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CORRELATION OF SEX, AGE, AND BODY MASS WITH HOOF SIZE IN WHITE-TAILED DEER FROM THE PIEDMONT WILDLIFE REFUGE, GEORGIA

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ABSTRACT

The distal forelimbs and mandibles of 157 white-tailed deer (*Odocoileus virginianus*) harvested during the 2001 fall hunting season on the Piedmont National Wildlife Refuge, Georgia, were used to explore the osteometric correlation of sex, age, and body mass with hoof size. The width of the right front, medial unguis and the linear distance from the tip of the dew-claw to the tip of the medial unguis were used as measures of hoof size. Linear regressions were calculated for each osteometric parameter for each sex individually and for the sexes combined. Regression R^2-values suggest that hoof width may be useful in estimating body mass, but not age. However, due to nearly complete range overlap, male white-tailed deer cannot be distinguished from females on the basis of hoof width or length.

Key words: white-tailed deer, hoof size, body mass, Georgia

INTRODUCTION

Most naturalists and outdoor enthusiasts in Georgia have heard or made the exclamation "look at the size of those deer tracks, what a massive buck!" Although *a priori* in nature, the basic reasoning of "the larger the animal the larger the track" seems reasonable. Taking into consideration the deformability of the substrate, the method of locomotion, and the speed of travel, the imprint left behind should provide some useful information concerning the track maker. Moreover, this line of reasoning has led paleontologists to use fossilized tracks of extinct organisms to suggest speed of movement, herding behaviors, community interactions, and the relative age of the track makers (1).

A correlation between body mass and hoof size for wild ungulates such as white-tailed deer could be extremely useful for biologists and land managers. Estimates of body mass often are used in paleobiological, anthropological, and wildlife management research. Paleobiological studies use body mass estimates in functional morphology studies and to postulate life history parameters such as growth rate and gestational period (2). In anthropological studies, estimates of body mass for prey species are necessary to generate meat weights available for native peoples (3). Modern studies have demonstrated that body size correlates with life history parameters such as home range size, nutritional physiology, and feeding ecology (4).

Body mass estimates generally utilize regression equations based on extant species. However, live weights of free-ranging extant mammals are often difficult to obtain. For game-mammals such as white-tailed deer, live weights are often not available. However, field dressed weights are readily available at hunter check-stations and may be used to accurately estimate live weight. As demonstrated by Hamerstrom and Camburn (5), a strong correlation exists between live weight and field dressed weight for white-tailed deer.

Previous analyses of white-tailed deer have found varying degrees of correlation between osteometric values and body mass. Scott (6) determined that bone diameter correlated more significantly with body mass than did bone length in cervids. Emerson (7) found a significant correlation between astragali dimensions and white-tailed deer live weight ($R^2 = 0.87$). Perdue (3) concluded a general correlation between body mass and measurements of radii, carpals, tibiae, and tarsals (average $R^2 \sim .75$). Morris (8) determined that a stronger correlation exists between metacarpal proximal area and live weight in females ($R^2 = 0.74$) than in males ($R^2 = 0.48$). It is surprising that these correlations exist when yearly variation in white-tailed deer body mass approaches 30% (9). In addition, to further complicate the relationship, Strickland and Demarais (10) found a significant correlation between age class mean body mass and soil fertility for white-tailed deer from Mississippi.

The goals of our study were to understand for white-tailed deer: 1) if hoof size is correlated with age, 2) if hoof size is correlated with weight, and 3) if there is clear distinction between female and male hoof size.

MATERIALS AND METHODS

As part of a larger study (8), cranial and postcranial material was collected from 350 white-tailed deer during the fall of 2001 at the US Fish and Wildlife Service hunter check station on the Piedmont National Wildlife Refuge (NWR) in Jones and Jasper Counties, Georgia. At the check station, hunter-harvested deer were sexed, aged (jaw pulled), and weighed (field dressed). Age determination was based on premolar and molar eruption and wear as outlined by Thompson (11). During the cleaning of the postcranial material, hoof measurements from the right forelimbs were obtained from a random subset (157 individuals, 55 females and 102 males). To quantify hoof size, two measurements were taken (Figure 1): 1) hoof length (HL) was defined as the linear distance from the tip of the dew claw to the tip of the medial unguis, and 2) hoof width (HW) was defined as the maximum width of the medial unguis. Average field dressed weight, average HL, and average HW was calculated for each sex within each age group. Data sets for weight, HL, and HW were analyzed using SPSS version 13 and shown to be normally distributed using the Kolmogorov-Smirnov Test. The significance of the differences in female and male mean values was analyzed using Student-t Tests. Linear regressions were calculated for each sex individually and for the sexes combined for age versus HL, age versus HW, weight versus HL, and weight versus HW.

