

TESTING NEW MEASURES OF AGE INDEPENDENT BODY SIZE IN WHITE-TAILED
DEER (*Odocoileus virginianus*)

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The four elements of the lower hind foot (calcaneus, metatarsal, naviculo-cuboid, and tibia) were tested for use as age-independent proxies of body size in white-tailed deer using known aged specimens from Ft. Hood Texas. Statistical analysis indicates that the calcaneum and the tibia are good proxies of age-independent body size in white-tailed deer. In addition to expanding the list of elements that can be used for studies of age-independent body size, these elements can also be used to age faunal remains to an ordinal scale of juveniles and adults. This is useful for research regarding prehistoric prey populations; as a single element can be used to determine prey body size and age simultaneously, which are the two variables used to assess changes in human subsistence practices via the archaeological remains of their prey.

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CHAPTER 1

INTRODUCTION

In the biological literature there is a plethora of information regarding the life history traits, behavioral patterns, and the biological variation in large bodied mammals, especially ungulates (Cote et al. 2004; Daigle et al. 1999; Damuth 1981; Dayan et al. 1991; Geist 1987, 1998; Leberg and Smith 1993; Mysterud et al. 2000, 2005; Purdue 1980; Sinclair and Parkes 2008; Taber 1982; Virtanen et al. 2002; Wenham and Pennie 1986; White et al. 2007; Wolverton et al. 2007). In North America, many focus their research on white-tailed deer (*Odocoileus virginianus*) populations (Brisbin and Lenarz, 1984; Brown et al. 1978; Fuller et al. 1986; Kie et al. 1983; Purdue 1983a, 1983b, 1987, 1989; Purdue and Smith, 2000; Purdue et al. 2006; Wolverton et al. 2007). Historically white-tailed deer (WTD) were an important resource and are commonly found in archaeological sites across North America. They offered a multitude of resources beyond just the meat they provided. For example, the hides were used to make clothing and blankets; the antlers were used for tool making, the stomachs and intestines were used for storing tallow, and ceremonial items were made out of deer hooves, hair, and hide (Halls 1984; Densmore 1929).

Phenotypic plasticity in size and behavior are hallmarks of deer and many studies document the morphological responses in deer to various geographic and environmental factors such as habitat productivity and climate (Purdue 1980; Van der Geer 2008; Geist 1987; Halls 1984; Wolverton et al. 2009). Research on modern deer from populations with different

population densities and predation levels, and from different habitats demonstrate the phenotypic plasticity of deer, such as maintaining reproductive efforts by decreasing body size under conditions of high population density or degraded habitats (Geist 1987, 1998; Kie et al. 1983; Lesage et al. 2001; Simard et al. 2008; Tremblay et al. 2005). Figure 1 illustrates the relationship between density levels, abundance of food, and body size in ungulates. According to Geist,

Two extremes in energy and resource availability thus impinge on a species over the course of its history; long periods of shortages generated by intraspecific competition in *maintenance* populations, and brief periods of superabundance during colonization. Two regimes of natural selection are thus possible; selection for *efficiency* for all life processes under *maintenance* conditions, and selection for rapid, prolific reproduction, and social competitiveness, including selection for luxury organs, during *dispersal* conditions. Mammals appear to adjust epigenetically to these conditions during ontogeny, growing into maintenance phenotypes under conditions of efficiency selection and into dispersal phenotypes under luxury conditions of selection. (Geist 1998:7).

In deer, higher population density creates higher intra-specific competition over resources and less food per animal, which can result in a smaller body size (maintenance/efficiency phenotype). At lower population densities, or even areas of higher plant productivity, there is less competition and more food per animal, which can result in a bigger body size, or the dispersal/luxury phenotype (Geist 1998; Wolverton et al. 2009). While several studies indicate that even at very low densities, adequate nutritional quality is important, it is clear that when crowded conditions exist, there is less food available per individual, and there is more intra-specific competition over the available resources. There are many factors that can affect the density of a population including sustained hunting, which results in an increase in body size (independent of age) in WTD (Wolverton et al. 2007), and this knowledge has been applied to zooarchaeological assemblages (Wolverton et al. 2008).

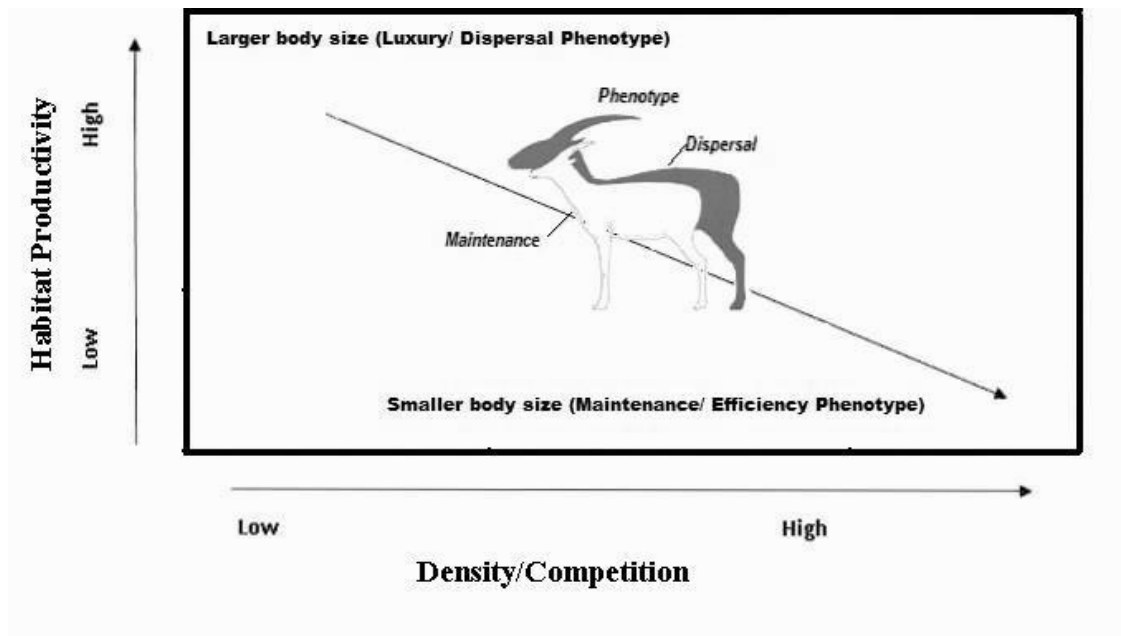


Fig. 1. Illustration of the relationship between density levels, food availability, and phenotypic plasticity resulting in different body size. Modified from Geist, 1998: p. 5

1.1 Measures of Body Size

There are numerous measures of body mass and size that are used in biology, such as dressed weight or hind foot length, which is measured from the end of the posterior calcaneum to the tip of the hoof (Figure 2). Body weights, either live weight (before any type of butchering/draining of fluids) or dressed weight (minus fluids and sometimes viscera), are commonly used in biology as an indication of absolute mass in deer, but this information is not readily available to archaeologists and fluctuates by season and year. Hind foot length (HFL) has also been used as a measure of size, specifically stature, in modern WTD studies (Ashley et al. 1998; Keyser et al. 2005; Simard et al. 2008; Toigo et al. 2006). Body size research in archaeology (used to assess human impacts on prey populations and ultimately changes in

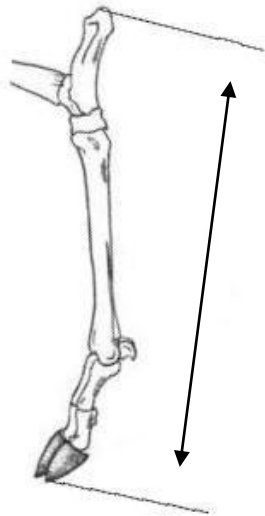


Fig. 2. A depiction of the distal hind limb in Cervidae. Hind Foot Length (HFL) measurement used for independent variable of stature and body size. Modified from Myers, P., R. Espinosa, C. S. Parr, T. Jones, G. S. Hammond, and T. A. Dewey. 2006. The Animal Diversity Web (online). Accessed May 12, 2009 at <http://animaldiversity.org>. University of Michigan, Museum of Zoology.

human subsistence behaviors for example), is limited to the use of measurements on skeletal remains.

1.2 Zooarchaeological Measures of Age Independent Body Size

Research regarding the astragalus in WTD has shown it to be a good candidate as a proxy of body size (independent of age). The astragalus is used for several reasons; it preserves well, it is commonly found in archaeological assemblages, and it reaches its maximum potential size at an early age (around 6 months) with little variation among age groups (Purdue 1987; Wolverton et al.2007). Because of this early maturation, changes in size reflect changes in body size and not age. This is referred to as age-independent body size (see Figure 3 as an example).

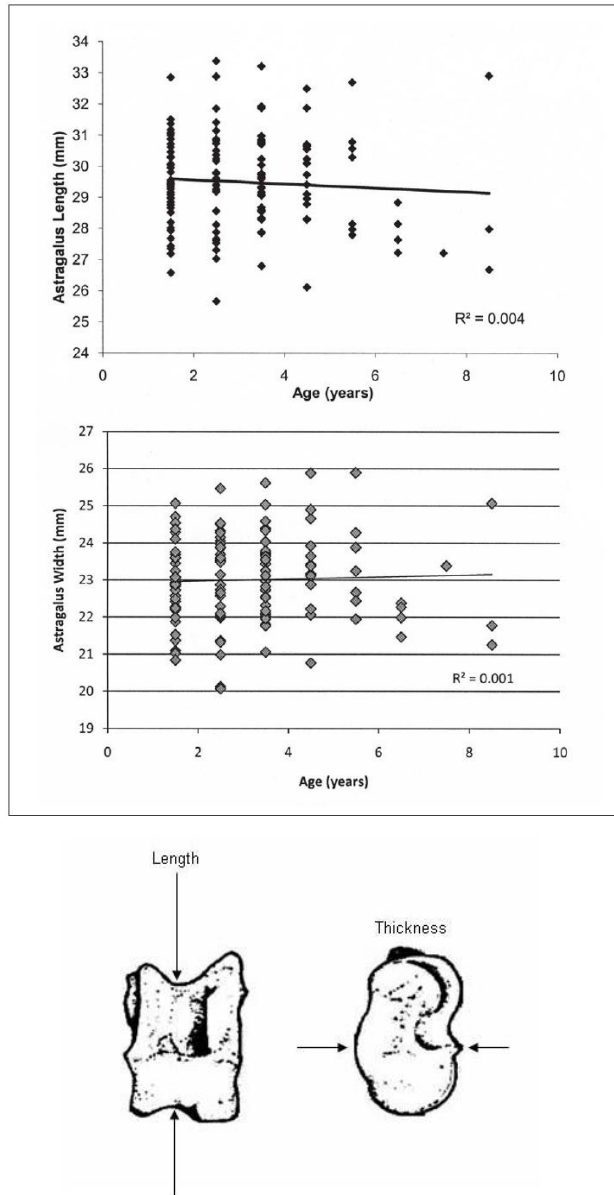


Fig. 3. Astragalus length and width for modern deer from central Texas showing no significant increase in size with age (from Wolverton et al., 2008: p. 9)

1.3 Thesis Goals

This thesis is a study of the other elements in the lower hind limb and uses measurements of the width, depth, and length (when appropriate) of each one to test their use as

body size proxies (Figure 4). For body size research in archaeological contexts, it is important to determine that changes in size between zooarchaeological assemblages are not related to differences in the age/sex composition of each sample. There are known differences in size between sexes, and each sex gains weight and mass with age. Currently archaeology is restricted to using this one element for body size research of white-tailed deer, which was a widely used prehistoric prey species in North America (Halls 1984), as other elements have not been evaluated for their usefulness as age-independent measures of size. This thesis assesses four

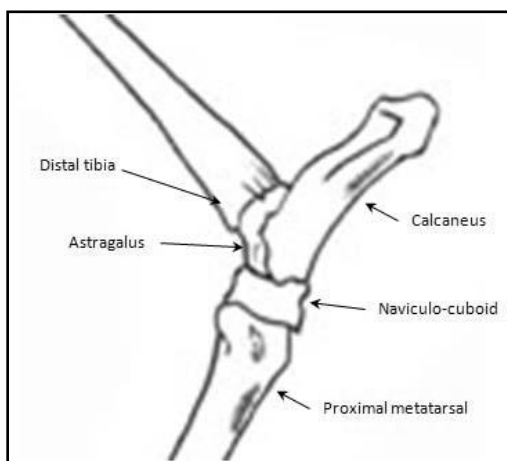


Fig. 4. The anatomical subregion of focus, the lower limb, upper foot. Modified from Myers, P., R. Espinosa, C. S. Parr, T. Jones, G. S. Hammond, and T. A. Dewey. 2006. The Animal Diversity Web (online). Accessed May 12, 2009 at <http://animaldiversity.org>. University of Michigan, Museum of Zoology.

