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A comparison study of subadult long bone growth between an Early Archaic population (Windover) and a Late Archaic population (Indian Knoll)

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A COMPARISON STUDY OF SUBADULT LONG BONE GROWTH BETWEEN AN EARLY ARCHAIC POPULATION (WINDOVER) AND A LATE ARCHAIC POPULATION (INDIAN KNOLL).

by

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Director: Randall Skelton RS

Human remains supply a variety of information about populations ranging from demographic statistics to health status. One approach to inferring nutrition and health status of past populations is to examine the growth rate of children by measuring their long bone lengths at various ages. In this research project the null hypothesis stated that long bone growth trajectories were the same between an Early Archaic population, Windover, and a Late Archaic population (Indian Knoll).

The collections, stated above, were chosen because of the abundance of well preserved, subadult, skeletal material. For Indian Knoll, data from previous studies on long bone growth were used. I collected the following data from Windover: long bone measurements, age, and sex. Age was estimated from dental eruption, union of the parts of the coxal bone, and epiphysis closure. Sex was estimated from the coxal bone. After entering the data into a spreadsheet program (Quattro Pro 5.0), graphs and regression formulae were generated to display growth differences between the two populations.

The results of this analysis supported the hypothesis that there were differences in the growth rate between the two subadult populations. For most of the bones, differences start to occur between the ages of 2 and 5. Windover steadily leads in bone growth until approximately the age of 12.

The differences in growth rate may be due to periods of nutritional stress in the Indian Knoll population, probably caused by a scarcity of reliable food sources.

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CHAPTER ONE

INTRODUCTION

1.1 PURPOSE OF RESEARCH

One major interest in anthropology is the investigation of the past in order to understand modern conditions of human beings. In physical anthropology, one of the primary sources of information about past lifeways is human skeletal remains. Human remains supply a variety of information about populations ranging from demographic statistics to health status. One approach to inferring nutrition and health status of past populations is to examine the growth rate of children as reflected in their long bone lengths at various ages. Physical anthropologists assume that differences in diet and subsistence should result in different long bone growth trajectories. In particular, that hunter-gatherer, horticultural, and agricultural populations should differ in their rates of long bone growth. In this research project I will test the null hypothesis that long bone growth trajectories are the same between an Early Archaic, purely hunter-gatherer sample (Florida) and a late archaic hunter-gather sample (Kentucky).

1.2 IMPORTANCE OF GROWTH STUDIES

The study of growth and development is a relatively new and interesting area of study for physical anthropologists that has emerged over the last several decades. Growth analysis of the human skeleton has only appeared in the literature since the 1960's (Johnston and Zimmer 1989). Since this time, physical anthropologists have recognized the importance of gathering growth and development data of subadults from skeletal collections and applying that information to the overall population. This information, in turn, has been used for comparative studies.

1.3 PROBLEMS OF GROWTH STUDIES

In order for data to be useful for study and comparison, it is important to use a well thought out research plan and techniques that are consistent and reliable. This process involves realizing problems specific to the research and understanding that they may "affect not only the design of the research but also interpretation and generalization from the results" (Johnston and Zimmer 1989). The first problem is that skeletal remains of subadults may be under represented in a prehistoric population. The remains of subadults tend to be fragile and small, and they decompose more quickly. In addition, burial practices differ from culture to culture. One society may bury their young, while another may not, especially those individuals of a very young age (fetal, perinatal, etc.).

The second problem is the difficulty in estimating the true chronological age at death in an immature skeleton.

Traditionally, age categories are narrower in subadults (usually one-year intervals) than in adults (usually five or ten year intervals) because researchers wish to record the rapid maturational changes that occur to the skeleton in subadults. The techniques used to estimate age at death in subadults typically score the maturation stages of various bones: epiphyseal union of long bones, epiphyseal union of the coxal bone, dental eruption, and dental attrition. The result is a skeletal (bone) age that is obtained by using some standard reference population as a basis of comparison. True chronological age for the specific population being studied may differ from the skeletal age of the reference population (Johnston and Zimmer 1989).

Using skeletal development as an indicator of chronological age produces two sources of error. First, children of the same chronological age can vary in their levels of maturation. Second, environmental and/or genetic factors can affect the rate of skeletal maturation in the population under study (Johnston and Zimmer 1989).

> "The truth is we do not know the chronological ages of the children of a sample with certainty. We estimate their skeletal ages and interpret them as the chronological ages that would have been attained if they had been maturing at the same rate as the children of the reference population. The results must be interpreted with caution" (Johnston and Zimmer 1989:12).

Measurement of long bones presents other problems in growth studies. The most severe problem is the question of whether to measure only the diaphysis or the diaphysis united with the epiphysis. In some cases, no epiphyses are present in archaeological samples due to small sample size, poor preservation, or poor recovery methods. In cases where they are present and recovered, their usefulness is questioned due to the unreliability of estimates of the thickness of epiphyseal cartilage. This makes it difficult to develop a consistent, continuous growth curve from infancy through the second decade of life (Johnston and Zimmer 1989).

Any conclusions from the study of subadult skeletal remains must be drawn carefully. The results of research from such samples do not necessarily represent the healthy individuals of that particular group. Subadults represent members of a population that died prematurely, possibly due to some illness that may have affected growth as well as longevity.

1.4 BENEFITS OF GROWTH STUDIES

Despite the problems listed above, the study of growth and development in subadults can provide useful data when studying the lifeways of populations from the prehistoric past. Studying subadult growth is a way of seeing the variation that arises among adults. This initiates the search for answers as to why these differences existed in a population.

Many hypotheses as to why there are growth and development differences in populations have been proposed, including these three: 1) Growth patterns reflect genetic mechanisms, 2) Growth patterns reflect environmental stress, 3) Growth patterns are a response to demands and opportunities posed by the ecosystem.

When looking at all of the previous points, it is obvious that inferences drawn from the data may be generalized beyond the subadult skeletons that are being measured. These inferences can be applied to understanding the health of the entire population. Some authorities believe that growth studies are an "excellent mirror of the conditions under which a group lived and their success at adapting to those conditions" (Johnston and Zimmer 1989:14).

1.5 WINDOVER

The Windover Pond Site (8BR246) is one of the most significant and informative archaeological finds in the New World. The site is located in east-central Florida, near the city of Titusville, approximately eight kilometers west of Cape Canaveral (Figure 1). Radiometric dating of the site indicates that burial activities occurred between 8,120 years B.P. and 6,990 years B.P. (Doran and Dickel 1988). It was discovered in the fall of 1982 when the land was being developed for residential housing (Doran and Dickel 1988a).

The human skeletal remains recovered at Windover are remarkable in that they allow research to be done on a

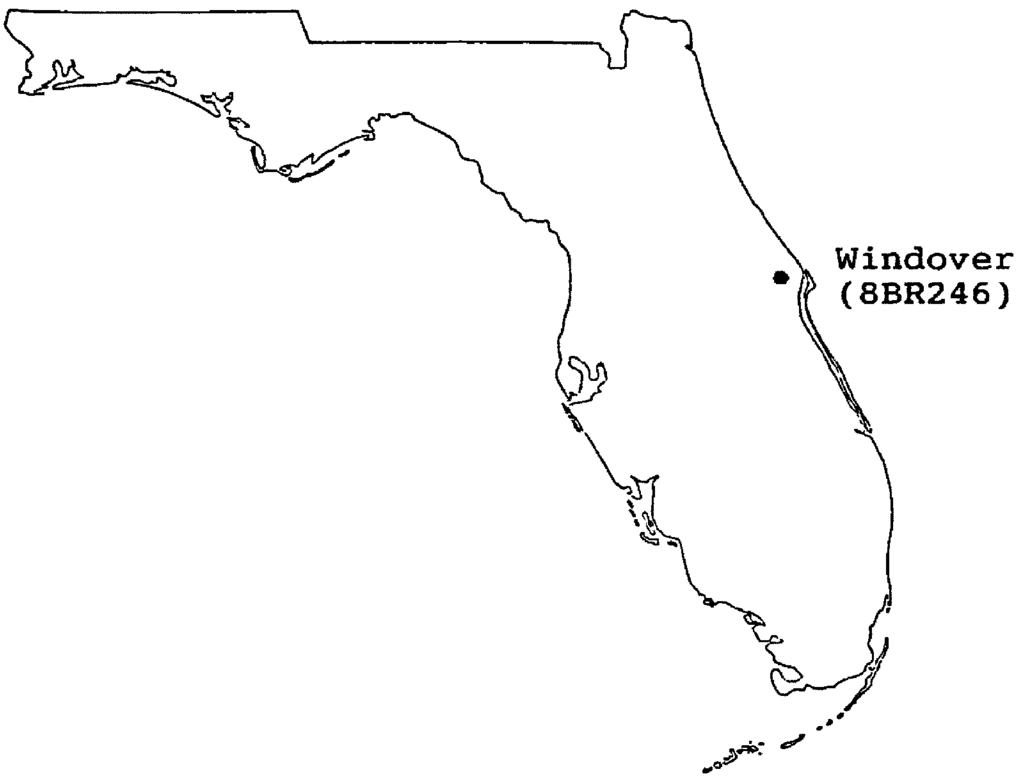


Figure 1. Location of Windover Site (8BR246).

population from the early to middle Holocene (Doran and Dickel 1988a). Windover appears to be the largest, most demographically intact skeletal sample from this time period in the New World. The collection contains "a minimum of 168 individuals" (Doran, Dickel, Newsom 1990:355), of which approximately half are subadults. This is of importance because these may offer a representative sample of subadults in an early Archaic population.