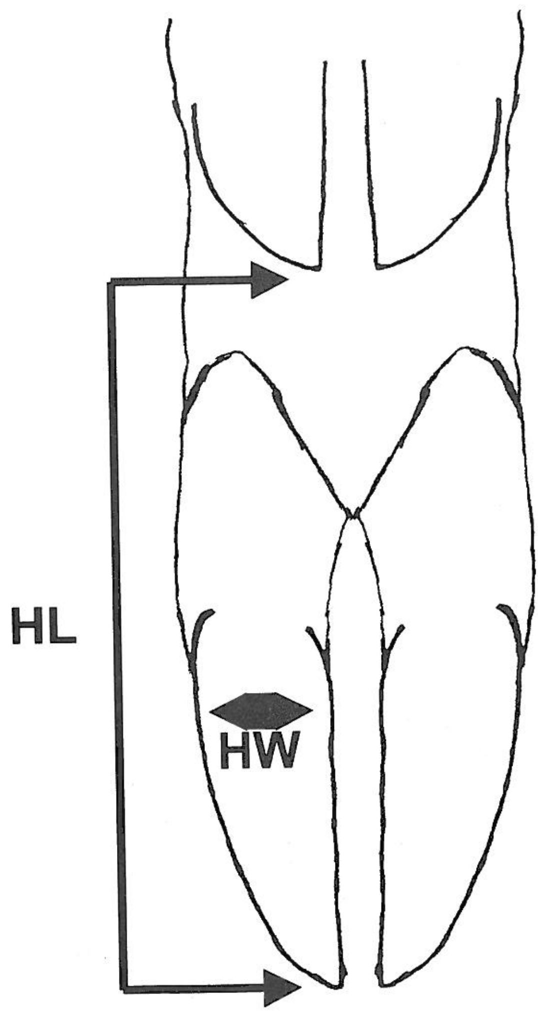

Figure 1. Linear measurements of white-tailed deer forelimb hoofs collected from the Piedmont National Wildlife Refuge, Georgia, during the 2001 fall hunting season. HL = linear distance from the tip of the dew claw to the tip of the medial unguis; HW = maximum width of the medial unguis.

RESULTS

Field dressed weights and osteometric mean and range values are presented in Tables I-III. Although range overlaps exist, field dressed weights are significantly ($p < 0.001$) greater for males compared to females. Males exhibit significantly ($p < 0.001$) longer HL values than females, however with nearly complete overlap (Table II, Figure 2A). Males also exhibit significantly ($p < 0.001$) greater HW values than females, but again with nearly complete overlap (Table III, Figure 2B). Linear regression equations, R^2-values, and p-values are presented in Table IV. R^2-values indicate fairly strong correlations for female age versus HW, female weight versus HL (Figure 2A), female weight versus HW (Figure 2B), male weight versus HW (Figure 2B), and the sexes combined weight versus HW.

Table I. Means and ranges for the field dressed weights (kg) for white-tailed deer collected from the Piedmont National Wildlife Refuge, Georgia, during the 2001 fall hunting season. Number of individuals indicated in (n).

Age (years)	Female	Range	Male	Range
.5	19.5 (6)	16.5 – 22.9	24.6 (8)	20.3 – 29.3
1.5	33.2 (12)	25.2 – 41.4	36.2 (52)	24.3 – 49.1
2.5	34.2 (20)	30.2 – 42.7	43.2 (34)	31.1 – 54.9
3.5	37.3 (7)	31.1 – 44.1	47.4 (7)	36.9 – 60.7
4.5	37.7 (6)	33.3 – 40.5	52.2 (1)	
5.5	38.2 (3)	36.0 – 42.3		
6.5	36.0 (1)			
Total	n = 55	16.5 – 44.1	n = 102	20.3 – 60.7

Table II. Means and ranges for the forelimb dew claw to medial unguis tip length (HL) for white-tailed deer collected from the Piedmont National Wildlife Refuge, Georgia, during the 2001 fall hunting season. Measurements in mm. The numbers of individuals in each age class is the same as Table I.