additional skeletal elements from the lower hind limb that are relatively high in bone density (Lyman 1994; Lam et al. 1999), to determine whether or not these elements are useful surrogates of age independent body size in white-tailed deer for the broader purpose of studying shifts in size through time (Figure 5). The ankle mechanism consists of three other elements that articulate with the astragalus (the distal end of the tibia, the naviculo-cuboid (NC), and the calcaneus). The proximal end of the metatarsal supports the assemblage, and articulates with the NC. The astragalus works as a double pulley system, allowing both the limb portions above and

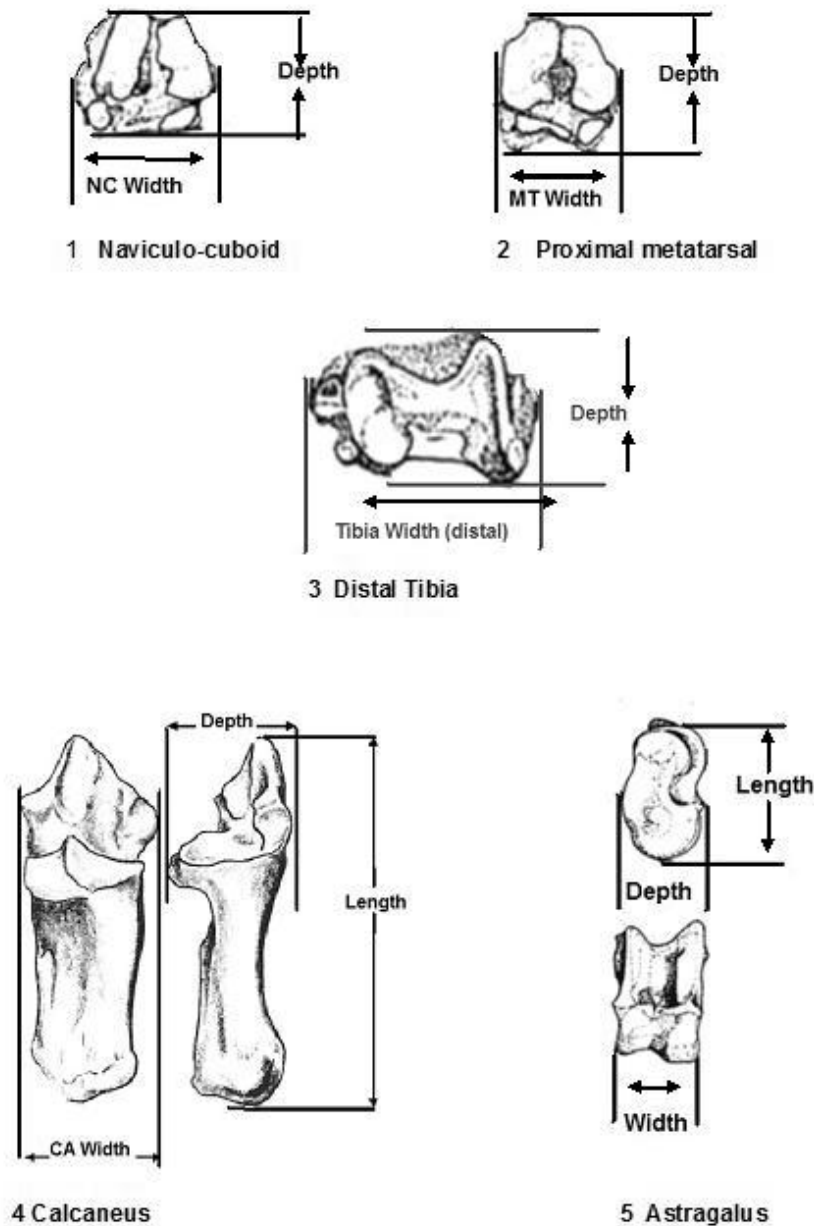


Fig. 5. The specific elemental measurements that were tested as proxies of age independent body size using modern white-tailed deer from Ft Hood, Texas. Based on those established by Purdue in 1987. Drawings 1 -3 and 5 were modified from Purdue, 1987: p. 3; drawing 4 modified from Gilbert, 1970: p. 320.

below it to move and rotate along the condyles on both ends. If the astragalus reaches early maturity and represents the maximum potential size of an individual, then the other elements so closely involved and connected to the astragalus should as well. Useful elements/measurements

will not have a correlation with age, but should correlate moderately to strongly with other measures of body size, such as dressed body weight (DBW) and hind foot length (HFL). The ability to use a series of elements enhances the analytical potential of biometric studies in zooarchaeology because abundances of skeletal elements vary by site and taphonomic context.

1.4 Previous Research

Body size research within archaeology has concentrated on the various animal species that have close associations with prehistoric humans, either as prey (Byers 2004; Dean 2007; Hill et al. 2008; Jacobson 2003; Klein 1982; Lyman 1979, 1987, 2006; Purdue 1987, 1989; Wolverton 2008, Wolverton et al. 2007, 2008; Smith 1974; Stiner 1990; Stiner et al. 2000; Ugan 2005a, 2005b), or as domesticates (Bar-Oz et al. 2004; Davis 1981; Hassanin et al. 2006; Hecker 1982; Zeder 2001).

The earliest research in archaeology to apply biological measurements of size, to help answer questions about prehistoric human subsistence patterns, involved the quantification of meat weights and the contribution to the human diet of specific prey species derived from archaeofaunal remains (Binford 1978; White 1953). The idea is based on the fact that certain animals (or even parts thereof) provide more meat than others, and therefore make a larger contribution to the diet than others. This type of research used real weights from modern species, or various types of prediction methods to estimate body weights of prey species (Emerson 1978, 1983; Lyman 1979; Madrigal and Holt 2002; Purdue 1983a, 1983b, 1987; Smith 1975). One of the difficulties with these methods is that weight is known to fluctuate between seasons, geographic gradients, genetic composition, and varying habitats, and within and between years (Purdue 1980; Wolverton et al. 2009). Other researchers study changes in prey populations in response to sustained human predation, for both large and small bodied animals

(Broughton 1999, 2002; Edwards 1967; Stiner 1990; Stiner et al. 2000; Wolverton 2008; Wolverton et al. 2007, 2008). Increased hunting pressure on prey populations creates changes in mortality profiles and/or survivorship curves across time, and this type of research can be a powerful tool when used with additional lines of evidence in zooarchaeological studies (Broughton 1999; Hill 2008; Koike and Ohtaishi 1985; Koike 1987; Lyman 1987; Lupo 2007; Munro 2004; Munro et al. 2005; Smith 1974; Stiner 1990, 1994; Wolverton 2008; Wolverton et al. 2008). Mortality profiles of prey populations under hunting pressure will show 1) a relatively higher percentage of juveniles and young adults, and 2) a loss or reduction in the oldest possible age classes (Broughton 1999; Hesselton and Hesselton 1982; Koike and Ohtaishi 1985; Koike 1987; Lyman 1987; Munro 2004; Stiner 1990; Wolverton 2007, Wolverton et al. 2008; Wolverton 2008). This trend is referred to as “steepened” survivorship (Wolverton 2008). An increase in hunting pressure steepens this curve because while it does not affect fertility, it does reduce the probability of surviving to the next age class (Caughley 1966, 1977; see Wolverton 2008).

1.5 Body Size, Environmental Factors, and Harvest Pressure

One of the difficulties with body size research applied to archaeological assemblages is in determining the causal factor(s) of change. Human hunting thins a population, and in effect creates more food per individual animal and less intra-specific competition, which can lead to an increase in body size in deer (Wolverton et al. 2007). The same result could be caused by an increase in habitat productivity due to changing climatic conditions that can also increase available resources through changes in available plant biomass. However, unlike habitat change, human hunting pressure has a measureable effect on the age composition of the prey population.

A change in habitat productivity does not have an effect on the mortality/survivorship of the population. A recent model considers both of these variables, age-independent body size and mortality/survivorship patterns, and provides a tool to determine the extent and degree of each causal factor (predation/hunting versus habitat productivity) from faunal remains (See Wolverton 2008). The model has been applied to a large assemblage of faunal remains from southeast Texas, which indicate an increase in hunting pressure and within bone nutrient processing between the pre pottery and post pottery time periods (Wolverton et al. 2008).

1.6 Summary of Thesis Chapters

This thesis considers both of these variables (size and age) by testing new elements for use as proxies of age-independent body size, as well as alternate aging methods using epiphyseal fusion rates instead of tooth wear and eruption patterns. The next chapter describes the areas of sample collection, the methods used for processing, and statistical analysis of the four skeletal elements. It also outlines the guidelines used to determine age at an ordinal scale from the fusion rates of the calcaneum and the tibia. Chapter 3 covers the results for the analysis of the Ft. Hood Specimens, as well as a comparison with the Austin specimens. Chapter 4 is a discussion of these results, and how they can be applied to prehistoric faunal assemblages. Chapter 5 covers the results and discussion of findings regarding the skeletal measurements from Eagle's Ridge, using the large faunal assemblage. This chapter looks at size comparisons using the skeletal measurements between the prehistoric ER fauna and the modern Ft. Hood and Austin samples. There are also examples of the types of analysis that can be performed with prehistoric data. Chapter 6 is a discussion of the results and the conclusion of the thesis.

CHAPTER 2

MATERIALS AND METHODS

2.1 Data Collection

One hundred fifteen hind limbs from white-tailed deer were collected from two central Texas locations. The first group was collected at hunting check stations within Fort Hood near Killeen, just north of Austin in Bell and Coryell counties in central Texas (Figure 6). These samples come from the same “managed” population of deer studied in previous body size research (Wolverton et al. 2007) but from the 2007 and 2008 hunting seasons. At the Fort Hood check station, each deer is assigned an age (using an eruption and wear schedule) and antler characteristics are recorded. The dressed body weight (DBW) in pounds is also measured (carcass weight minus viscera). One hundred one specimens were collected from Fort Hood; thirty-three from the 2007 hunting season and sixty-eight from the 2008 hunting season. Specimens from Fort Hood are obtained by clipping the distal tibia and leaving the entire lower foot intact, allowing hind foot length to be measured.

The second group is from suburban areas west of Austin, Texas that have not undergone any type of population management; they live in areas with high population densities and an over-browsed habitat. These populations are thought to be near or at the carrying capacity of their environment. These samples were collected by Orion Research and Management Services, Inc. during unselective culling in 2005 through 2007. The Austin sample represents an “unmanaged” group of deer (Wolverton et al. 2007). Only fourteen specimens were collected

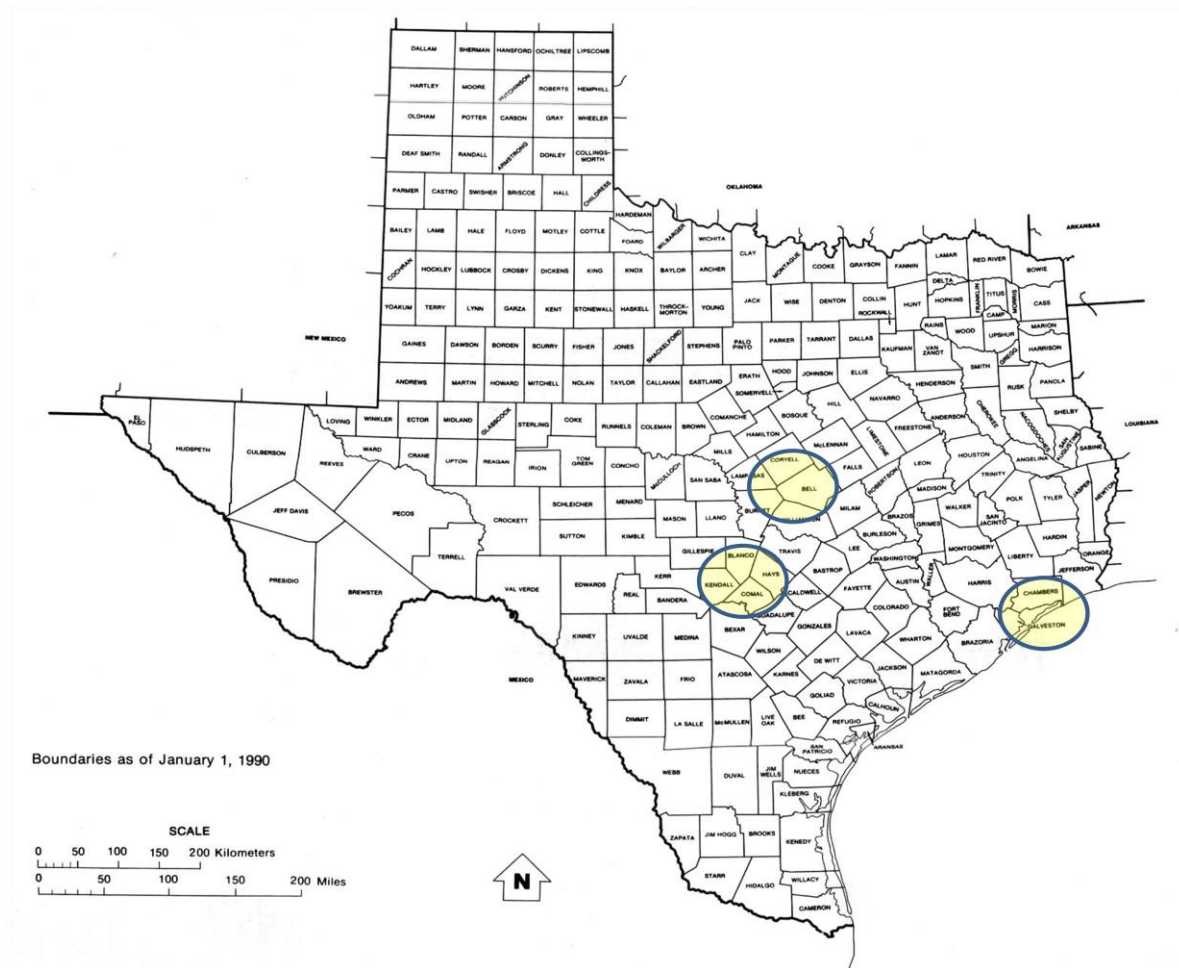


Fig. 6. County map of Texas showing the locations of sample collections; Ft. Hood (central Texas), the Austin area (south central Texas), and the Eagle’s Ridge site on the southeast coast. Accessed online May 15th 2009 at <http://www.lib.utexas.edu/maps/states/texas.jpg>. Courtesy of the University of Texas Libraries, The University of Texas at Austin

from the Austin area. However, comparisons can still be made with the Ft Hood sample by comparing variation and means of individuals of the same age and sex. Specimens from the unmanaged Austin population are clipped at the distal tibia and the proximal metatarsal in the field, and Hind Foot Length (HFL) has not been recorded for that population, skeletal measures can only be compared to DBW. After field collection, specimens are transported to UNT’s

Environmental Archaeology Lab, where they are frozen until the time of processing. During processing, the specimens are defleshed, disarticulated, boiled gently, dried and measured.