Excavations at Windover were different from those typical of a traditional, land-based excavation because it is a wet site. The first objective for this project was to drain the pond in order to excavate the burials and assorted materials properly. The remains were two meters below the pond bottom with one to three meters of standing water on top. The remaining objectives were to 1) maintain the integrity of the sponge like-peat deposit, 2) maintain the integrity of the site, and 3) keep the dewatering system going for five months out of the year for several consecutive years. The dewatering system chosen to achieve these goals was a well point system (Doran and Dickel 1988a).

Through analysis of the data recovered, it appears that the bodies were placed in the pond approximately 48 hours after time of death and show no indication of postmortem damage. The speed of burial and the fact that the bodies were placed under water would "ensure the chemical preservation of the buried remains as well as physical protection from scavengers" (Doran and Dickel 1988a:273).

Skeletal material removed from the wetsite in the 1984 field season was conserved using PEG 3350. In the following seasons of 1985 and 1986 Rhoplex AC-33 was used and considered a more satisfactory preservative (Doran and Dickel 1988a).

The information to be obtained from Windover is vast, despite the fact that living areas have never been found in association with the pond. The wide array of artifacts buried with the remains suggest that the Windover Pond population was a cultural group well adapted to their environment with "time, energy, and resources to devote to non-essential activities" (Doran and Dickel 1988a:274-275). Ongoing research is being carried out to answer questions pertaining to brain tissue that was recovered, environmental reconstruction of Archaic Florida, demographic questions on mortality and fertility rates, and, as addressed in this paper, questions pertaining to subadult variation in growth as compared to other populations (Doran and Dickel 1988a).

1.6 INDIAN KNOLL

The Indian Knoll site, located in Ohio County in west central Kentucky on the Green River, (Webb 1946) (Figure 2) consists of a large shell midden (Cassidy 1980). This particular site has yielded over 1000 burials that have contributed information about the Late Archaic riverine

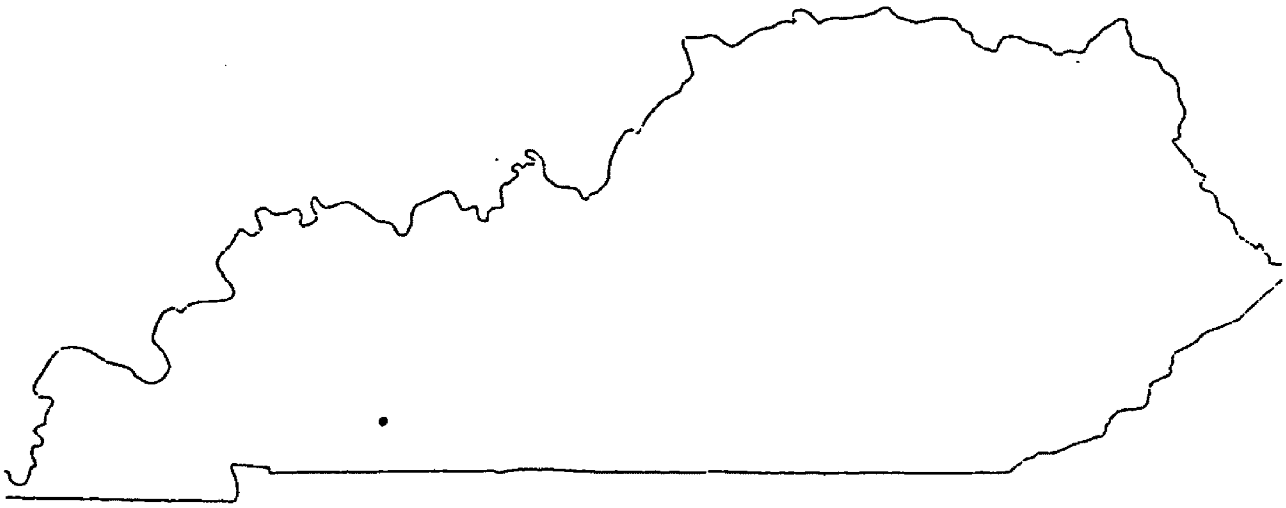


Figure 2. Location of Indian Knoll Site (OH-2).

adaptation (Rothschild 1979). Carbon-14 dating of the human remains yielded a maximum average age of 5,302 ± 300 years B.P. and a minimum of 3,963 ± 350 years B.P. (Cassidy 1980).

In contrast to the Windover site, the information from Indian Knoll is not limited to burials. This area was not only a cemetery, but also a living area for approximately 500 years based on the accumulation of midden debris (Snow 1948). Differing hypotheses exist as to whether the site was occupied seasonally (Winters 1969) or permanently (Webb 1946).

Culturally, the site is classed into the Shell Mound Tradition of the Late Archaic. "In contradistinction to some other Archaic traditions, river mussels and snails apparently provided stable food sources, allowing either sedentary or semisedentary occupation of sites and supporting relatively large populations" (Cassidy 1980:122). The site includes a large mound constructed of gastropod and pelecypod shells left over from the river harvest (Webb 1946).

Anthropologists have extracted data from which the dietary practices of this well adapted people may be reconstructed in detail. Freshwater resources were the mainstay of a diet which also included deer, small mammals, vegetables, fish, hickory nuts, acorns, and some domesticated squashes.

Life expectancy averaged 18.6 years which is relatively short. A large number of the individuals show signs of trauma, perhaps indicating violent death. Explanations for this occurrence range from blood feuding to competition for valued resources (Fagan 1991).

1.7 ORGANIZATION OF THESIS

The following chapters are organized to present my research as clearly as possible. The materials and methods I chose to use are presented in Chapter Two. This chapter outlines the techniques, equipment, and form I used to gather my data, how both sites information was gathered and organized, the computer program chosen to analyze data, and how the results of the regression analysis were to be interpreted.

Chapter Three presents my raw data and the results of the analysis. The chapter includes tables, regression analysis output, confidence intervals, and graphs.

Chapter Four (Discussion) and Chapter Five (Conclusion) interprets my results and presents arguments as to the differences exhibited in the two research groups. Chapter Five also suggests topics for further research.

CHAPTER TWO

MATERIALS AND METHODS

2.1 COLLECTIONS USED FOR RESEARCH

The collections used in this research are the Indian Knoll and Windover prehistoric remains. The foremost reason these collections were chosen was the abundance of well preserved, subadult, skeletal material.

2.2 WINDOVER DATA

Permission to use the Windover collection was granted by Dr. Glen Doran, a professor at Florida State University. Data were collected from August 4 through August 9, 1994, at the Physical Anthropology Lab, Department of Anthropology, Florida State University.

The human remains selected for study were the subadults. For the purposes of this research, subadult was defined as those individuals whose dentition had not fully erupted and/or whose epiphyses were not attached with the epiphyseal lines obliterated. With these guidelines in mind, I recorded the information on a research form designed for this purpose (Figure 3 and 4).

