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Estimating Body Fat by Using Bioelectrical-Impedance Measurements: A Preliminary Assessment

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Abstract

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We evaluated a technique for measuring body fat content of marten *(Martes americana)* by using a noninvasive bioelectrical-impedance device with four electrodes to introduce a current into the body. Instantaneous readings of resistance were significantly correlated with fat-free mass (determined from solvent extraction) of carcasses of 17 skinned ($r = 0.83$, $P = 0.01$) and 6 intact ($r = 0.89$, $P = 0.03$) marten. Estimates of percentage of body fat were not accurate among skinned animals but were accurate among unskinned animals. With further refinement, this technique may be useful because the device is noninjurious, easily used, quick, and portable.

Keywords: Body composition, body fat, fat-free mass, marten, *Martes arnericana,* Wyoming.

Contents

Introduction

Assessment of body composition is important in determining the nutritional status of an animal population. Estimation of body fat reserves, of particular importance in this regard, has been reported for several vertebrates, including mammals (Pitts and Bullard 1968), birds (Blem 1976), amphibians (Fitzpatrick 1976), and reptiles (Derickson 1976). Although many methods for estimating body fat content are available, most (for example, back fat, abdominal fat, bone marrow, and kidney index) are suitable only for studies of dead animals (Cheatum 1949, Riney 1955). A humane technique that is objective, repeatable, useful for all age and sex groups, and usable with live and dead animals is needed. Measurement of whole-body bioelectrical impedance, an approach used successfully in studies of humans (Lukaski and others 1985), is based on the constancy of fat-free body components as respects body water and the negative correlation of fat with the volume of body water (Pace and Rathbun 1945). This report summarizes results of a preliminary assessment of this technology for estimating body composition in the marten *(Martes americana).*

Methods

We obtained 23 marten carcasses (14 males, 9 females), 17 having been skinned, from local furtrappers. All carcasses were sealed in plastic bags and frozen for about 2 months until processed.

Determinations of bioelectrical-impedance were made using a four-terminal impedance plethysmograph (Model BIA-101, RJL Systems).[1] Electrodes were clipped on the dorsal surfaces of the elbow and wrist of the right forelimb and at the knee and ankle of the right hindlimb. A current of 800 microamperes at 50 kilohertz was introduced into the specimen at the distal electrodes, and the voltage drop was detected by the proximal electrodes. Resistance (A) was read directly from a digital meter on the instrument.

Percentage of body fat (%BF) was determined by using an ether-extract technique (Buskirk and Harlow 1989). Fat-free mass (FFM) was calculated from %BF as follows:

$$FFM = BF - [\%BF(BM)/100] ,$$

where BM was total body mass (all units in grams).

We used stepwise linear regression as an exploratory tool to analyze relations among body length, resistance, and reactance as independent variables and FFM as the dependent variable. Skinned and intact animals were analyzed separately. Any variable with an F-to-enter probability of ≤ 0.05 was retained in the final regression equation. Statistical inferences regarding differences between FFM measured from ether extraction versus FFM estimated from the regression model were tested by using methods described by Reynolds (1984).

[1] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable

Results

Body fat averaged about 5 percent of total mass and was similar for both skinned and unskinned animals (t-test, t = –0.32, P = 0.752) (table 1). None of the bioelectrical measures was significantly correlated with any of the body measurements among either skinned or unskinned animals (table 2). The stepwise regressions showed that A was a significant contributor to the prediction of FFM for unskinned animals but not for skinned animals (table 3). For skinned animals, the addition of A increased explained variance (adjusted R^2) from 0.74 with BL only to 0.93 with BL and A. Among skinned animals, A was not a significant contributor (t = –0.25, P = 0.809). Fat-free mass, estimated from the regression equations on unskinned animals (table 3), averaged *8* percent of measured values (range - 14 percent to +29 percent).

Most of the correlation between estimated FFM and measured FFM was from the high correlation of BL and FFM (table 2). Of more interest was the estimation of %BF. By using estimated FFM from the regression equation for all animals (table 3), we calculated estimated %BF and found no difference between mean values of actual (x 4.01) and estimated ($\bar{X}$= 4.83) %BF (e* = 15.71, D = -0.82, P>0.10; table 4). Results were similar when the sample was disaggregated into skinned and unskinned individuals. Comparisons of estimated and actual %BF for individual animals, however, showed wide variation (table 4). Among unskinned animals, values were generally concordant, except for one individual (ID 27) whose estimated FFM exceeded its total weight by 62 grams. Values were much more variable among skinned animals (table 4); estimated %BF was not correlated with measured %BF (r = 0.11, P = 0.34).

Discussion

Our evaluation produced mixed results. We were able to predict fat-free mass with high precision and accuracy by using body length and bioelectrical impedance as independent variables. Most of the predictive power, however, was contributed by body length, with little improvement due to impedance. This was especially true for the skinned carcasses where impedance did not contribute enough predictive power to enter into the stepwise regression. But among the unskinned carcasses, impedance was a significant predictor and was included in the regression equation. Unfortunately, our sample size of unskinned carcasses was small (only six animals), thereby reducing the power of our regressions.