2.2 Testing Morphometric Variation in the Hind Foot Bones of White-Tailed Deer

Figure 5 details the measurements that were recorded for each element, which include maximum width and depth dimensions, using digital calipers and recorded to the nearest .01 mm. Maximum length was recorded for the calcaneum, for both fused and unfused specimens. Fusion data was collected to determine growth rates before and after fusion occurs. Differences in growth patterns between the sexes are also considered. These measurements mirror those developed for the hind-limb elements by Purdue (1987).

2.3 Statistical Analyses

These skeletal measurements were tested for significant relationships with measures of body size (DBW) and stature (HFL) using correlation and linear regression analyses. Normality is tested using Shapiro-Wilk's test, to determine whether or not normality can be assumed for the size data. Bivariate scatter plots are used to test for linear relationships between dependent (DBW/HFL/age) and independent (skeletal measures) variables. A parametric test, Pearson's correlation (r), will be used to test the direction (positive or negative) and strength of relationships between variables from data that are normally distributed and are recorded at an interval scale. Data that do not pass normality tests or that are ordinal scale (such as age) will be tested non-parametrically against skeletal size variables with Spearman's rho, which provides a correlation of ranks. For any skeletal variables that demonstrate significant correlations with DBW and HFL, linear regression analysis will be used to validate the use of these skeletal measures as proxies of DBW or HFL in WTD.

2.4 Ordinal Age and Fusion Data

In the process of recording these data, there were several errors discovered in the aging of teeth by wear patterns and eruptions used in the field. In the 2008 sample, there were 3 individuals that were classified incorrectly. One was classified as a four and a half year old, yet it has unfused epiphysis in both the tibia and the calcaneum (both bones fuse by the second year, see Table 1).

Table 1

Age in months of fusion for elements used in this study (distal tibia, calcaneus, and the proximal metatarsal). * The fusion ages for the distal end of the metatarsal are included here because the entire bone could be found archaeologically, however the proximal end used in this research does not have a fusion area. Data from Purdue 1983.

		Initial fusion	½ Fused	Complete fusion
Tibia	Bucks	14-17	17	23
	Does	14-17	14-17	20
Calc	Bucks	14-17	20	26-29
	Does	4-17	20	26-29
MT*	Bucks	17	23	26-29
	Does	20	20	26-29

Two other individuals were classified as one and a half year olds, with completely fused epiphysis in both the tibia and the calcaneum. There were also 3 similar errors in the Austin sample.

These were adjusted to ages based on fusion dates, 1.5 years for the unfused specimen, and 2.5 years for the fused ones. I also added an additional classification based on the fusion rates of the tibia and calcaneum; juvenile (unfused, partially fused) and adults (completely fused). This will be used as an additional check in biometric analyses, by comparing the skeletal measurements between juveniles and adults, as well as by individual age class. The ability to use a single element for age and size comparisons will be useful for archeological research, and the fusion of these two bones corresponds to the age-categories already used in many

zooarchaeological studies (Munro 2004; Stiner 1990; Wolverton et al. 2008.) There may be errors in the aging of other individuals that I cannot detect as easily; a five year old aged as a three year old for example. This is generally the reason that archaeologists collapse the tooth wear data into an ordinal scale of adults and juveniles, and fusion data can be used in the same way.

2.5 Archaeological Applications

The faunal assemblage from the Eagle's Ridge (41CH252) site was used to test the usefulness of skeletal measures as size proxies. This site has been used for previous analysis of human subsistence behaviors during the mid Holocene, and indicates an increase in harvest pressure and intensification of within bone nutrient processing from the pre-pottery periods to the post pottery periods (Wolverton et al. 2008). The assemblage itself contains thousands of bones, and a large percentage of them are white-tailed deer remains (Reitz and Keck 1998). The same measurements were recorded for elements from archaeological specimens at Eagle's Ridge. Further details on this site, with the results and a discussion, follow that of the initial research with the modern Ft. Hood specimens.

CHAPTER 3

RESULTS

3.1 Fort Hood Data Distribution

The distribution of sampled deer by hunting season, age, and sex are shown in table 2.

The sample obtained from the 2007 hunting season is heavily skewed towards males (85% bucks). The 2008 group has a more equal distribution between the sexes (56% bucks, 44% does).

Table 2:
Distribution of Ft. Hood data by hunting season, age group and sex ($n = 101$).

GROUP		AGE							Total
		.5	1.5	2.5	3.5	4.5	5.5	6.5	
2007	Bucks	1	4	3	12	3	4	1	28
	Does	1	1	2	0	1	0	0	5
	Total	2	5	5	12	4	4	1	33
2008	Bucks		10	9	11	4	3	1	38
	Does		2	7	13	8	0	0	30
	Total		12	16	24	12	3	1	68

The combined sample approximates a normal age distribution (Figure 7), but both groups lack females in the oldest age groups. The combined data was used to provide adequate sample sizes for growth analyses (weight and hind foot length by age). However, it was necessary to exclude 11 specimens from the correlation and regression analyses for several reasons. First, in the youngest age group (0.5 yr.) there are only 2 individuals, which may or may not be representative of the populations' youngest group. The two individuals that were collected

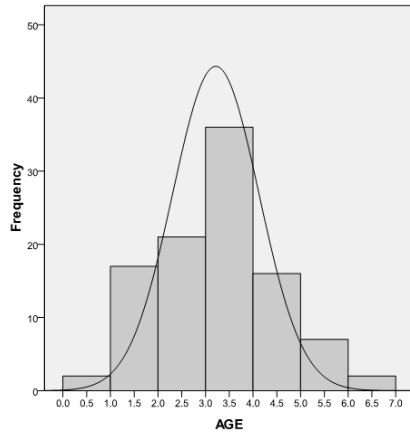


Fig. 7. Histogram showing the age distribution of the combined Ft. Hood 2007 and 2008 samples.

could be the smallest or the largest in the group, and a larger sample is needed to determine the spread of the variation in size among the 0.5 yr. olds. In the oldest age groups, the 5.5 yr. olds ($n=7$) and 6.5 yr. olds ($n=2$), all the individuals are males (which are considerably larger than females), and including them in these analyses will skew the results (see discussion in 3.3).

3.2 Growth Patterns - Dressed Weight

The results indicate that weight continues to increase with age for both sexes, although males weigh more than females of the same age and gain more mass than females with age (Tables 3A and B). When looking at bucks and does separately, weight begins to taper off earlier in females than in males, and at around 1.5 years a larger separation between the sexes occurs (Figure 8). This is consistent with other biological studies and due to the tradeoff between growth and reproductive capabilities; the females need to expend energy to mate, survive gestation periods, and give birth (Purdue 1989; Geist 1987; Halls 1984). This energy could otherwise be used for growth, as is seen in the males, who continue to grow to maximum potential at around 2.5 years of age.

Table 3
Dressed body weight by age group for bucks and does from Ft. Hood 2007 and 2008 hunting seasons (n=101).

A					
Does DW					
AGE	Mean	N	Std. Dev	Variance	S. E.
.5	31.00	1	.	.	.
1.5	56.33	3	.577	.333	.333
2.5	67.56	9	10.549	111.278	3.516
3.5	71.00	13	6.856	47.000	1.901
4.5	74.33	9	11.895	141.500	3.965
Total	68.57	35	11.922	142.134	2.015

B					
Bucks DW					
AGE	Mean	N	Std. Dev	Variance	S. E.
.5	40.00	1	.	.	.
1.5	71.57	14	10.959	120.110	2.929
2.5	105.67	12	14.587	212.788	4.211
3.5	110.74	23	11.690	136.656	2.438
4.5	121.71	7	11.456	131.238	4.330
5.5	124.86	7	14.554	211.810	5.501
6.5	125.00	2	22.627	512.000	16.000
Total	103.53	66	23.365	545.914	2.876

There is a significant difference between the dressed weight of males and females. Correlation analysis indicates a moderate, positive correlation between DW and age ($r = 0.509$, $p = .000$).

Body weight is known to fluctuate with seasons or even climatic events (droughts, harsh winter/summers), and is not a measure of size that is readily available to archaeologists. Body weight increases with age, but what about the length of the lower hind limb; does this increase with age as well?

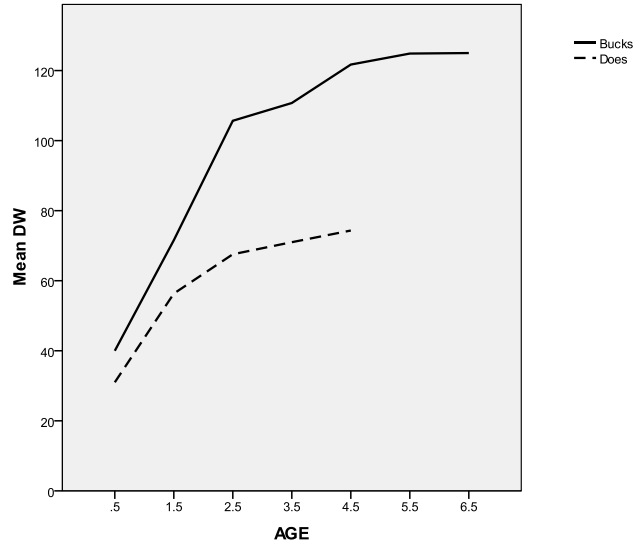


Fig. 8. Average dressed weight for bucks(top line) and does ($n=101$, Ft. Hood 2007-2008 hunting seasons).

3.3 Growth Patterns - Hind Foot Length

The data for both males and females indicate that this measure is mature by 1.5 years of age, around the time that the calcaneus begins to fuse (Figure 9).

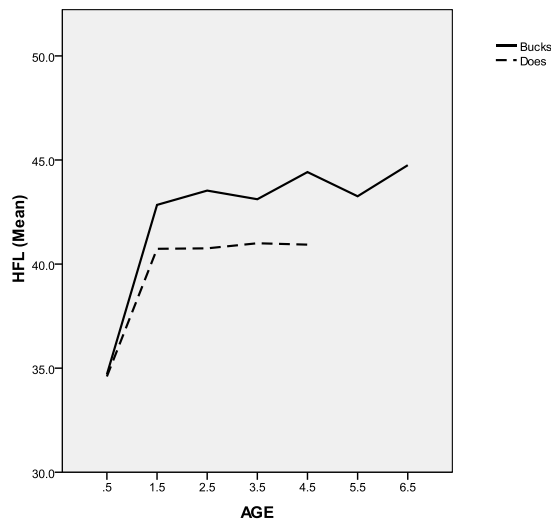


Fig. 9. Average hind foot length for bucks (top line) and does ($n=101$) from Ft. Hood 2007-2008 hunting seasons.

A scatterplot of all age groups indicates there is a weak non-significant, positive correlation between HFL and age (Figure 10A). However, I believe that this is the result of the problems with distribution discussed earlier. The combination of having only two 6 month old individuals, the youngest and smallest in the population, and having all the oldest age groups dominated by males, creates this weak, positive correlation. However when looking only at the 1.5 – 4.5 year old age groups, there is no significant correlation between the length of the hind foot and the age of the individual (Figure 10B).