2.3 EXPLANATION OF DATA COLLECTION FORM

The data collection form was divided into six sections. The sections are as follows: 1) provenance and data recording information, 2) long bone measurements, 3) aging by dental eruption, 4) coxal bone aging and sexing, 5) scapula sexing, and 6) general comments section. At the

WINDOVER

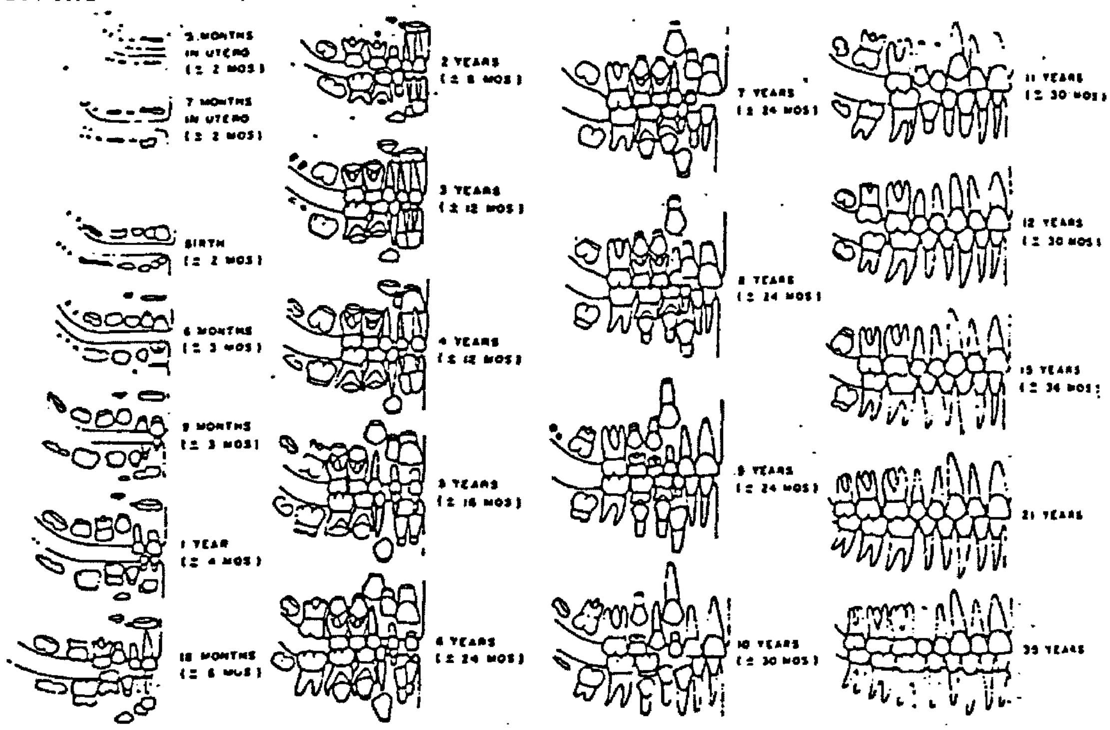
FS (Burial)# ______________________ DATE ____________
Association ______________________
Recorder(s) ______________________

LONG BONE MEASUREMENTS: EPIPHYSEAL CLOSURE

____	Humerus:	R ____	L ____	DIAM(R) ____	(L) ____	P ____	D ____
____	Radius:	R ____	L ____	DIAM(R) ____	(L) ____	P ____	D ____
____	Ulna:	R ____	L ____	DIAM(R) ____	(L) ____	P ____	D ____
____	Femur:	R ____	L ____	DIAM(R) ____	(L) ____	P ____	D ____
____	Tibia:	R ____	L ____	DIAM(R) ____	(L) ____	P ____	D ____
____	Fibula:	R ____	L ____	DIAM(R) ____	(L) ____	P ____	D ____

AGE ASSESSMENT: ______________________
Comments: ______________________

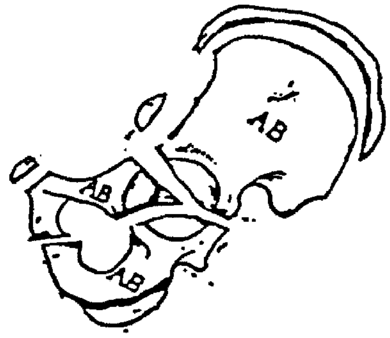
DENTAL ERUPTION:



AGEASSESSMENT: ______________________
Comments: ______________________

Figure 3. Data Collection Form (Page One).

COXAL:
Age:



AGE ASSESSMENT:____
Comments:____
____

Sex:
Greater Sciatic Notch: Angle: M________ F________ IND________

Depth: M________ F________ IND________

"Arch" Criterion: M________ F________ IND________

Curvature of Iliac Crest: M________ F________ IND________

Auricular Surface: E(F)______ NE(M)______ IND________

Comments:____
____

SCAPULA:
Sex:
Visual sexing: Size: Larger (M)___ Smaller(F)_______ IND______

Rectangular(M)___ Squarer(F)_______ IND______

Glenoid Fossa: M________ F________ IND______

Deltoid Tubercle: M________ F________ IND______

Teres Major: M________ F________ IND______

Metrical sexing: ScL' _____ ScB _____ ScLs'_____ ScLax_____

ScWte'_____ ScLc' _____ ScLg _____ ScBg'_____

ScDg' _____ ScWde'_____ ScWs _____ ScWax_____

G E N E R A L C O M M E N T S :
____
____
____
____
____
____

KEY: M=Male F=Female IND=Indeterminate R=Right L=Left DIAM=Diameter
P=Proximal D=Distal E=Elevated NE=Non-elevated
1=No union 2=Union w/noticeable line 3=Union/no line

Figure 4. Data Collection Form (Page Two).

conclusion of each section, an age assessment and comments area was included for notes specific to that section. I designed the form using techniques developed by physical anthropologists at the University of Montana and elsewhere in the study of human osteology. In the following paragraphs I explain the purpose of each section and references.

2.3a BURIAL AND RECORDING INFORMATION

The first section of each form is labeled with the site name, Windover, and the specimen number. The specimen numbers are those used by Dr. Glen Doran. This is to maintain consistency and make the information available for future research.

The date the information was gathered, the association of the remains in burial context, and who recorded the data follows the FS/burial number.

2.3b LONG BONE MEASUREMENTS

The long bone measurements were taken using equipment on loan from the physical anthropology lab at the University of Montana, Missoula, MT. The measuring procedures used for each bone are those described by Bass (1987).

An osteometric board was used to obtain the maximum length in millimeters of the humerus, radius, ulna, femur, tibia, and fibula. For each element, a right and left measurement was taken when possible. Fragmentary bones were not measured.

If epiphyses were not attached, only the diaphysis was measured. If epiphyses were attached, they were included in the measurement. This procedure maximized the amount of collectable data from collections where epiphyses are variably attached and may be missing. Epiphyseal closure was notated in this section by a number of 1 (no union), 2 (union with noticeable line), or 3 (union/no line). Right and left proximal and distal epiphyses were scored separately for each individual. The guidelines used for inferring age from epiphyseal closure are those adopted by the Workshop of European Anthropologists (Anonymous 1980).

2.3c DENTAL ERUPTION

Age was also estimated for individuals from the Windover excavation from dental eruption. When possible, photographic x-rays of the mandibles and maxillas were used. These were useful in showing the position of non-erupted teeth.

In order to assess the age of each individual examined, the dental eruption chart presented by Ubelaker (1978) was used. Each individual was examined, then the closest corresponding match on the chart was picked. The chart indicates an age plus or minus a number of months. The ages assessed were then compared to Dr. Doran's previous estimate of age and inconsistencies were resolved by re-checking.

2.3d COXAL

When dental eruption evidence was missing I used the technique of Camp and Cilley (1931) to estimate age from the fusion of the coxal bone. A diagram of the coxal bone from this source was used on the data form. When examining the coxal, elements of the bone were circled to indicate fusion. Two methods were used to estimate sex in cases where the coxal bones were present. The first method is relatively new and was developed by Schutkowski (1993). The criteria observed are the angle and depth of the greater sciatic notch, "arch" criterion, and curvature of the iliac crest.

According to Schutkowski (1993), females exhibit a greater sciatic notch angle greater than 90 degrees. Males have an angle of approximately 90 degrees. Depth of the greater sciatic notch indicates sex in that females exhibit a shallow notch, while males have deep notches. Curvature of the Iliac crest indicates sex in that males exhibit a more pronounced S-shape. This S-shape is less pronounced in females. The "arch" criterion is the observation that, when oriented correctly, "the "arch" that is formed by drawing a cranial extension from the vertical side of the greater sciatic notch crosses the auricular surface" (Schutkowski 1993:201) in females while the extension "leads into the lateral rim of the auricular surface" (Schutkowski 1993:201) in males.