Age (years)	Female	Range	Male	Range
.5	79.1	74.2 – 84.7	88.1	82.8 – 92.5
1.5	86.5	81.2 – 93.3	90.7	80.6 – 101.1
2.5	87.6	78.4 – 97.6	90.6	79.9 – 102.1
3.5	88.7	81.0 – 96.0	94.9	88.4 – 110.0
4.5	90.2	85.5 – 94.4	83.5	
5.5	91.5	86.9 – 98.3		
6.5	90.9			
Total	n = 55	74.2 – 98.3	n = 102	79.9 – 110.0

Table III. Means and ranges for the maximum width of the forelimb medial unguis (HW) for white-tailed deer collected from the Piedmont National Wildlife Refuge, Georgia, during the 2001 fall hunting season. Measurements in mm. The numbers of individuals in each age class is the same as Table I.

Age (years)	Female	Range	Male	Range
.5	14.9	13.6 – 16.4	17.4	15.6 – 20.6
1.5	18.2	13.4 – 21.0	19.9	13.1 – 22.2
2.5	18.8	15.7 – 20.7	20.0	18.7 – 23.0
3.5	18.3	13.2 – 21.2	21.7	18.3 – 25.1
4.5	20.2	18.6 – 22.0	17.6	
5.5	20.4	18.0 – 21.9		
6.5	20.2			
Total	n = 55	13.2 – 22.0	n = 102	13.1 – 25.1

Table IV. Linear regression equations, R^2-values, and *p*-values for age and weight versus the forelimb dew claw to medial unguis tip length (HL) and the medial unguis width (HW) for white-tailed deer collected from the Piedmont National Wildlife Refuge, Georgia, during the 2001 fall hunting season. F = female, M = male, F + M = females and males combined.

Character	Equation	R^2	*p*-value
Age vs. HL: F	0.138x – 9.308	0.246	<0.001
Age vs. HW: F	0.430x – 5.229	0.407	<0.001
Weight vs. HL: F	0.783x – 34.790	0.445	<0.001
Weight vs. HW: F	2.066x – 4.653	0.502	<0.001
Age vs. HL: M	0.018x + 0.317	0.016	0.207
Age vs. HW: M	0.177x – 1.636	0.168	<0.001
Weight vs. HL: M	0.310x + 10.370	0.049	0.025
Weight vs. HW: M	2.905x – 19.804	0.452	<0.001
Age vs. HL: F + M	0.033x – 0.736	0.028	0.035
Age vs. HW: F + M	0.176x – 1.247	0.107	<0.001
Weight vs. HL: F + M	0.549x – 12.388	0.169	<0.001
Weight vs. HW: F + M	2.630x – 14.545	0.505	<0.001