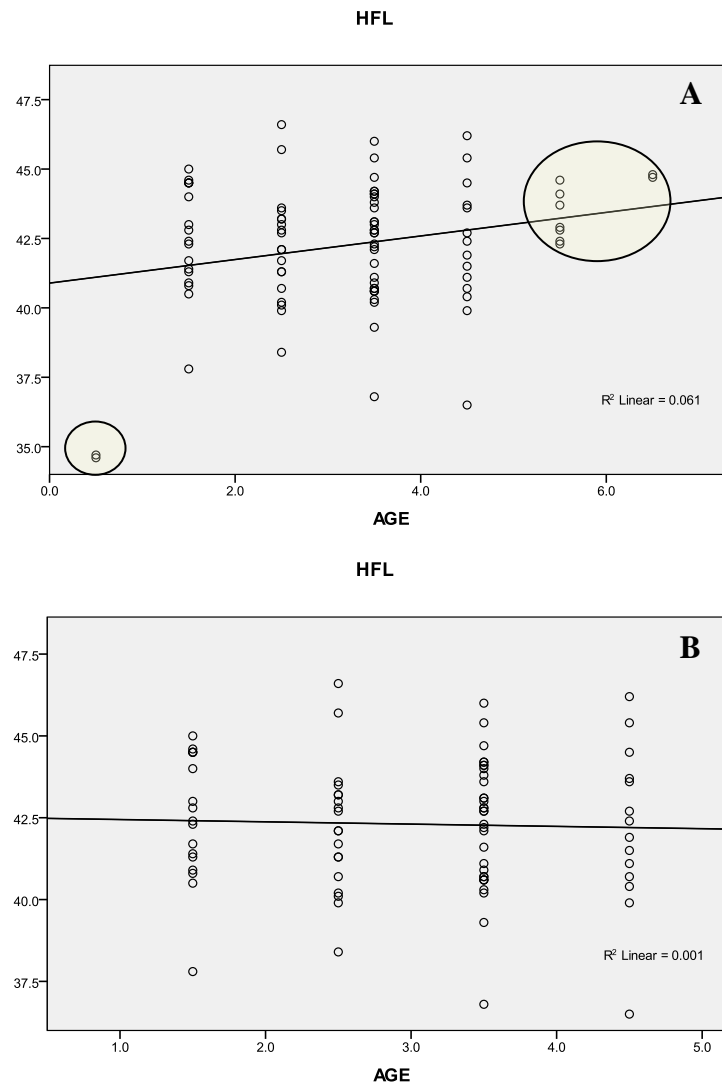


Fig. 10. Graph A includes all individuals ($n=101$) showing a weak, positive correlation with age. Graph B excludes the youngest and oldest age groups (discussion in text, $n=90$) showing no correlation with age.

There is a moderate to strong, positive correlation between dressed weight and hind foot length ($r = .682, p=.000$). Hind foot length can be considered a good measure of stature and body size in white-tailed deer after 1.5 years of age. Further research with the youngest age group (0.5 yr.) is needed to determine the exact timing of the maturity in hind foot length. A bivariate plot of DW and HFL, separated by juveniles and adults, indicates that even though juveniles have not gained their full weight yet, their HFL's are comparable to those of adults (Figure 11). A student's t-test shows a significant difference between ordinal age (adults or juvenile) and dressed weight, but no significant difference between hind foot length and ordinal age (Table 4). While body weight may fluctuate seasonally and with disruptions in the

Table 4

Results of the t-test indicate a significant differences between the dressed weight of adults and juveniles, but no significant differences between the HFL of adults and juveniles.

		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.
DW	Equal	11.450	.001	-4.206	87	.000	-23.499	5.587
	Not			-5.393	44.80	.000	-23.499	4.358
	Equal							
HFL	Equal	.634	.428	.484	79	.630	.2454	.5071
	Not			.450	26.92	.657	.2454	.5458
	Equal							

availability of food, hind foot length is a measurement that relates to stature, and the potential size of an individual. This measurement is not one that would change with seasons or climatic factors (as seen in mass or body weight), the foot length does not fluctuate within the lifetime of the individual. However, it is not a measurement that is commonly available in an archaeological assemblage, as the entire lower limb is rarely found intact. However, it is an additional measure that can be used to validate the use of certain elements as age independent proxies of body size.

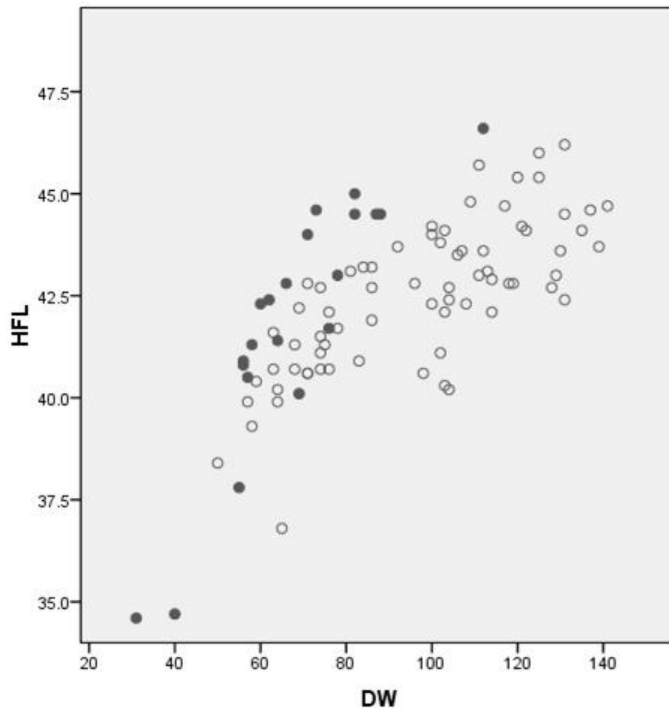


Fig. 11. Scatterplot of dressed weight and hind foot length for juveniles (dark, closed circles) and adults from Ft. Hood 2007 and 2008 hunting seasons ($n=101$).

3.4 Normality Tests for Variables

Table 5 lists the results of the Shapiro-Wilks tests which indicate that normality can be assumed for all of the independent variables, and parametric tests can be used. The only exception is when analyzing these variables for correlations with age, as it is an ordinal variable, and Spearman's Rho will be used, which is a test of the correlation of ranks.

3.5 Age Independent Measures

The results of the correlation analysis with age for each of the skeletal measurements are listed in Table 6. The width of the calcaneus shows a weak, negative, non-significant correlation with age. In this case, a negative correlation with age does not really make sense, a bone is not going to get slightly smaller with age. A one way ANOVA indicates no significant differences in the

Table 5
Results of Shapiro-Wilk's normality tests for each skeletal measurement.

	Statistic	df	Sig.
CAWidth	.979	74	.259
CADepth	.972	74	.097
CALength	.980	74	.287
MTWidth	.986	74	.561
MTDepth	.977	74	.189
NCWidth	.990	74	.852
NCDepth	.975	74	.151
TIWidth	.992	74	.930
TIDepth	.986	74	.564
ASTL	.974	74	.139
ASTW	.982	74	.376
ASTth	.987	74	.631

Table 6
Spearman's correlation coefficient for analysis between age and each skeletal measurement.

	Spearman's Correlation Coefficient	p value (2 tailed)
CA Width	-.054	.618
CA Depth	.129	.246
CA Length	-.012	.912
MT Width	.181	.094
MT Depth	.118	.275
NC Width	.117	.277
NC Depth	.101	.347
TI Width	.025	.820
TI Depth	.041	.717

mean calcaneum width between the age groups ($F = 0.491, p = .689$). The depth of the calcaneum has a weak, positive, non-significant correlation with age. The length of the calcaneus

does not have a significant correlation with age. (Figure 12). The width and depth of the metatarsal also show a weak, positive, non-significant correlation with age (Figure 13).

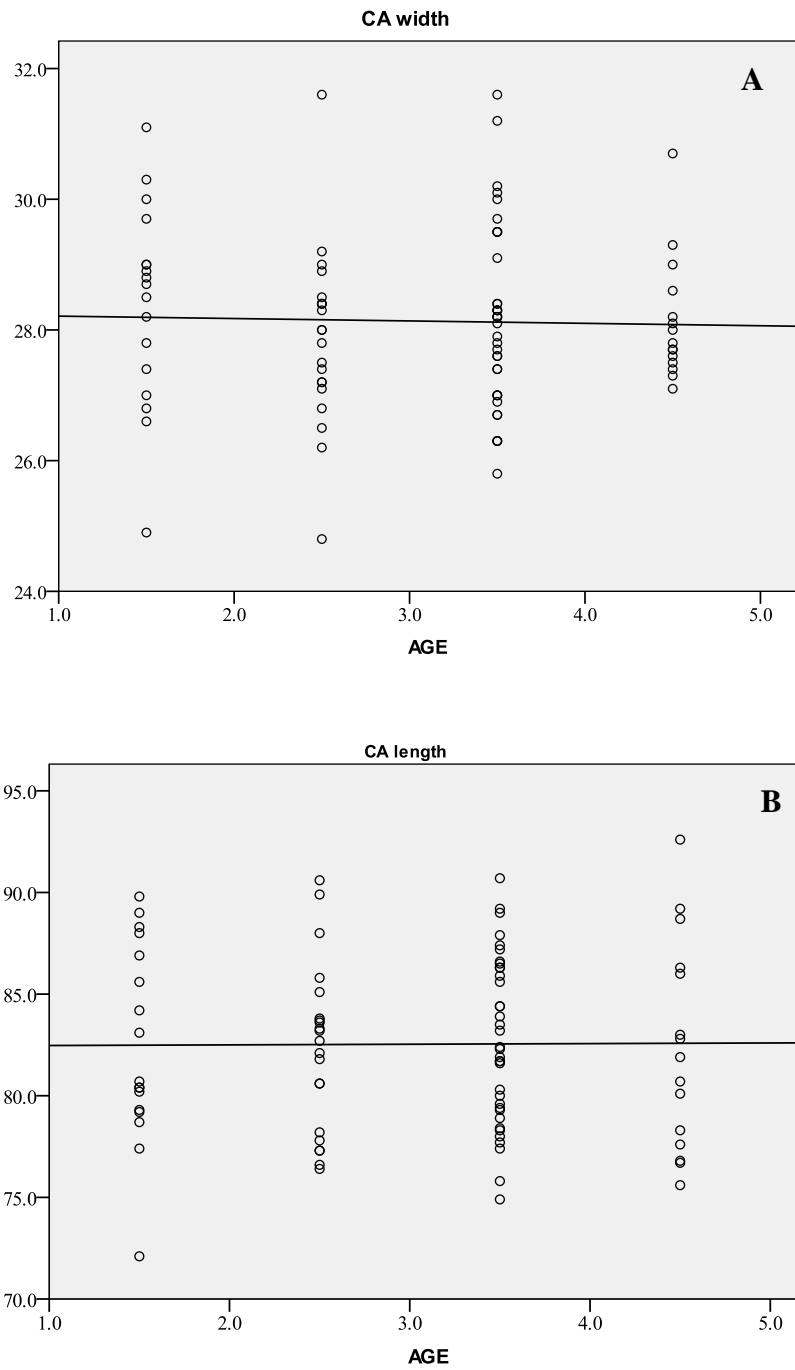


Fig. 12. Bivariate plot of calcaneum width (A) and length (B) with age.

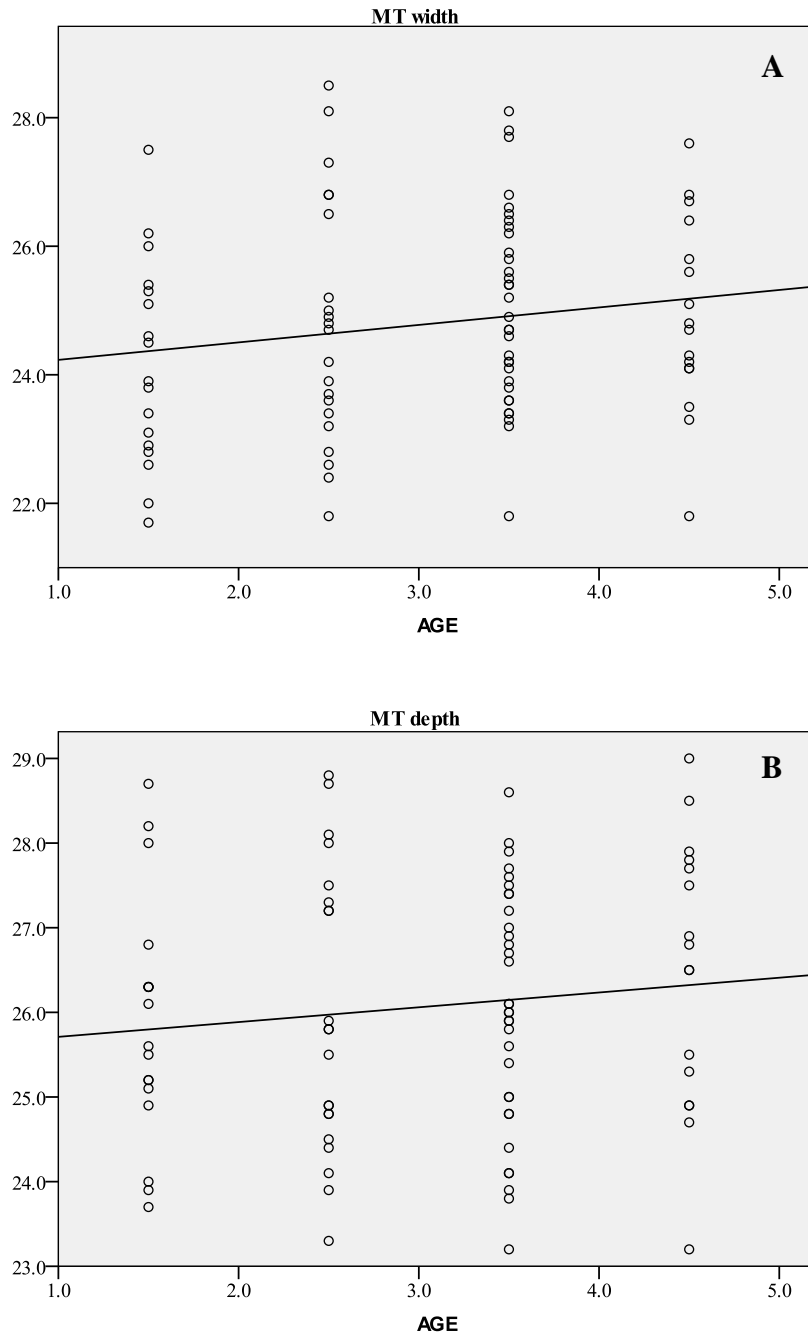


Fig. 13. Bivariate plot of metatarsal width (A) and depth (B) with age.