Weaver (1980) studied the auricular surface in an effort to estimate subadult sex. He looked at the auricular surfaces and determined that having an elevated auricular surface is a characteristic of females, while non-elevated surfaces are characteristic of males.

2.3e SCAPULA

This section of the data form was intended to record specific scapula measurements designed by Skelton (1978) in an effort to sex individuals. Unfortunately, time did not allow for this research to be completed.

2.3f GENERAL COMMENTS

This final section was a "catch-all" for information that could not be recorded on other sections of the form, to record any anomalies or diseases on the bones, and to list any problems that may have occurred while recording the data.

Below the General Comments section was a key listing the abbreviations and numbers used in recording information.

2.4 INDIAN KNOLL DATA

I used age and bone length data for Indian Knoll from Johnston (1962). This article was useful for two reasons. 1) It gave me a format for arranging my data and 2) it included data for the ages newborn (NB) to age 5.

Table 2 of Johnston (1962) lists ages from fetal to 5.5, number of individuals in age group, mean bone lengths, and the standard deviation for bone lengths. I did not use Johnston's data for fetal individuals because the fetal cases in the Windover collection were too fragmentary to use for comparison. I used the midpoint of Johnston's ranges, and assigned a value of .5 to the newborns. For example, my newborn group corresponds to Johnston's NB to 0.5. The 0.5 to 1.5 age group would correspond to my age 1 group, and so on up to age five.

The data collected for ages 6 to 18 were taken from Sundick (1972). Within some of the bone groupings in Indian Knoll, none or only one individual was present in the 16, 17, and 18 year old categories. This indicates that this collection had few or no subadults of these ages. Sundick's data gathering techniques were similar to Johnston's which made integrating the information relatively easy. I chose to use the tables that did not list the bones with epiphyseal closure (Sundick 1972 - Tables 7a, 11a, 13a, 16a, 22a, and 26a) in order to maintain consistency. On each table Sundick listed age, number of individuals in the age group, mean bone lengths, and their standard deviation.

2.5 ORGANIZATION OF DATA FOR ANALYSIS

The data from Johnston (1962) and Sundick (1972) were combined to form an overall data set for the Indian Knoll collection. The Windover data were then compiled into a format similar to Johnston's. Left bone lengths were used on all occasions, unless there was not a left bone, then the right was used. This was to maintain consistency with the methods that Johnston used. Also for consistency, I chose to use only dental eruption to age individuals. Individuals that had no mandibles or maxillae were omitted from the case study. After compiling data, I found that only ages 2-15 were well represented at Windover. At Indian Knoll, ages 2-15 were represented in the humerus and ulna bone categories, and 2-18 in the remaining bone categories. I chose to work only within these age ranges.

2.6 COMPUTER ANALYSIS PROGRAM

The program used to calculate and plot regression lines was QUATTRO PRO 5.0. For each individual, age and bone lengths were recorded by burial number on a spreadsheet. From this information, spreadsheet formulas were used to calculate the means and standard deviations for each bone in a given age group. The means information was entered into Quattro Pro, arranged so as to be comparable between the two samples, graphs and regression formulae were generated to display differences between the two populations.

2.7 REGRESSION ANALYSIS

"Given a collection of paired sample data, the regression equation describes the relationship between two variables. The graph of the regression equation is called the regression line (or line of best fit, or least-squares line)" (Triola 1995:493). The preceding quote defines a relationship between x, which is called the independent variable, and y, the dependent variable. In this case study, x represents age in years, while y is the long bone length in millimeters. Therefore, in my analyses, the regression lines represent the relationship between age and long bone length.

The regression line is expressed as $y = mx + b$. In this formula y equals the dependent variable, m is the slope of the line, x is age, and b represents the y-intercept or constant. In my analyses, the slope of the regression line (or x-coefficient) is the amount of change in the length of a long bone (growth) per year. Therefore, I will refer to it as the growth rate.

The squared correlation coefficient, r-sqared, is a measure of the accuracy, or strength of the relationship, of the regression line. "The value of r-squared will always be between 0 and 1. The higher the value of r-squared, the better the line fits" (Downing and Clark 1989:unknown). Specifically, r-squared represents the amount of variability in the dependent variable (bone length) that is accounted for by the independent variable (age).

The Quattro Pro program was used to perform the regression analysis after I entered the long bone length data. The objective of the analysis was to generate a regression formula that would allow the slope and y-intercept of the regression line to be estimated.

For Windover, I performed regression analysis on age groups 2 through 10 and 2 through 15. Preliminary regression analyses suggested that the subadult growth curve undergoes a transition at about age 10. The age group of 2 to 10 from Windover was used in my final analysis for two reasons. First with the Windover collection I did not have a reliable age group under the age of 2 to compare to Indian Knoll. Second, I found that using the entire 2 to 15 age range biased the y-intercept, making it too large to compare meaningfully to Indian Knoll.

For Indian Knoll, the regression analysis was performed on the age groups 2 through 18, except for two bone categories - the humerus and ulna. These two bone categories were analyzed using ages 2 through 15 because data were unavailable for older age categories.

After completing the Indian Knoll regression output, I prepared confidence intervals for the slope of the regression line for each bone. "A confidence interval (or interval estimate) is a range (or an interval) of values that is likely to contain the true value of the population parameter" (Triola 1995:288). Two common choices for the level of confidence are 95% and 90% I prepared intervals for both of these levels of confidence. The choice of 95% is most common due to it's providing a good balance between precision and reliability. It is this interval, based on the x coefficient (slope) for Indian Knoll to which the corresponding Windover x coefficient is compared to test the hypothesis that the growth rate for a given bone is the same in both populations.

CHAPTER THREE

RESULTS

3.1 RESULTS OF ANALYSIS

The results of my analysis are represented in 4 tables and 2 figures. I have also included graphs that show the long bone growth comparisons between the Windover population and the Indian Knoll population.

3.2 TABLES

Tables 1 and 2 include of the Windover sample sizes and mean bone lengths in millimeters. The humerus, radius, and ulna were grouped together on Table 1, while the femur, tibia, and fibula were grouped on Table 2. For both tables, the first column, labeled "Estimated age in years", gives the age groups 1 through 15. The second, third, and fourth columns are headed by the particular long bone being recorded. For each bone, the letter n represents the number of individuals in each age group, and the mean of that age group is listed under the heading "mean".

Tables 3 and 4 include the Indian Knoll sample sizes and mean bone lengths in millimeters. The humerus, radius, and ulna were grouped together on Table 3, while the femur, tibia, and fibula were grouped on Table 4. The first column, labeled "Estimated age in years", are the age groups 1 through 18. The second, third, and fourth columns are headed by the particular long bone being recorded. For each bone, the letter n represents the number of individuals in each age group, and the mean of that age group is listed under the heading "mean".

TABLE 1
Windover Mean Bone Lengths in Millimeters
(Humerus, Radius, Ulna)

Estimated age in years	Humerus		Radius		Ulna	
	n	mean	n	mean	n	mean
1	0	0	1	66	1	75
2	1	111	1	87	1	99
3	0	0	0	0	0	0
4	1	166	1	132	0	0
5	1	151	1	117	1	129
6	2	154.5	2	135.5	4	121
7	1	185	0	0	0	0
8	2	205	1	152	2	174.5
9	2	199.5	2	161.5	2	175.5
10	2	212.5	2	170.5	2	187
11	0	0	0	0	0	0
12	3	212.6	4	177.75	4	194.5
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	5	241.8	4	183.5	4	202.5

TABLE 2
Windover Mean Bone Lengths in Millimeters
(Femur, Tibia, Fibula)

Estimated age in years	Femur		Tibia		Fibula	
	n	mean	n	mean	n	mean
1	0	0	0	0	0	0
2	1	145	0	0	1	116
3	0	0	0	0	0	0
4	2	199	0	0	1	191
5	1	208	3	172.3	1	165
6	3	226.3	4	160.25	2	180
7	0	0	0	0	1	214
8	1	256	1	218	1	251
9	2	279.5	2	238.5	2	230
10	2	309.5	2	255	3	252.6
11	0	0	0	0	0	0
12	3	301.6	4	266.25	3	262.6
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	4	331.75	4	284.5	2	273.5