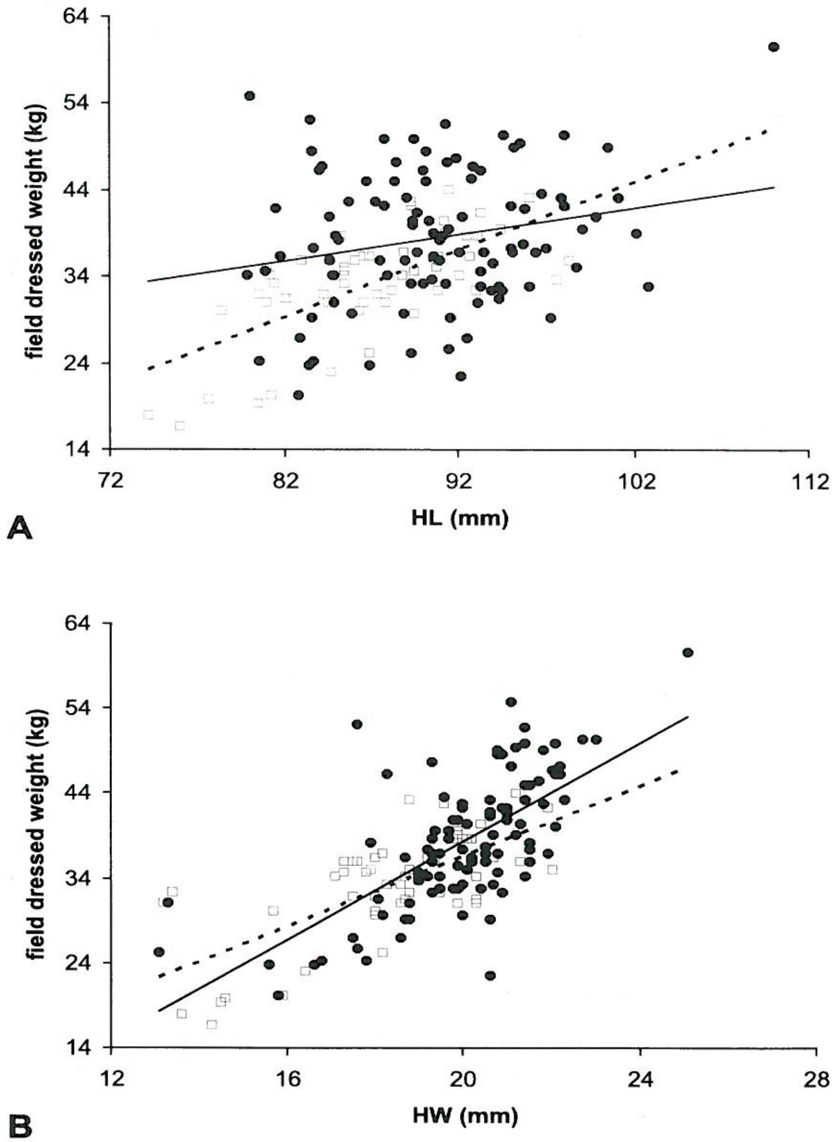

Figure 2. Scatter-plots for forelimb hoofs: A, the dew claw to medial unguis tip length (HL) versus weight; and B, the medial unguis width (HW) versus weight in 157 white-tailed deer (55 females and 102 males) collected from the Piedmont National Wildlife Refuge, Georgia, during the 2001 fall hunting season. Females denoted by open squares and dashed linear regression line. Males denoted by solid circles and solid linear regression line. Regression equations, R^2-values, and p-values are presented in Table IV.

DISCUSSION

For a sample of > 200,000 white-tailed deer analyzed from Mississippi, Strickland and Demarais (10) determined that males reached 95% of the maximum body mass between 3.5 and 4.5 years of age, and females reached 95% of the maximum body mass by 3.5 years. Roseberry and Klimstra (12) found similar results for white-tailed deer from Illinois. In the Illinois herd, a significant difference in hindfoot length between same-aged males and females was noted, with maximum hindfoot length reached by 1.5 years and 2.5 years in females and males, respectively. In north-central Minnesota, Fuller et al. (13) found that male white-tailed deer reached 95% maximum dressed weight at 7.5 years and females attained 95% maximum dressed weight at 3.5 years. Again, however, 95% maximum hind-foot length was reached by 2 years in both sexes, prior to the expected attainment of maximum body mass.

For the Piedmont NWR sample analyzed by Morris (8), 95% maximum dressed weight was attained by males at 5.5 years and females at 2.5 years. In the present subset of the Piedmont NWR sample, males and females attained 95% maximum dressed weight by 4.5 and 3.5 years, respectively (Table I). Males reached 95% maximum mean HL at 1.5 years and HW at 3.5 years, while females reached 95% maximum mean HL at 2.5 years and HW at 4.5 years (Table II, III). For both HL and HW, 7.8% of the male measurements exceed the maximum female value, suggesting a possible size at which males could be distinguished from females.

For white-tailed deer from the Georgia Piedmont, the disconnect between age at mean maximum weight and age at mean maximum HL and HW suggests that a significant relationship between body mass and hoof size probably should not exist. The white-tailed deer hoof appears to reach maximum size several years prior to the realization of maximum body mass. As a group, R^2-values associated with age versus HL or HW regressions do not suggest strong correlations. However, R^2-values associated with the weight versus HW regressions indicate fairly strong correlations and may allow resource managers to estimate the weight of live white-tailed deer based on the track size. The present study indicates that male and female weight, HL, and HW are significantly different as well. However, the nearly complete overlap in the scatter-plots of HL and HW versus dressed weight indicates no clear difference between male and female hoof size, and therefore is likely of little use to the field biologist in distinguishing males and females.

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