The naviculo-cuboid also shows a weak, positive, non significant correlation with age in the width and depth measurements (Figure 14). The width and depth of the tibia have no significant correlations with age (Figure 15). Each of the skeletal measurements from the four elements

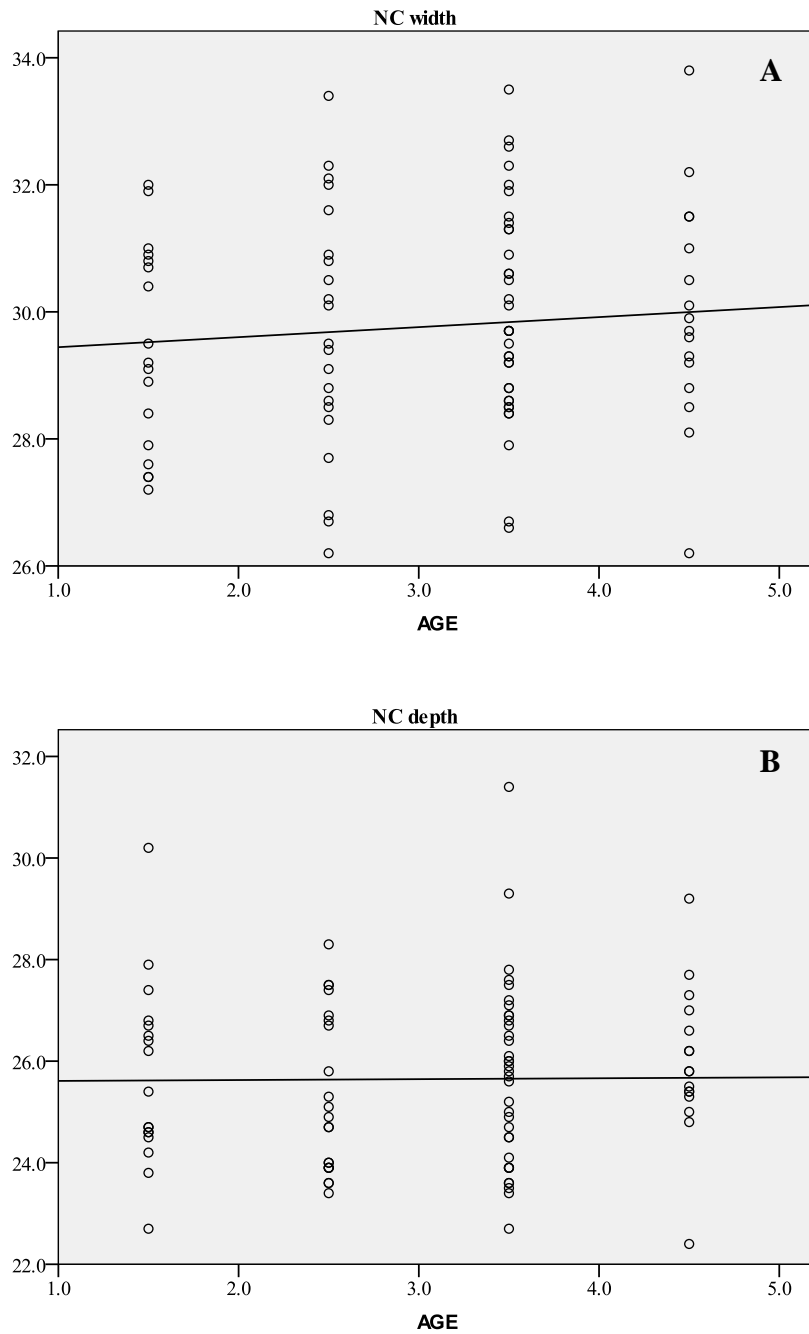


Fig. 14. Bivariate plot of naviculo-cuboid width (A) and depth (B) with age.

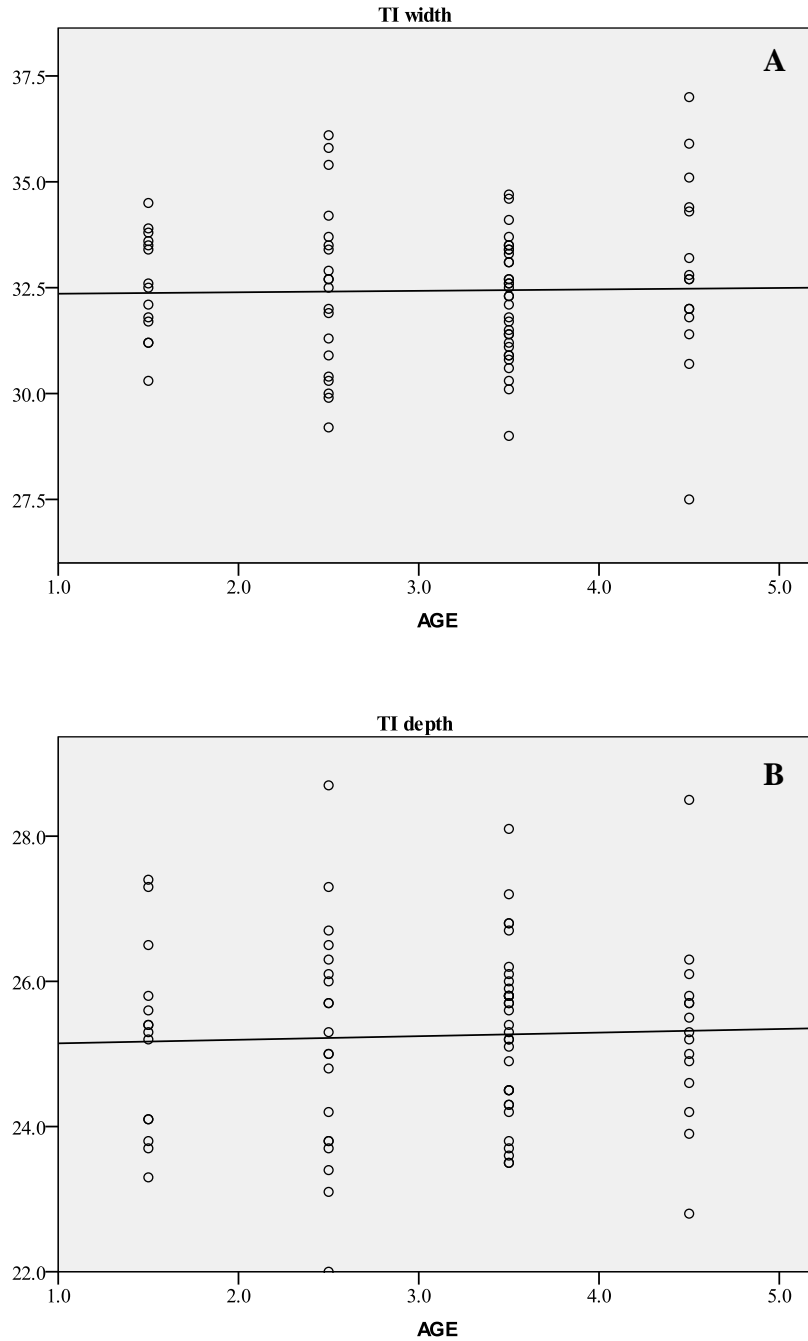


Fig. 15. Bivariate plot of tibia width (A) and depth (B) with age.

tested have the potential to be used for body size reasearch. Two elements, the metatarsal and the naviculo-cuboid, have slight relationships with age according to satsitcal analysis. These relationships are very small however, and other tests show no significant differences between

the 4 age classes. Two of the elements, the calcaneus and the tibia, have no correlations with age (age independent); however to be useful proxies of body size in white-tailed deer, there needs to be some type of correlation between these measurements and DBW or HFL.

3.6 Significant Correlations with Measures of Body Size and Stature

Correlation and regression analysis indicate moderate to strong, positive correlations between each of the skeletal measurements and the common measures of body size in WTD, specifically DW (Table 7) and HFL (Table 8). The correlations range from .309 to .747 for DW and from .532 to .875 for HFL. The calcaneum width and length have moderate, positive

Table 7
Spearman’s correlation and regression values for all element measurements with dressed weight.

Element	measure	n	r	r ²	\bar{x}
Calcaneum	Width	89	.475	.226	28.136
	Depth	90	.628	.438	22.189
	length	89	.662	.394	82.535
Metatarsal	Width	87	.733	.537	24.790
	Depth	87	.731	.534	26.069
Naviculo-cuboid	Width	89	.747	.557	29.803
	Depth	89	.625	.390	25.679
Tibia	Width	82	.633	.401	32.455
	depth	82	.625	.391	25.256
Astragalus	Length	85	.309	.095	23.796
	Thickness	85	.612	.301	20.509

correlations with both DW and HFL. The width of the metatarsal has a moderate, positive correlation with HFL, while the depth measurement has a strong, positive correlation. Both metatarsal measurements have a strong, positive correlation with DW. The naviculo-cuboid width and depth have strong, positive correlation with HFL, and moderate to strong correlations with DW. The tibia measurements have moderate, positive correlations with DW and HFL. The length and thickness of the astragalus have moderate correlations to DW, and the lowest

correlations in the group. The astragalus measurements show moderate, positive correlations with HFL. The results of the correlation and regression analysis have shown that some elements are slightly correlated with age (metatarsal, naviculo-cuboid) while others have no correlations at all (calcaneum and tibia) which make them good candidates for use as age independent proxies of body size. All elements have moderate to strong, positive correlations with common measures of body size in white-tailed deer (dressed weight and hind foot length).

Table 8
Spearman's correlation and regression values for all element measurements with hind foot length.

Element	measure	n	r	r ²	\bar{x}
Calcaneum	Width	82	.609	.370	28.056
	Depth	82	.532	.283	21.85
	length	82	.875	.766	82.272
Metatarsal	Width	82	.685	.469	24.722
	Depth	82	.720	.519	25.987
Naviculo-cuboid	Width	82	.771	.594	29.664
	Depth	82	.706	.498	25.612
Tibia	Width	82	.697	.486	32.377
	depth	82	.589	.347	25.123
Astragalus	Length	82	.564	.318	
	Thickness	82	.659	.434	

3.7 Comparison of Fort Hood and Austin Samples

The averages for dressed weight by age and sex are listed in Table 9, and show the same basic patterns as the deer from Ft. Hood in regards to weight. Males weigh more than females, and both sexes gain weight with age. Comparing the biometric results from the two samples in regards to skeletal measurements, as well as dressed weight, it is clear that the deer from Ft. Hood are larger than those collected from the Austin area (Table 10). The average DW for the Ft. Hood bucks is 101.23 lbs compared to just 76.63 lbs. for the Austin bucks. The does are

Table 9
Average weight by age(A) and sex(B) for the Austin specimens.

A			Std.	Std. Error	Minimu	Maximu
AGE	Mean	N	Deviation	of Mean	m	m
.5	38.00	1	.	.	38	38
1.5	62.20	5	6.099	2.728	52	68
2.5	79.50	4	17.176	8.588	58	99
3.5	90.00	2	11.314	8.000	82	98
6.5	94.00	1	.	.	94	94
8.5	70.00	1	.	.	70	70
Total	72.21	14	17.885	4.780	38	99

B				Std. Error	Minimu	Maxim
SEX	Mean	N	Std. Deviation	of Mean	m	um
Bucks	76.63	8	18.181	6.428	52	99
Does	66.33	6	17.212	7.027	38	85
Total	72.21	14	17.885	4.780	38	99

Table 10
Comparison of biometric data (means) for Ft. Hood and Austin specimens.