TABLE 3
Indian Knoll Mean Bone Lengths in Millimeters
(Humerus, Radius, Ulna)

Estimated age in years	Humerus		Radius		Ulna	
	n	mean	n	mean	n	mean
1	42	93.14	24	73.96	29	82.86
2	7	113.57	6	91.33	5	99.2
3	11	125.64	7	97.86	7	108
4	9	136.78	8	108.5	8	120.63
5	6	154.67	5	120	4	132.75
6	6	145.4	6	109.3	4	120.5
7	7	153.5	6	120.1	5	132.2
8	3	169	3	133.3	2	147.5
9	6	185.8	6	143.8	6	158.9
10	9	206.4	7	159.4	9	174.7
11	1	201.5	1	160	1	180
12	2	222.5	3	182.3	2	188.8
13	6	223	8	174	6	187.3
14	2	239.8	9	199.4	3	223.7
15	1	260	4	202.8	2	219.5
16	0	0	1	211.5	0	0
17	0	0	1	236	0	0
18	0	0	1	225	0	0

TABLE 4
Indian Knoll Mean Bone Lengths in Millimeters
(Femur, Tibia, Fibula)

Estimated age in years	Femur		Tibia		Fibula	
	n	mean	n	mean	n	mean
1	38	115.63	38	96.87	25	92.44
2	8	148.13	7	120.57	5	113.8
3	11	166.73	10	138.2	6	134.17
4	11	183.82	10	154.3	7	144.71
5	6	213.67	7	178.43	3	171.67
6	7	190.2	6	156.9	6	155.3
7	7	211	6	175.8	5	169.3
8	3	236	3	196	3	189
9	6	263.1	6	220	5	206.6
10	9	294.4	9	240.4	9	230.8
11	1	281	1	233	0	0
12	3	328	2	288.5	2	289.8
13	9	321.7	9	266.7	9	255.7
14	9	366.1	9	300.9	8	285.4
15	5	373.2	4	310	5	297.4
16	1	379	2	308.5	2	294
17	1	437	1	365	1	344
18	1	400	2	333.5	1	313

3.3 REGRESSION ANALYSIS

Regression analysis on each age group produced the following results. The constant in the output represents the y-intercept. The standard error of the y estimate represents a measure of how accurately y can be predicted, given x.

Number of observations is the number of age group means used in the analysis. Degrees of freedom for the data set corresponds to the number of observations that can vary after certain restrictions have been imposed on all observations (Triola 1995). The x coefficient represents the slope of the line - which is interpreted as the amount of bone growth that occurs with an increase in age. The standard error of the coefficient is a measure of the uncertainty in the estimate of the slope. The following results were produced:

FIGURE 5
Windover Regression Analysis Results

HUMERUS

Ages 2 to 10:	
Constant	96.71429
Standard Error of Y Estimate	12.88533
R Squared	0.877764
Number of Observations	8
Degrees of Freedom	6
X Coefficient(s)	11.97619
Standard Error of Coefficient	1.824543
Ages 2 to 15:	
Constant	111.5016
Standard Error of Y Estimate	14.08919
R Squared	0.880322
Number of Observations	10
Degrees of Freedom	8
X Coefficient(s)	9.281416
Standard Error of Coefficient	1.209919

RADIUS

Ages 2 to 10:	
Constant	76.92197
Standard Error of Y Estimate	9.29952
R Squared	0.911265
Number of Observations	7
Degrees of Freedom	5
X Coefficient(s)	9.478324
Standard Error of Coefficient	1.322731
Ages 2 to 15:	
Constant	89.4409
Standard Error of Y Estimate	11.39958
R Squared	0.885119
Number of Observations	9
Degrees of Freedom	7
X Coefficient(s)	7.208196
Standard Error of Coefficient	0.981524

FIGURE 5
(continued)

<u>ULNA</u>

Ages 2 to 10:	
Constant	69.53846
Standard Error of Y Estimate	11.38439
R Squared	0.919872
Number of Observations	6
Degrees of Freedom	4
X Coefficient(s)	11.71923
Standard Error of Coefficient	1.729413
Ages 2 to 15:	
Constant	86.421
Standard Error of Y Estimate	14.06299
R Squared	0.88566
Number of Observations	8
Degrees of Freedom	6
X Coefficient(s)	8.830329
Standard Error of Coefficient	1.29529

<u>FEMUR</u>

Ages 2 to 10:	
Constant	112.534
Standard Error of Y Estimate	7.4568
R Squared	0.98464
Number of Observations	7
Degrees of Freedom	5
X Coefficient(s)	18.9908
Standard Error of Coefficient	1.06063
Ages 2 to 15:	
Constant	137.554
Standard Error of Y Estimate	16.7838
R Squared	0.93371
Number of Observations	9
Degrees of Freedom	7
X Coefficient(s)	14.3488
Standard Error of Coefficient	1.44511

FIGURE 5
(continued)

TIBIA

Ages 2 to 10:	
Constant	63.60659
Standard Error of Y Estimate	13.02596
R Squared	0.925012
Number of Observations	5
Degrees of Freedom	3
X Coefficient(s)	19.10659
Standard Error of Coefficient	3.140838
Ages 2 to 15:	
Constant	108.6233
Standard Error of Y Estimate	17.38253
R Squared	0.886265
Number of Observations	7
Degrees of Freedom	5
X Coefficient(s)	12.838
Standard Error of Coefficient	2.056729

FIBULA

Ages 2 to 10:	
Constant	96.9624
Standard Error of Y Estimate	19.2103
R Squared	0.85464
Number of Observations	8
Degrees of Freedom	6
X Coefficient(s)	16.1562
Standard Error of Coefficient	2.72015
Ages 2 to 15:	
Constant	121.625
Standard Error of Y Estimate	21.9928
R Squared	0.82967
Number of Observations	10
Degrees of Freedom	8
X Coefficient(s)	11.7896
Standard Error of Coefficient	1.88865

FIGURE 6
Indian Knoll Regression Analysis Results

HUMERUS
Ages 2 to 15:

Constant	90.34837
Standard Error of Y Estimate	7.521233
R Squared	0.974576
Number of Observations	14
Degrees of Freedom	12
X Coefficient(s)	10.69481
Standard Error of Coefficient	0.498653

95% Confidence Interval for slope 11.76442 - 9.625203

90% Confidence Interval for slope 11.57294 - 9.816685

RADIUS
Ages 2 to 18:

Constant	66.52882
Standard Error of Y Estimate	7.910749
R Squared	0.972852
Number of Observations	17
Degrees of Freedom	15
X Coefficient(s)	9.08
Standard Error of Coefficient	0.39164

95% Confidence Interval for slope 9.920069 - 8.239931

90% Confidence Interval for slope 9.769679 - 8.390321

ULNA
Ages 2 to 15:

Constant	77.00851
Standard Error of Y Estimate	8.298775
R Squared	0.960304
Number of Observations	14
Degrees of Freedom	12
X Coefficient(s)	9.374462
Standard Error of Coefficient	0.550203

95% Confidence Interval for slope 10.55465 - 8.194275

90% Confidence Interval for slope 10.34337 - 8.405553

FIGURE 6
(continued)

FEMUR
Ages 2 to 18:

Constant	107.6015
Standard Error of Y Estimate	16.41155
R Squared	0.96845
Number of Observations	17
Degrees of Freedom	15
X Coefficient(s)	17.43426
Standard Error of Coefficient	0.812493

95% Confidence Interval for slope 19.17706 - 15.69147

90% Confidence Interval for slope 18.86506 - 16.00346

TIBIA
Ages 2 to 18:

Constant	89.39436
Standard Error of Y Estimate	15.22052
R Squared	0.961128
Number of Observations	17
Degrees of Freedom	15
X Coefficient(s)	14.51174
Standard Error of Coefficient	0.753528

95% Confidence Interval for slope 16.12806 - 12.89542

90% Confidence Interval for slope 15.8387 - 13.18478

FIBULA
Ages 2 to 18:

Constant	88.25272
Standard Error of Y Estimate	15.92425
R Squared	0.955751
Number of Observations	16
Degrees of Freedom	14
X Coefficient(s)	13.72708
Standard Error of Coefficient	0.789397

95% Confidence Interval for slope 15.42034 - 12.03383

90% Confidence Interval for slope 15.11721 - 12.33696

TABLE 5
Summarization of Growth Rates (GR)

