusion was consistent with those of Cheatum (1949) for white-tailed deer in New York and Riney (1955) for red deer in New Zealand. In contradistinction, Bischoff (1954) and Bear (1971) found only consistency could be correlated to percentage fat levels.

Table 4. Correlation between overall physical condition and fat indices by season of year. Note kidney fat has the highest correlation (fit) with physical condition and femur marrow fat the lowest.

Index	*Season*	*Correlation with Physical Condition*	*Significance Level*
Femur Marrow Fat	Fall	0.179	>0.10
	Winter	0.270	0.01
	Spring	0.376	0.001
	Summer	0.351	0.001
	All	0.314	0.001
Kidney Fat	Fall	0.683	0.001
	Winter	0.630	0.001
	Spring	0.776	0.001
	Summer	0.734	0.001
	All	0.715	0.001
Heart Fat	Fall	0.440	0.001
	Winter	0.261	0.01
	Spring	0.710	0.001
	Summer	0.734	0.001
	All	0.506	0.001
Pericardial Fat	Fall	0.570	0.001
	Winter	0.396	0.001
	Spring	0.809	0.001
	Summer	0.526	0.001
	All	0.570	0.001
Tail Fat	Winter	0.726	0.001
	Spring	0.664	0.001
	All	0.714	0.001

Fat indices are important to the investigator for they characterize the overall physical condition of the animal. In turn, physical condition portrays changing environmental and physiological demands in the near past and provides information on which management policies are based. The number of fat indices utilized should be minimal to avoid excessive costs, training, or time. Additionally, as suggested by Riney (1955), a useful indicator of physical condition should: (1) reflect condition equally well for both age groups and sexes in all seasons; (2) be reproducible by different technicians; and (3) reflect a continuous scale in physical condition.

Percentage femur marrow fat in the animals examined during this study did not fulfill these requirements. Although percentage femur marrow fat could be determined inexpensively, simply, and quickly with the Hobart fat extractor, marrow fat appeared to be the poorest indicator evaluated (Table 4).

Data from the present study as well as those by Riney (1955) and Ransom (1965) emphasize the following limitations to the use of marrow fat for determining physical condition: (1) changes in the upper range of physical condition are not reflected in marrow fat and (2) differential physiologic demands between sexes and age classes are not reflected in marrow fat. Irregular synthesis and utilization render marrow fat a highly questionable indicator of overall physical condition in the Southeast as a whole. Its usefulness in other regions and specific seasons where the technique has been used successfully (Cheatum 1949), however, should not be overlooked, particularly when the animals approach inanition. It should be emphasized further that to utilize bone marrow fat as the primary or definitive indicator of physical condition may lead to a false conclusion.

Kidney fat was the best overall fat index for evaluating physical condition regardless of age, sex, or season (Table 4). The high correlation with physical condition is probably related to rapid response to physiologic changes and available food (Riney 1955, Ransom 1965, Bear 1971). Its value is justified, therefore, as an indicator of condition in all seasons, for all ages above 6 months, and for both sexes. The use of kidney fat as an indicator of condition previously was extended to include age classes younger than adults (Riney 1955) since the depot matures early. During the present study subjective kidney fat estimations did not differ significantly among observers.

Since heart and pericardial fat did not correlate as well with overall physical condition as did kidney fat, these parameters were not considered as reliable as the latter. The poorer overall relationship was attributed primarily to lower correlation in the winter (Table 4). For other seasons, these 2 indices were almost as useful as kidney fat. Like kidney fat, heart and pericardial fat responded early to physiologic changes and nutritional acquisition, thereby extending their reliability as indicators of physical condition to deer less than 1 year old for both sexes.

Tail fat correlated well with physical condition (Table 4) in the limited number of observations. It should be noted that during these periods of observation (winter and spring) physical condition ratings were either low or high on the scale. Tail fat probably would be a good indicator only at these 2 extremes, since deposition and utilization occur rapidly and since 1 sequence or the other is in motion. This would limit the reliability of tail fat to the winter and spring and probably to adults. Harris (1945) suggested a similar pattern.

The employment of various fat reserves as indicators of physical condition suggested that kidney fat was superior to other indices. Heart and pericardial fat were found to be nearly as reliable as kidney fat in all seasons with the exception of winter. Tail fat was correlated with physical condition during the winter and spring. Femur marrow fat content was not a suitable indicator of physical condition alone due to extensive variability between it and other parameters evaluated. A judgment of overall physical condition should include all available information.

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