	Ft Hood (n = 90)		Austin (n = 14)	
	Bucks	Does	Bucks	Does
DW	101.23	69.68	76.63	66.33
HFL	43.255	40.891		
CA L	84.33	79.464	82.125	77.883
CA W	28.582	27.379	27.925	26.967
MT W	25.385	23.815		
MT D	26.752	24.952		
NC W	30.591	28.591		28.625
NC D	26.389	24.529		24.3
TI W	33.182	31.376	31.975	30.917
TI D	25.739	24.539	25.063	24.233
AST L	29.865	28.724		
AST TH	21.041	19.712		

smaller as well with the average DW of 69.68 lbs. for the Ft. Hood sample and 66.33 for the Austin sample. While it was not possible to collect HFL on the Austin samples, the length of the calcaneum in both sexes is longer in the Fort Hood sample, and theoretically the HFL would be longer as well (see the following discussion on regression analysis for HFL and skeletal variables).

Bivariate plots illustrate the differences in size between the Ft. Hood and Austin samples in the length and width of the calcaneum and the width and depth of the tibia (Figure 16). The Austin samples are in the lower end of the range when compared to the Ft. Hood samples.

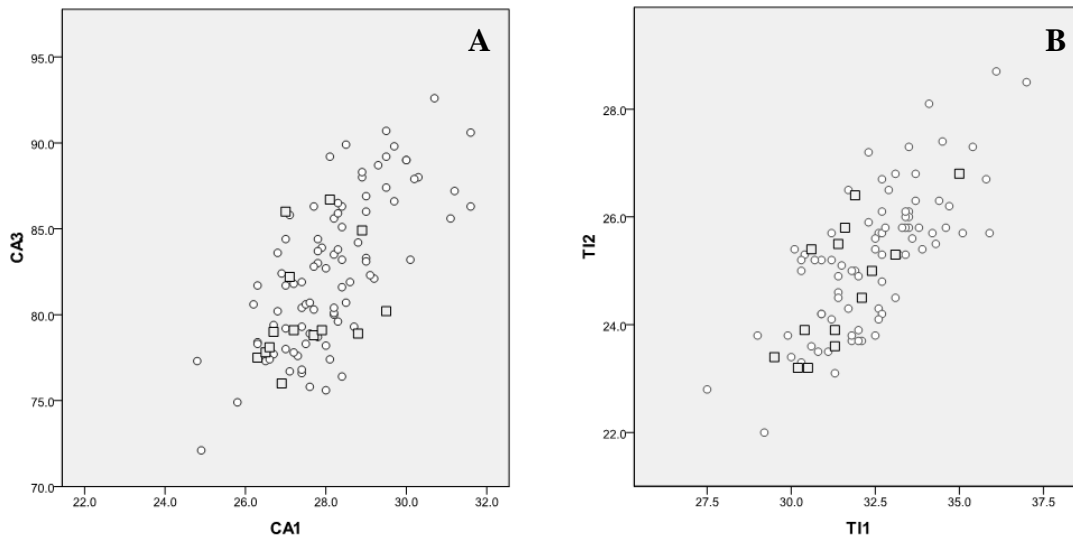


Fig. 16. Bivariate plot showing the difference in size between the Ft. Hood (circle) and Austin (square) samples, using the calcaneum (A) and the tibia (B).

Further analysis indicates a significant difference between the two samples in the width of the tibia ($F = 1.192$, $t = 2.249$, sig. 2 tailed = 0.036), but not the depth of the tibia ($F=0.015$, $t = 1.561$, sig. 2 tailed = 0.135). There is a significant difference between the two groups in calcaneum length ($F = 2.178$, $t = 2.218$, sig. 2 tailed = 0.038) and width ($F = 0.683$, $t = 2.056$,

sig. 2 tailed = 0.52) as well. This could be an effect of the small sample size collected, and not having a full range of individuals from that population.

CHAPTER 4

DISCUSSION FT. HOOD/AUSTIN

4.1 Ft. Hood and Austin Samples

The individuals from Austin are smaller overall than those from Ft. Hood in almost every measurement, especially weight and hind foot length (HFL). This data demonstrates what many have documented in the biological literature; that deer from crowded, overabundant populations will be smaller (compared to those in less dense populations); this is due to their phenotypic plasticity and response to variations in density levels and food availability per animal, as well as the intra-specific competition that will increase with limited resources under such conditions. However, the extent of the difference may not be known with only 14 individuals used in this study, which may not be a good representation of the population. Due to these low sample sizes, only the Ft. Hood specimens were used for the growth and size analyses.

4.2 Growth Patterns of Weight and HFL

The results indicate a statistically significant increase in weight with age in both sexes, although more so in males than in females. Females weight levels off earlier than males, due to their reproductive constraints. Hind foot length also matures early (by 1.5 yr.), and there is no significant correlation with age.

4.3 New Proxies for Age Independent Body Size

The results indicate that there are no significant correlations with age and the calcaneum or the tibia measurements. In other words, the differences in dimensions of these elements are

reflective of variation in size, and not differences in age; they are good proxies of age-independent body size in white-tailed deer (WTD). Even though both these elements have epiphyseal fusion areas, previous research by Purdue(1987) indicates that they reach 90% of their adult size by 6 months of age, just as the astragalus does. Once these bones begin to fuse (at around 1 year and 2 months for both), the element itself has reached its maturity. The metatarsal and the naviculo-cuboid have weak, positive, non-significant correlations with age, however, these relationships are very weak and further testing (ANOVA) indicates no significant differences between the four age groups. Expanding the list of elements that can be used for research regarding prehistoric subsistence practices, including hunting, and intensification efforts through time, enhances the analytical potential of future research. The composition of species/elements recovered from archaeological sites differs greatly, depending on many variables such as site function, site formation processes, taphonomic factors, and recovery methods. All of these elements and measurements have moderate to strong correlations with other commonly used measures of body size in modern WTD research, specifically dressed weight and hind foot length.

4.4 Correlations with other Measures of Body Size

All of the elements tested indicate moderate to strong correlations with both DW and HFL. The strongest correlation is that of the length of the calcaneum length to the length of the hind foot ($r = .875$). This is explained by the fact that the length of the calcaneum is a portion of the total HFL measurement, with a ratio ranging from 0.188 - 0.200, in other words the calcaneus makes up about 18.8 – 20 % of the total length of the Hind foot. The calcaneum begins to fuse and stop growing around the same time as HFL levels off (around 1.5 yr.). For the Ft Hood sample, it is interesting to note that some of the longest HFL and calcaneum lengths are those of

juveniles (Figure 17). This is evidence that the controlled culling program at Ft. Hood is working, and the juveniles from the 2007 and 2008 hunting seasons had some of the longest hind foot lengths and calcaneum lengths, and the potential to become larger than their adult counterparts (longer bones equals the opportunity to obtain more mass with age). Archaeologically calcaneum length may be a good measure of body size for studies of prehistoric sites with abundances of deer remains.

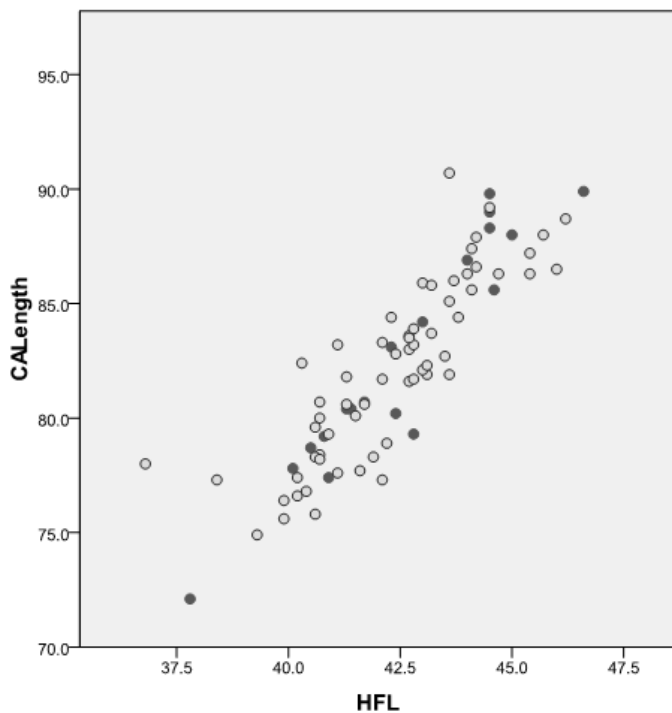


Fig. 17. Bivariate plot of hind foot length and calcaneum length for juveniles (dark circle) and adults (light circle).

4.5 HFL Prediction Using Calcaneum Length

HFL was predicted using the length of the calcaneus and the following equation generated from regression tests (Predicted HLL = $8.99 + .406 (\text{CA Length}) \pm 2.07$). The predicted values were then compared to the actual HFL for each specimen (Table11). The

predicted values are all within the margin of error, and are quite accurate when compared to the actual values. There does seem to be a tendency to overestimate smaller individuals and underestimate larger ones, but only slightly (Figure 18).

Table 11.

Comparison of predicted hind foot lengths with actual hind foot lengths for Ft. Hood samples. Hind foot length is predicted using regression equations and the length of the calcaneum.

Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
44.1	43.7	42.7	42.1	39.3	39.4	44.5	45.4
45.4	44.4	43.6	45.8	41.7	41.7	34.7	37.0
44.0	44.0	44.5	45.2	41.3	42.2	44.7	45.2
42.7	42.9	42.8	42.2	40.7	40.8	43.7	45.0
42.1	42.8	41.4	41.6	36.8	40.7	42.8	43.9
41.3	41.6	44.1	43.5	40.2	40.1	43.1	42.4
46.0	44.1	44.6	43.7	42.2	41.0	- NA	45.2
43.6	42.2	42.3	42.7	41.5	41.5	42.3	43.3
44.0	44.3	45.0	44.7	43.7	43.9	44.2	44.1
42.8	42.8	43.6	43.5	40.6	41.3	40.2	40.4
42.1	40.4	41.1	42.8	41.1	40.5	41.7	41.8
43.0	43.9	42.9	43.1	40.4	40.2	44.5	45.1
42.8	41.2	44.7	44.0	42.7	42.9	45.4	44.0
45.7	44.7	42.7	42.7	-NA	41.2	44.2	44.7
44.8	43.5	43.1	42.2	40.1	40.6	44.6	46.0
46.2	45.0	40.8	41.1	41.3	41.7	-NA	41.6
43.5	42.6	41.6	40.5	38.4	40.4	- NA	45.8
42.4	41.6	42.8	43.1	40.6	40.8	- NA	45.1
43.0	43.2	40.7	41.5	40.6	39.8	- NA	40.1
43.8	43.3	40.9	41.2	40.3	42.4	- NA	46.6
42.3	42.2	39.9	40.0	42.1	42.2	- NA	43.0
42.4	42.6	36.5	- NA	42.4	44.4	40.7	40.7
43.0	42.3	40.5	40.9	44.1	44.5	34.6	36.9
44.5	44.8	41.9	40.8	43.2	43.0	40.7	41.8
46.6	45.5	39.9	39.7	37.8	38.3	40.9	40.4

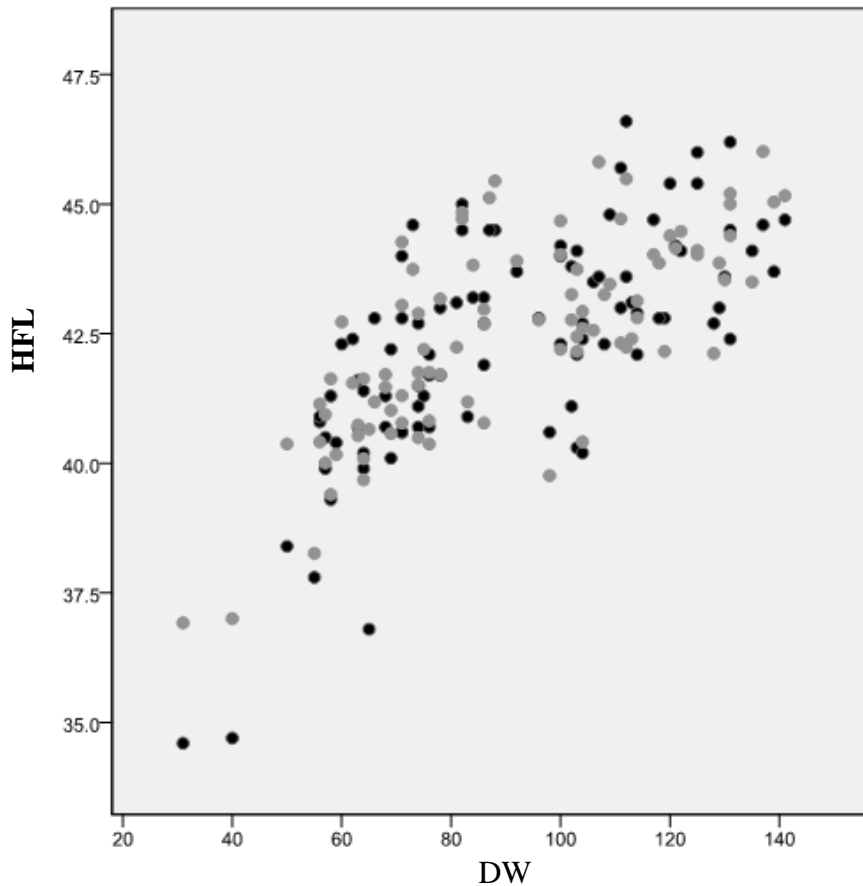


Fig. 18. Bivariate plot of actual hind foot length to dressed weight (dark circles) and the predicted hind foot length to dressed weight (light circles) for all Ft. Hood samples ($n=101$).