Bone	GR at Indian Knoll	GR at Windover
Humerus	10.69481 mm/year	11.97619 mm/year
Radius	9.08 mm/year	9.478324 mm/year
Ulna	9.374462 mm/year	11.71923 mm/year
Femur	17.43426 mm/year	18.9908 mm/year
Tibia	14.51174 mm/year	19.10659 mm/year
Fibula	13.72708 mm/year	16.1562 mm/year

TABLE 6
Summarization of Confidence Interval (CI) Results

Bone	95% CI Range for GR at Indian Knoll	90% CI Range for GR at Indian Knoll
Humerus	11.76442 to 9.625203	11.57294 to 9.816685
Radius	9.920069 to 8.239931	9.769679 to 8.390321
Ulna	10.55465 to 8.194275	10.34337 to 8.405553
Femur	19.17706 to 15.69147	18.86506 to 16.00346
Tibia	16.12806 to 12.89542	15.8387 to 13.18478
Fibula	15.42034 to 12.03383	15.11721 to 12.33696

TABLE 7
Significance of Windover GR Compared to Indian Knoll GR
Using the 95% and 90% CI Ranges

Bone	Windover GR	Indian Knoll GR	Significance
Humerus	above ranges at 90 & 95 CI	w/in both ranges	more rapid growth rate at Windover
Radius	w/in both ranges, but larger than Indian Knoll	w/in both ranges	Windover falling w/in range may be result of one or more bones in lower or higher age group reducing overall slope for bone growth
Ulna	above ranges at 90 & 95 CI	w/in both ranges	faster bone growth rate at Windover
Femur	above range at 90 CI w/in range at 95 CI, but larger than Indian Knoll GR	w/in both ranges	faster bone growth with 90% confidence at 95% Windover is just slightly w/in range, may be due to other bones reducing overall slope for bone growth
Tibia	above ranges at 90 & 95 CI	w/in both ranges	faster rate of bone growth at Windover
Fibula	above ranges at 90 & 95 CI	w/in both ranges	faster rate of bone growth at Windover

3.4 GRAPHS

The relationship between long bone length and age for all of the bones was used in preparing the following graphs (Figures 7 through 12). Each graph visually aids in understanding the results of the regression analysis. A strong, positive correlation between age and the growth rate is evident in the graphs.

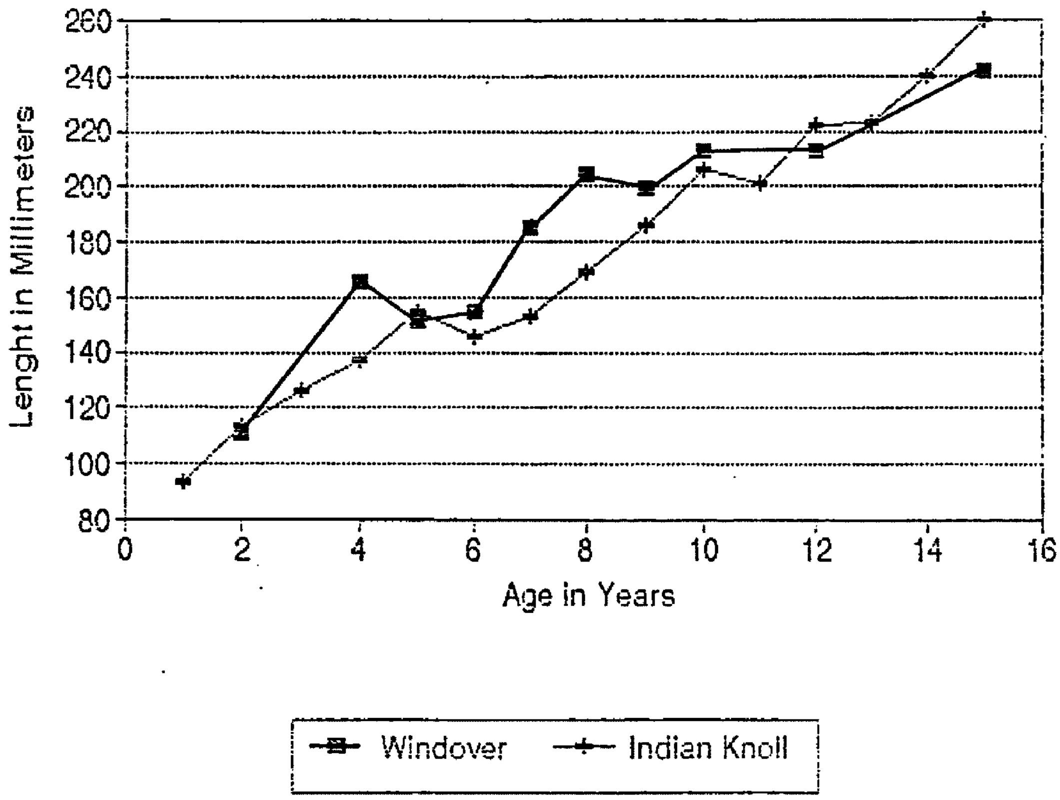


Figure 7. Humerus Growth Through Subadult Years.

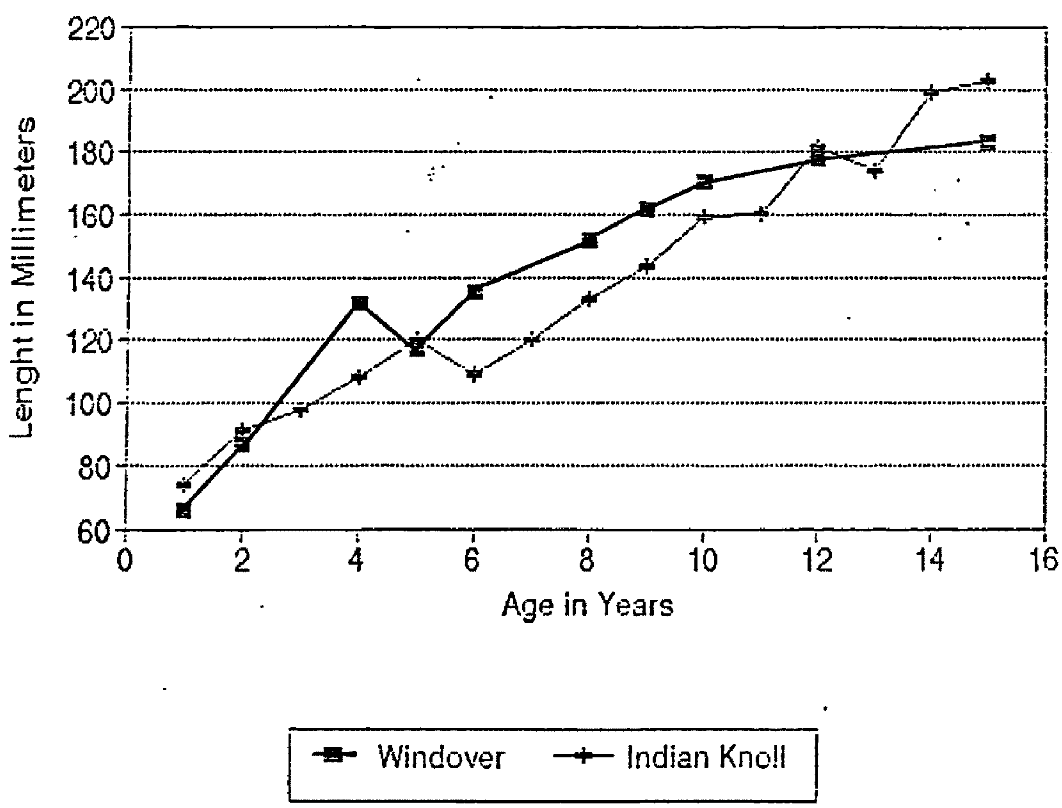


Figure 8. Radius Growth Through Subadult Years.