Direct comparisons of impedance-estimated with extraction-estimated percentage of body fat showed a lack of correlation among skinned animals and a positive correlation among unskinned animals. The lack of correlation among skinned animals may have been from loss of body fluids associated with the skinning itself. When body cavities of skinned animals were opened, an unmeasured loss of blood and other fluids may have occurred. Mean values of total percentage of body water for all animals (table 1) did not differ among skinned and unskinned carcasses (t-test, t = 1.78, P = 0.127). Although body length did not differ between skinned and unskinned carcasses (t = –0.50, P = 0.619), both resistance and reactance differed significantly (t = 3.43, P = 0.003 for resistance; t = -2.41, P= 0.025 for reactance). It is therefore likely that skinning led to changes in either water content or ionic distribution in the carcasses.

Table I-Physical characteristics of marten (mean SD) obtained from trappers in Wyoming, 1987[a]

Characteristic	Skinned (n = 17)	Unskinned (n = 6)
Body length (cm)	41.8±2.4	42.3 ±1.8
Mass (g)	866.9±179.3	1053.7 ±305.9
Body fat (%)[b]	4.5±2.3	5.6 ±2.1
Fat-free mass (g)	828.0 ± 174.9	992.1.±280.4
Total body water(%.)	67.9 ±1.5	65.5 ±3.3

[a] Includes data from Buskirk and Harlow (1989).
[b] Calculated from ether extraction of whole body.

Table 2-Correlations among selected variables estimated from skinned and unskinned marten[ab]

Marten	A	B	Z	BL^2/A	BL
Skinned (n = 17):					
Length (cm)	-0.25	0.05	-0.25	0.67**	NA
Mass (g)	-.20	.08	-.20	-.58*	0.81***
Water (%)	-.20	-.38	-.20	.11	-.10
FFM (g)	-.24	-.02	-.24	.61*	.83***
Fat (%)	.35	.45	.35	-.43	-.24
Unskinned (n = 6):					
Length (cm)	-.30	.34	-.30	.59	NA
Mass (9)	-.64	.16	-.64	.85*	.89*
Water (%)	-.05	-.44	-.05	-.17	-.76
FFM (9)	-.65	.18	-.65	.87*	.89*
Fat (%)	-.20	-.04	-.20	.21	.33

NA = Not applicable.
[a] Significance levels: * = P $\leq$ 0.10, ** = P < 0 01, and *** = P < 0.001.
[b] A = resistance, B = reactance, Z= $(A^2 + B^2)^{-2}$, and BL = body length.

The animals we studied were all quite lean, with measured percentage of body fat values averaging only 4.8 percent (range 0.6 percent to 8.7 percent). It is possible that bioelectrical impedance measurements cannot be taken with sufficient precision to reliably estimate such low body composition values. Results from our small sample of unskinned carcasses showed that percentage of body fat could be estimated within 5 percent of measured values (which also were subject to unmeasured error) in five of the six cases and within 2 percent in four cases.

Table 3 - Regression statistics from stepwise analyses based on variables described in table 2

Sample	Regression parameters
Unskinned (n = 6):	
Regression equation	FFM = 117.01(BL) - 0.51(A) - 3541.43
Standard error	75.33
Adjusted R^2	.93
Significance	.009
Skinned (n = 17):	
Regression equation	FFM = 61.12(BL) - 1726.25
Standard error	101.67
Adjusted R^2	.66
Significance	0
All animals (n = 23):	
Regression equation	FFM = 67.95(BL) - 0.24(A) - 1719.93
Standard error	122.55
Adjusted R^2	.67
Significance	0

Because the four-terminal impedance plethysmograph is portable, easy to use, rapid, and noninjurious, we believe that it may be used as a field tool for analyzing body composition, in particular fat reserves, of living animals. Large sample sizes of live animals exhibiting variable body fat composition are necessary to fully evaluate this technique.

Table 4—Measured and estimated body composition values for skinned and unskinned marten[a]

Identification number	Sex	Total mass	Fat-free mass		Fat mass		Body fat	
			Meas.	Est.	Meas.	Est.	Meas.	Est.
			– – – Grams – – –				– – Percent – –	
Unskinned:								
21	F	983	914	898	69	85	7.0	8.7
22	M	1498	1387	1373	111	125	7.4	8.3
23	M	1327	1263	1197	64	130	4.8	9.8
27	M	1000	954	1062	46	-62	4.6	-6.2
30	F	680	665	646	15	34	2.2	5.0
32	F	834	770	752	64	82	7.7	9.9
Skinned:								
26	M	1103	1067	963	37	140	3.3	12.7
28	F	640	616	596	24	44	3.8	6.8
29	M	1021	975	841	46	180	4.5	17.7
31	M	907	841	749	66	158	7.3	17.4
33	F	624	604	657	20	-33	3.2	-5.4
34	F	680	655	780	25	-100	3.7	-14.7
35	M	1162	1099	1024	63	138	5.5	11.9
36	M	907	898	1024	9	-117	1.0	-12.9
37	M	765	699	902	66	-137	8.7	-17.9
38	F	652	600	627	52	25	8.0	3.9
39	M	907	902	871	5	36	0.6	3.9
41	M	925	870	963	55	-38	6.0	-4.1
44	M	935	896	932	39	3	4.1	0.3
46	F	709	655	627	54	82	7.6	11.6
48	F	702	687	719	15	-17	2.2	-2.4
49	M	964	925	841	39	123	4.1	12.8
50	M	1134	1089	963	45	171	4.0	15.1

[a] Measured values from Buskirk and Harlow 1989.

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