While I am not recommending that predicting HFL for use in archaeological studies is a good idea, it does validate the use of the calcaneum as a proxy of size in WTD; a longer calcaneum means a longer HFL and theoretically a larger individual, or at the very least, an individual of greater stature, that has the ability to obtain more mass in times of adequate and abundant resources. Using the covariation between the width and depth (or width and length) measurements for each element will allow for size comparisons between samples, as illustrated with the Ft. Hood and Austin samples (Figures 14 and 15). Applying these findings to an archaeological assemblage helped to uncover some issues in using these elements for zooarchaeological research, in regards to availability of elements and the ease of collecting these

measurements from archaeofaunal assemblages. These are discussed in the following chapter along with the results and comparisons from the Eagle's Ridge assemblage.

CHAPTER 5

EAGLE'S RIDGE

5.1 Eagle's Ridge Site Information

Eagle's Ridge (41CH252) is a stratified shell midden site located in Chambers County, Texas, approximately 40 miles east of Houston on the Trinity River Delta, near Lake Charlotte (Figure 6). The site was excavated in 1995 by Geo-Marine Inc. during the Wallisville Lake Project for the U.S. Army Corps of Engineers. The phase III recovery effort consists of 4 block excavations with a total of 65 1 X 1 meter units. The three stratigraphic layers indicate that the occupations at this site began in the Middle Archaic (ca, 4200 BP) and continued into the Late Archaic (ca, 3000 BP) and Prehistoric (ca, 2300BP) time periods. Archaeological evidence supports long term, repeated occupations, with concentrations in the Summer/Spring and Fall (Ensor 1998).

The ceramic styles of the Upper Texas Coastal Plain (UTCP) culture area have been linked with cultures to the east, in the Lower Mississippi Valley (LMV). The construction techniques and decorations are stylistically similar to LMV Tchefuncte and Mandeville wares, but the material used for temper and clay is local (Ensor 1998, Hood 2007). The site contains one of the earliest examples (ca, 2300BP) of locally made pottery on the upper Texas coast, which begins to appear at the end of the Late Archaic and into the Early Ceramic (Clear Lake) period (Aten 1983, Ensor 1998).

In this region, there appears to be an increase in human populations beginning in the Late Archaic, and continuing into the Late Prehistoric, such as the Clear Lake period at Eagle's Ridge.

At the regional level, Aten (1983) suggests that ceramics along with other advances in procurement technologies may have been the catalyst for increased population densities in the southeast coastal areas of Texas, and created the need for groups to split off into several different entities. At Eagle's Ridge, during the Clear Lake period, there appears to be a decrease in seasonal movements between the coastal and inland areas, and evidence of increasing territorial boundaries (Aten 1983, Ensor 1998).

Resources previously utilized at this site disappear from the archaeological record during the early ceramic period, around 2000B.P. (Ensor 1998). At this time there is a reduction in the shellfish and marine resources at the site. It is believed that Lake Charlotte became landlocked at this time and could not sustain the shellfish or marine life that utilized brackish waters (Ensor 1998). Contemporaneous shell midden sites indicate that aquatic resources were still being procured at other sites in close proximity. However, at Eagle's Ridge white-tailed deer are a continuously used resource, before and after the adoption of pottery. Analysis of approximately 25% of the faunal assemblage indicates that white-tailed deer are the highest ranked prey at this site and remain the dominant taxon through all time periods (Reitz and Keck 1998). While the status of deer as the main resource does not change across time, recent research indicates a change in the hunting pressure and with-in bone nutrient processing of white-tailed deer at this site after the adoption of pottery (Wolverton et al. 2008).

5.2 Collection of Skeletal Measurements

All available elements (calcaneum, metatarsal, tibia, and naviculo-cuboid) from the Eagles Ridge faunal assemblage (blocks B, C, and D) were measured in the same manner as the Ft. Hood and Austin samples (see Figure 5). The provenience information was also recorded regarding the block, strata, and level that the bones were recovered from. There were some

issues regarding data collection with the metatarsal and the calcaneum. In the ER assemblage, there are only 4 metatarsal specimens that can be fully measured for width and depth. The majority are broken in half, and cannot be fully measured. While this issue may be specific to this assemblage, it prevents me from doing a detailed analysis on this element with this prehistoric assemblage.

One of the issues with the calcaneum is that very young individuals have an unfused epiphysis (often missing) which limits the ability to measure the length. The calcaneum begins to fuse at 1 yr and 2 months to around 1 yr and 5 months (see table 1). The completely unfused ends should only be from individuals that are younger than this. These individuals would not be used for size comparisons. If the epiphysis was unattached, but available, I measured the length, and recorded it as unfused. If the epiphysis was missing, then I did not measure the length of the calcaneum, and did not use these individuals for size analyses.

There were no issues with the measurements of the tibia, even though it has a fusion area as well. The tibia can be used for biometric analysis and to age specimens, as the lines of fusion preserve very well (Figure 19). Because of the location on this element, the skeletal measurements of width and depth can still be taken even for most unfused bones. There were no problems in collecting the measurements of the naviculo-cuboid.

5.3 Results

The sample collected from the ER faunal assemblage consists of a total of 91 specimens. There are a total of 25 calcaneum, of which 11 are incomplete and not able to be measured for all dimensions (especially length). Four of them are juveniles with unfused epiphysis, of which three were missing and therefore the length was not measured. There are 10 individuals that are



Fig. 19. View of the line of fusion for modern specimen from Ft. Hood.(white bone , 1.5 yrs old, female) and specimens from Eagle's Ridge (darker bones, both unfused, unknown sex). The fusion line for the elements in the photo on the right are highlighted with an orange line for greater visibility.

adults and are complete. As previously discussed there were only 4 metatarsals complete enough to measure, due to intense fracturing of this long bone at this site . There are a total of 32 complete naviculo-cuboid bones, of which only one could not be measured for depth due to damage. There are a total of 30 tibia, 9 have unfused or partially fused epiphysis and are juveniles. Two of the tibia are broken in such a way that it is not possible to determine if the bone is fused or not, and the other 19 individuals are adults.

The average skeletal measurements for the Eagle's Ridge sample are listed in Table 12, along with those of Ft. Hood for comparison. In each case the deer from the Eagle's Ridge sample are smaller. Comparisons with each skeletal measurement with the Ft. Hood and Austin samples indicate that the deer from Eagle's Ridge are not only smaller than those from Ft. Hood, but in some cases, smaller than those from Austin. This is especially noticeable in the length of the calcaneum (Figure 20). This measurement is strongly correlated with HFL and, as shown with the know-aged samples from Ft. Hood, can be a good measure of body size in white-tailed deer. The deer from ER have calcaneum lengths between 70.1 and 82mm. Those from Ft. Hood

range from 72.0 to 90.7 mm. It is possible that the sample could be positively or negatively skewed.

Table 12.
Comparison of skeletal elements for Ft. Hood and Eagle's Ridge samples.

Group		TI width	TI depth	CA width	CA length	NC width	NC depth
Ft Hood	Avg	32.4	25.2	28.1	82.5	29.8	25.7
	N	82	82	89	89	89	89
	Std. Dev	1.70	1.29	1.34	4.38	1.74	1.69
	Skewness	0.350	0.189	0.353	0.139	0.061	0.604
	SE Skewness	0.266	0.266	0.255	0.255	0.255	0.255
Eagle's Ridge	Avg	31.3	24.5	26.4	77.0	28.7	23.9
	N	28	29	15	10	32	31
	Std. Dev	1.30	1.49	1.73	4.53	1.55	1.53
	Skewness	-0.429	0.039	-0.250	-0.318	0.698	0.197
	SE Skewness	0.441	0.434	0.580	0.687	0.414	0.421

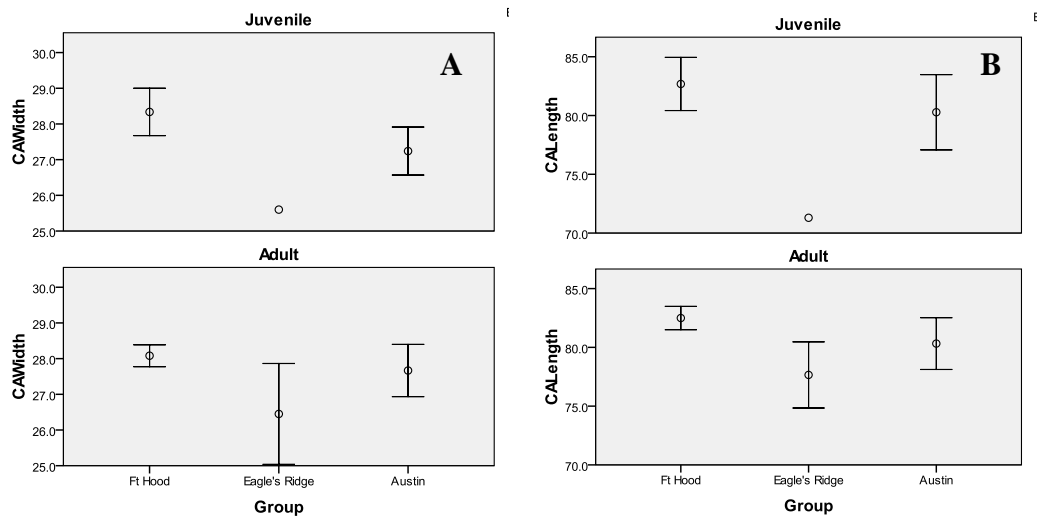


Fig. 20. Illustration of boxplots showing size differences in the length (A) and width (B) of the calcaneum for three different samples, separated by adults and juveniles.

One way to determine if the degree of skewness is significant is to compare the value for Skewness with the negative and positive range derived from the value of twice the "Standard Error of Skewness". If the value for skewness falls within this range, the skewness is considered not seriously violated. To check the distribution of the ER sample, the standard evaluation of skewness for the length of the calcaneum was considered. I chose this variable because it is a good measure of body size, strongly correlated to hind foot length, and there are differences in size between males and females. If a sample contains too many females, it would be positively skewed, too many males will skew the data the other way.

The skewness value for the length of the calcaneum (ER sample) is 0.687, with a standard error of skewness of -0.318. The skewness value does not fall within the range of twice the standard error of skewness (-0.636 – 0.636) and does appear to be positively skewed. This could mean that the sample of adults taken from the ER faunal assemblage contains more than the average number of females, skewing the sample towards the smaller end of the scale.

Another possibility is the low sample sizes for each element. A comparison of size using the length and width of the calcaneum and the width and depth of the tibia also indicate that the deer from ER are smaller in both juveniles and adults (Figure 21). Identifying and resolving issues (such as skewedness caused by imbalanced distribution of sex and age) are important when analyzing archaeological assemblages. However, there may be another issue here regarding the body size of deer and the geographic location where the specimens were recovered. Recent research indicates that prehistoric deer from southeast Texas are significantly smaller than those from central Texas and central Missouri (Wolverton et al. 2009). The authors conclude that this is most likely due to the food availability per animal and the net productivity of plants during the growing season in these particular areas. Central Missouri today has a higher crop yield than

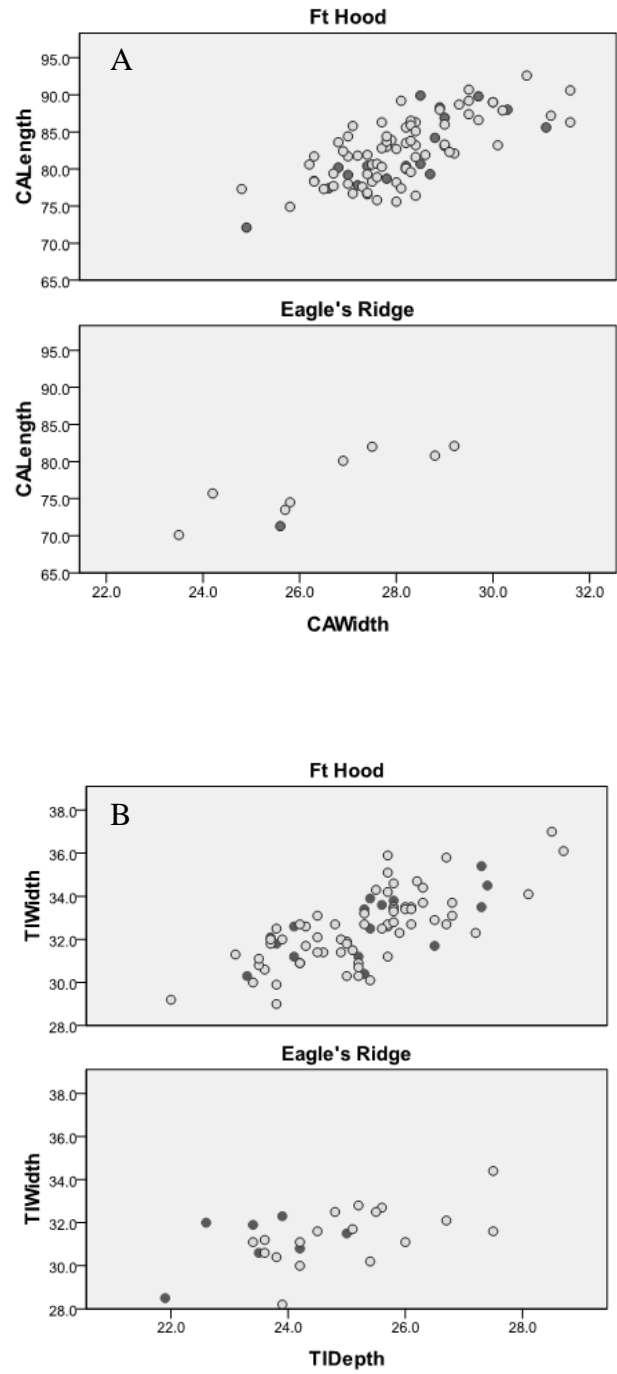


Fig. 21. Bivariate plots illustrating the size differences between juveniles (dark circles) and adults from Ft. Hood and Eagle's Ridge samples, using the calcaneum (A) and the tibia (B) measurements.

that of southeast Texas, and a higher productivity in regards to plant growth, resulting in a more available food per individual and a larger body size (Wolverton et al. 2009).