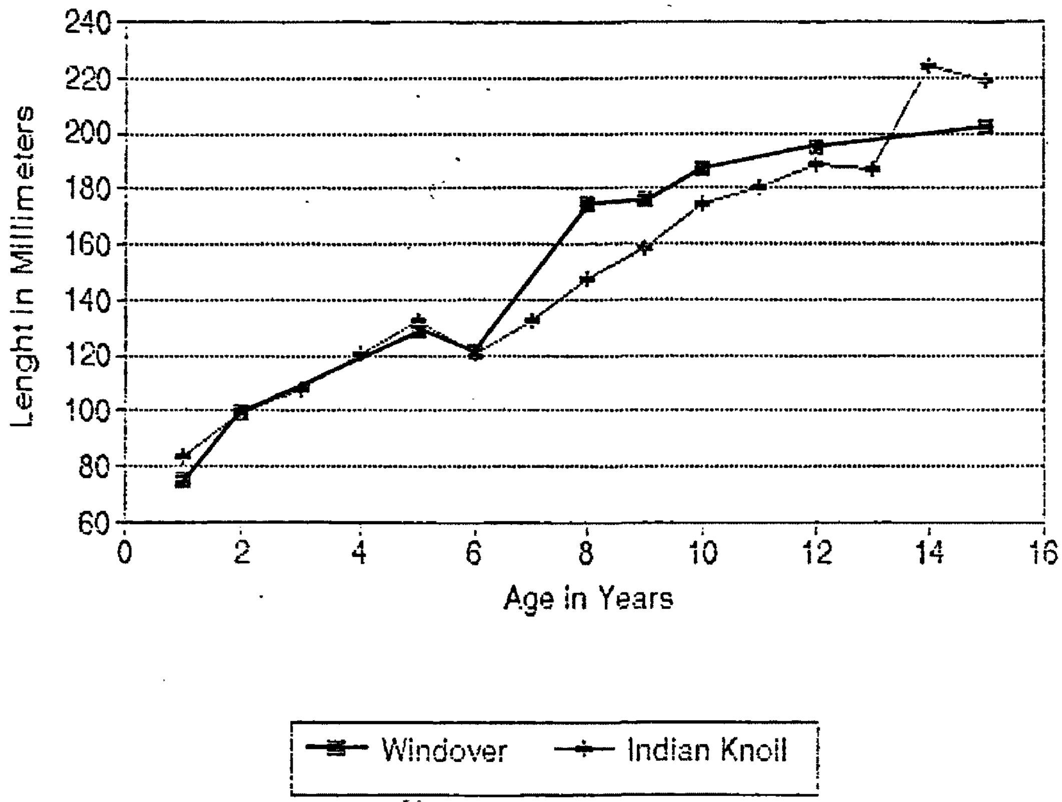


Figure 9. Ulna Growth Through Subadult Years.

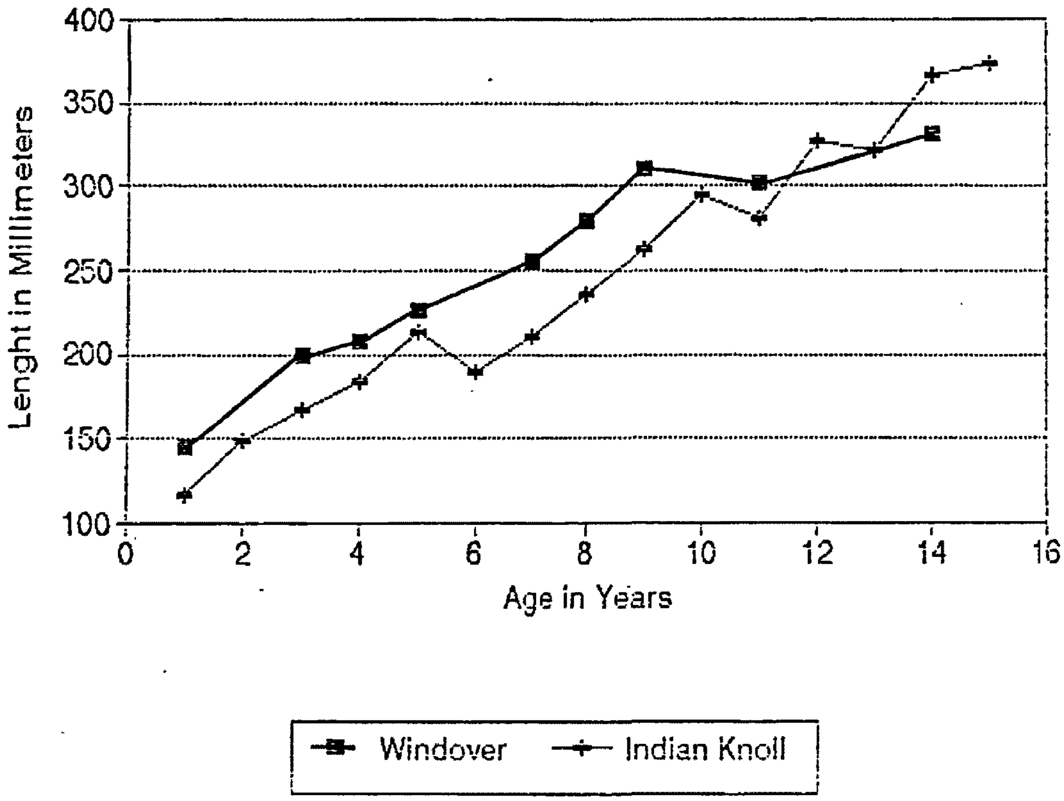


Figure 10. Femur Growth Through Subadult Years.

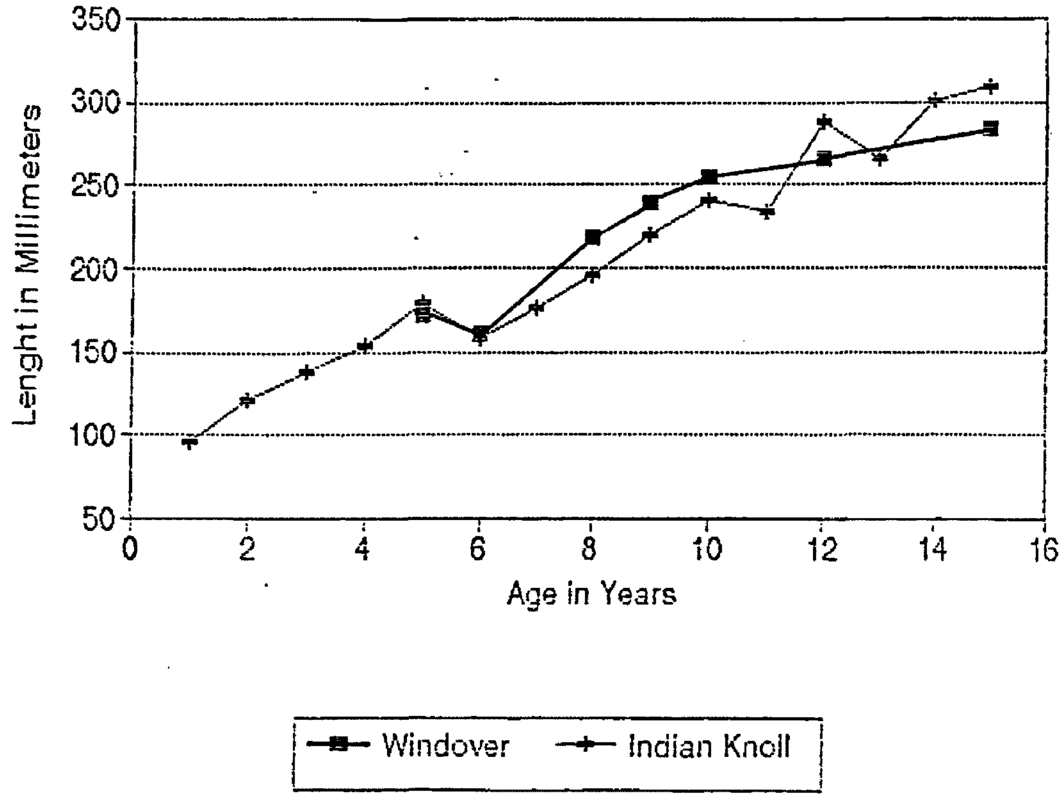


Figure 11. Tibia Growth Through Subadult Years.