So far I have only compared the prehistoric elements to those of modern populations from varying density levels and different geographic locations. There are a number of ways in which these elements can be used to analyze archaeological assemblages and changes in body size/age through time at one site (using strata or levels), or between sites.. In addition to metric comparisons of size, histograms can be created. Histograms are used to compare changes in the relative percentage of juveniles and adults between strata at one site (Figure 22, using Eagle's Ridge data) or between several sites, as shown in Figure 23, using tibia counts from Ft. Hood, $n=82$; Austin, $n=14$; and Eagle's Ridge, $n=30$. These changes are then analyzed in relation to patterns of prey mortality and human hunting.

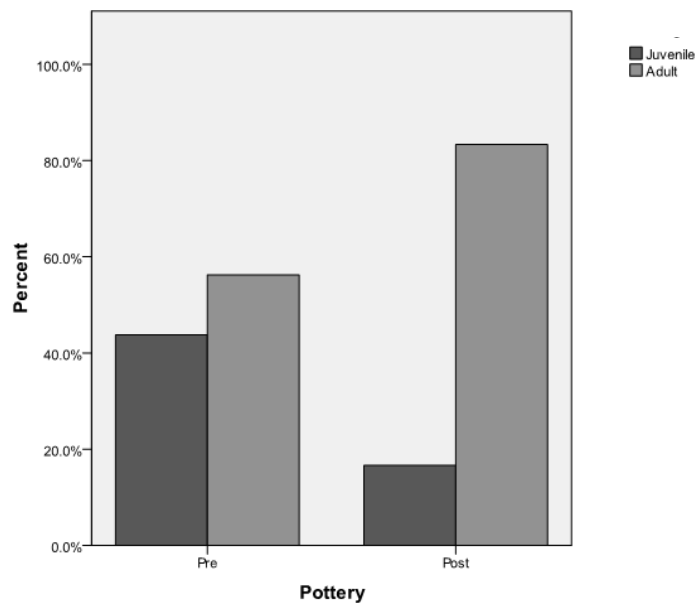


Fig. 22. Relative percent of juveniles (dark) and adults (light) for Eagle's Ridge before (pre) and after (post) pottery levels using limited sample. ($n=30$).

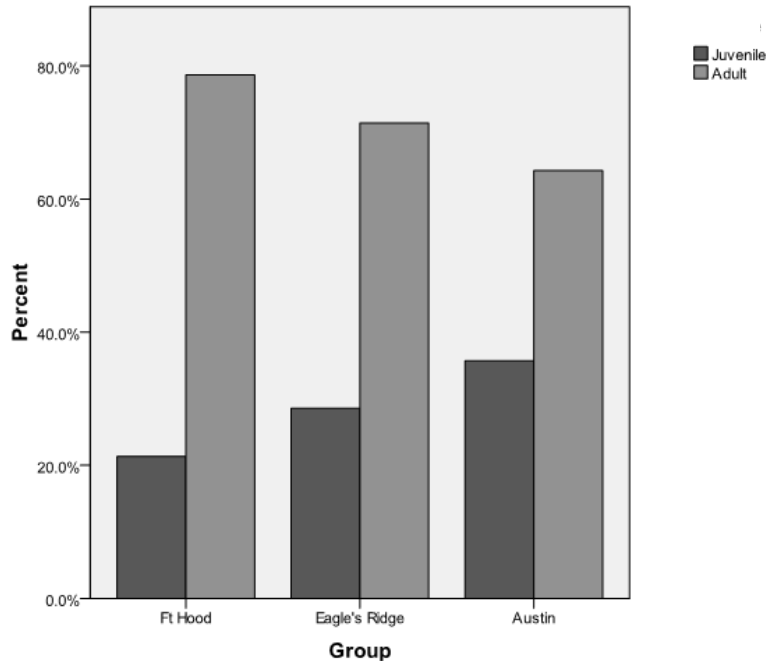


Fig. 23. Relative percentage of juveniles (dark) and adults (light) for the three different samples used in this study to illustrate the use of ordinal age in comparative archaeological studies, using a single element, (the counts for the distal end of the tibia in this example).

With these new elements, the tibia (or the calcaneum), I can compare the width or depth of juveniles and adults separately, and between pre and post pottery levels simultaneously (Figure 24). The example would indicate that both juveniles and adults were larger during the pre-pottery period than during the post-pottery period, which does not coincide with the previous analysis (Wolverton et al. 2008). However, this example has only 18 individuals from the pre-pottery and 12 from the post-pottery period, and a total of at least 30 individuals from each time period would be necessary for an accurate representation of the population (Lyman 1987). This is simply an example of the utility of these new elements for analysis with archaeological data.

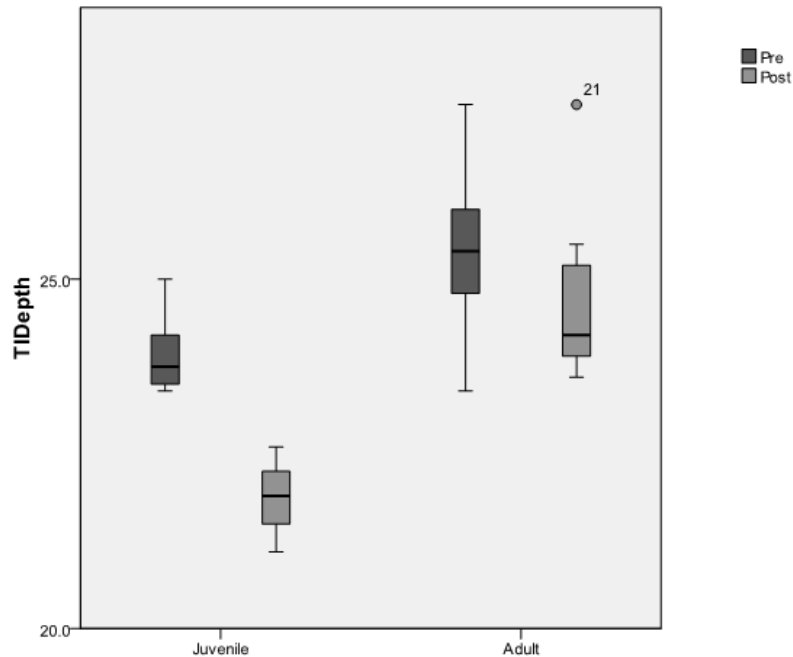


Fig. 24. Boxplots illustrating the size difference in tibia depth, between juveniles and adults, before and after potteryis adopted at the Eagle’s Ridge site.

5.4 Discussion

The usefulness of measuring two new elements (the tibia and the calcaneum) , which have been shown to be age independent proxies of body size in WTD, were tested with the ER faunal assemblage. The distal end of the tibia and the calcaneum were well preserved and abundant in the archaeological assemblage examined. The issues with missing, unfused epiphyseal ends (calcaneus) which I encountered during collection can be managed, because the individuals that have completely unfused ends (the ones that would become separated from the shaft) are under 1.5 years of age. The individuals that are 1.5 yrs and older have fusion lines as the bone is half fused by 1 year and 8 months (Purdue 1987). The length of the calcaneum of these youngest individuals (0.5 – 1.5 yrs) are not used in size analysis. The tibia did not present

any problems even though it has a fusion area as well. It was easy to determine the line of fusion (or absence) in the prehistoric specimens.

Bivariate plots, boxplots, and several size and age comparisons between the three samples indicate that these elements are useful in determining size differences, as well as differences in the relative percentage of juveniles and adults across time. However, the contradictory results from the ER analysis are probably a result of low sample sizes for each element per strata, and are therefore unreliable. Further data collection of all available elements is needed to resolve this issue, and only served here as a demonstration of how the tibia and calcaneum can be used in this type of research.

The addition of these two new age independent body size proxies (the tibia and the calcaneum) expands the list of potential elements that can be used in body size research but also will add the ability to collect age data from the same element, and enhance the analytical capabilities of future research.

CHAPTER 6

CONCLUSION

The primary goal of this thesis was to assess the four elements (calcaneum, distal tibia, proximal metatarsal, and naviculo-cuboid) for their usefulness as proxies of age-independent body size in white-tailed deer; specifically for application in prehistoric research. Using known age and sex specimens from Ft. Hood, Texas, the patterns of growth for each elements dimension were analyzed for correlations with age, weight, and stature. Previous research using the astragalus has shown it to be a good age-independent proxy of body size in white-tailed deer, as it is not correlated with age and the variation in dimensions reflect differences in size and not age (Wolverton et al. 2007, 2008, 2009). The four elements tested in this research are closely associated with the astragalus and either articulate with the astragalus (the calcaneum, distal tibia, and naviculo-cuboid), or provide support underneath the ankle assemblage (the proximal metatarsal).

The results of the statistical analysis indicate that two of these elements, the calcaneum and the tibia, are also good measures of age-independent body size in white-tailed deer. There are no significant correlations with age and they both moderately to strongly correlate with common measures of body size in white-tailed deer (dressed body weight and hind foot length). The distal tibia and the calcaneum mature early, reaching 90% of their adult size by six months (Purdue 1987). Even though both elements have fusion areas, this research indicates that both are mature by 1.5 years of age. The metatarsal and the naviculo-cuboid showed weak, positive correlations with age, even though at this sample size, they are not significant. The slight

positive relationship with age excludes these two elements from being considered age-independent, but they are still strongly correlated to dressed weight and hind foot length.

Bivariate plots comparing the skeletal measurements of the calcaneum and the tibia indicate that they are useful for detecting size differences between modern populations living in varying habitats and density levels (Ft. Hood and Austin). The juveniles collected from Ft. Hood during the 2007-2008 hunting season had some of the largest recorded calcaneum and hind foot lengths. There is a strong correlation between the two, and both are correlated positively with weight. These results indicate that the culling program at Ft. Hood is succeeding, and these juveniles had the potential to become even larger than their adult counterparts (with proper and adequate nutrition)

These measurements have also proven to be useful for the analysis of prehistoric faunal assemblages to track changes through time in the size and age of prey remains. In previous research, the astragalus has been used to determine changes in body size across time, while teeth or the fusion rates of long bones have been used to analyze changes in age across time (Wolverton et al. 2008). With the tibia and the calcaneum, both size and age can be recorded from the same element. Special consideration is needed for the calcaneum needs to be used with prehistoric specimens, and those with completely unfused epiphyseal ends should not be included in size analyses. Application of these methods to the large faunal assemblage from the Eagle's Ridge site (southeast coast of Texas) demonstrates the utility of using one of these two elements in prehistoric research. Not only does it allow the researcher the ability to compare differences in size between juveniles and adults, but size measurements are recorded from the same element, which assures that the biometric data and the age data are coming from the same

individuals. It also allows the researcher to look at these changes in size across levels or strata from the same site, as well as comparisons between sites.

The primary goal and application of these methods within archaeology is to be able to track changes through time in the size and age of various prey animals, detecting possible changes in hunting strategies, hunting pressure, or even resource depression. The most commonly used element in zooarchaeological body size research (for deer) thus far is the astragalus. While I am not negating its importance as a truly age independent proxy of body size in white-tailed deer, it does not allow the researcher the ability to age the element as an adult or a juvenile as it has no fusion area. The addition of these two new age independent body size proxies (the tibia and the calcaneum) will add this ability for future analyses. Not only does it expand the list of potential elements that can be used in zooarchaeological research, it also expands the types of analysis that can be performed with prehistoric research.

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