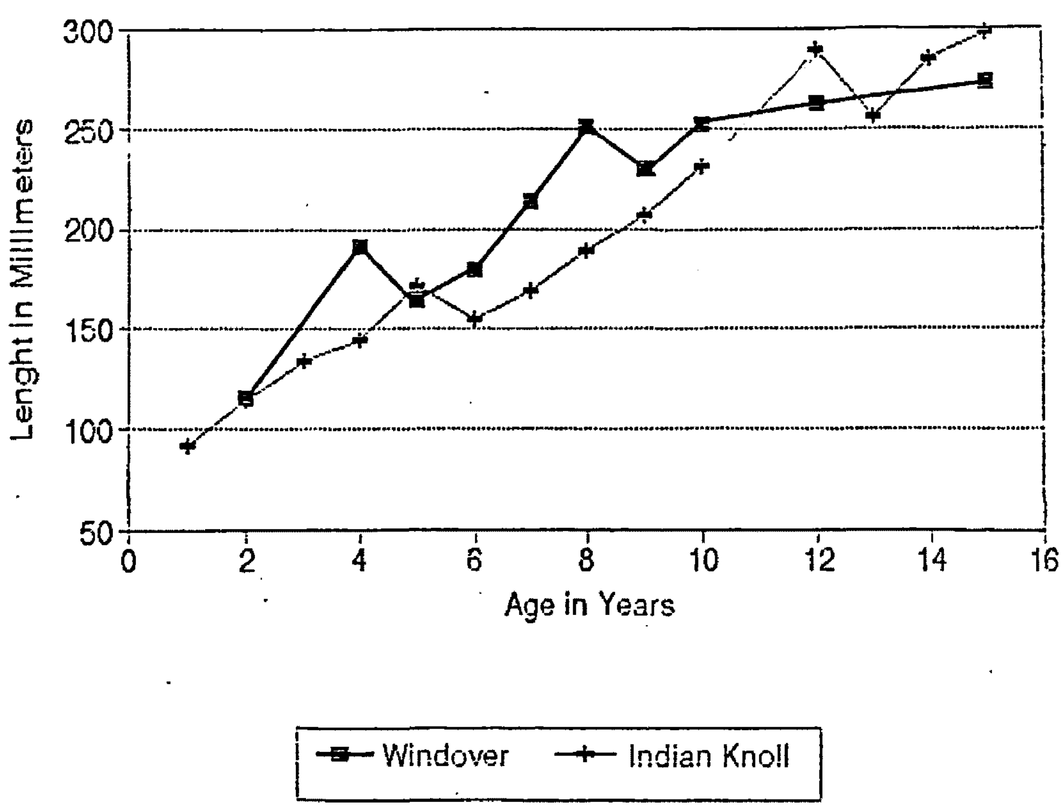


Figure 12. Fibula Growth Through Subadult Years.

CHAPTER FOUR

DISCUSSION

4.1 DISCUSSION OF ANALYSES

In this chapter, I interpret the results of my data analysis. I attempt to provide explanations for the differences recorded between the two populations.

The regression analyses for all bones show a strong, positive correlation between the x variable (age) and the y variable (long bone growth). The amount of variability in long bone length explained by age ranges from 85.5% (fibula) to 98.5% (femur). For most of the bones, differences in growth in the two populations start to occur between the ages of 2 and 5. Windover consistently leads in bone growth, for all bones, until approximately the age of 12, when the growth rate tapers off and drops below the growth rate of Indian Knoll.

4.2 INTERPRETATION OF RESULTS

In the past, it has been assumed in anthropology that hunters-gatherers, like the people who lived at Windover, have had to struggle with the environment and resources in order to survive. However, more recent research has challenged this model. Through ethnographic studies (Lee and Devore 1968; Sahlins 1972) it has been found that hunting-gathering peoples have adequate and varied food supplies, and suffer malnutrition less often than horticulturists and agriculturalists (Cassidy 1980). It is now theorized that prehistoric hunter-gatherers collected enough resources at one time to last several days, and then only foraged as necessary. In this situation, the food supply is relatively predictable due to their knowledge of season and locality (Cassidy 1980). These populations maintained a level of nutrition above the minimum, and people rarely starved outright (Yesner 1980).

The Windover Pond individuals were a small population of hunter-gatherers moving quite frequently, probably between adequate water resources for game. "The early Archaic people had to hunt or collect everything they ate and gather all of the raw materials they needed to make clothing, tools, and fabrics. They had to carry many of their personal possessions with them as they moved to take advantage of game, water, and other resources" (Milanich and Fairbanks 1980:75). Unlike Indian Knoll, evidence shows no intense exploitation of one type of resource (shell fish and mussels at Indian Knoll). Living areas have never been found in association with the site. The artifacts, found in association with the burials, suggest that this population had a material culture sufficient to sustain their way of life.

Indian Knoll, though usually classified as a hunting-gathering society, was also part of the Shell Mound Tradition of the Archaic. Archaeological investigations suggest that the people at Indian Knoll took advantage of a subsistence strategy that relied on resources which were seasonally predictable, shell fish (Cassidy 1980), and which allowed semi-sedentism or sedentary occupation of the site (Webb 1946). The river mussels and snails, in addition to local, dependable vegetal resources (hickory, walnut, acorn) provided stable food sources (Cassidy 1980) to support a large population. Evidence of warfare in the population (Fagan 1991) may be a result of people defending their territory and/or valuable resources from competitors.

The differences in food procurement strategies between Windover and Indian Knoll, and the hypothesis that Indian Knoll was supporting a large population becoming more dependent on limited, local, seasonal food resources is important in my conclusions. I propose that the differences in the growth of the two populations may be due to malnutrition at Indian Knoll. My definition of malnutrition is provided by Cassidy (1980) "as a general term for physical states that result from lack or scarcity of food or deficiencies of specific nutrients" (Cassidy 1980:129). Malnutrition is rare among hunter-gatherers, but more frequent among groups that depend on a limited number of resources (Jerome, Pelto, and Kandel 1980). The population at Indian Knoll may have become larger and increasingly dependent on limited, predictable resources. This may explain why the Indian Knoll subadults move more slowly through the stages of bone maturation. With a growing population, resources may have become scarce and caused varying degrees of malnutrition and delayed maturation for approximately two to three years. This would mean that a child in a society where malnutrition is common may not reach a degree of maturity typical of 5-year-olds in other societies until the age of 7 or 8 years (Johnston and Zimmer 1989). The longer the period of time that children are experiencing periods of inadequate nutrition, the greater the lag in the skeletal ages.

Growth differences due to infectious disease are not very likely. Although disease did exist in both populations, overall good health was evident in the collections from Indian Knoll (Cassidy 1980) as well as Windover (Doran 1988). It is possible that if Indian Knoll subadults lived past the first twelve months, nutrition was stable enough to sustain life to at least middle age (Cassidy 1980).

One other possible explanation of the difference between Windover and Indian Knoll populations is that it may reflect different genetic heritages. I do not believe this to be the case. These two groups were living in the approximately same area (Southeast) which suggests to me that they were probably genetically similar. Therefore, differences in there growth curves, are probably not due to differences in genetics.

From this information and the results of the statistical analysis, I hypothesize that the difference in growth rate is a result of mild food shortages occurring at Indian Knoll. Perhaps subadults were not considered a priority to feed when there were food shortages, or, possibly, these shortages occurred in late winter, when food resources were at a low for everyone (Cassidy 1980). This is not to say that the people of Windover did not experience food shortages or malnutrition, but not to the same extent as at Indian Knoll. From the archaeological investigations at the mortuary pond, it appears that Windover had a much smaller population to maintain, and that the people were more mobile.

CHAPTER FIVE

CONCLUSION

5.1 EFFECT OF RESULTS ON ORIGINAL HYPOTHESIS

In this research project, the objective was to test the null hypothesis that long bone growth trajectories between Indian Knoll and Windover were the same. In the previous chapters I explained my research procedures, formulated, tabulated, and presented my data and statistical analysis. The results obtained have allowed me to reject the original null hypothesis, and conclude that there are differences in growth rates between these two populations.

As stated in Chapter Four, I believe these differences to be the result of periods of nutritional stress in the Indian Knoll population. The stress is malnutrition probably caused by a scarcity of reliable food sources. This, coupled with a large population to support, resulted in the subadults of the population not obtaining adequate nutrition to reach and/or complete stages of maturation and bone growth as quickly as at Windover.

5.2 IMPLICATIONS FOR ISSUES IN ANTHROPOLOGY

Anthropologists analyze prehistoric skeletal remains excavated from archaeological sites in the hope of using the information gathered from the analysis to assist in reconstructing the lifeways of prehistoric peoples. Skeletal remains display a history of changes through time that appear to represent responses to changing diets, food economics, and times of hardship in a population (Cohen 1987). The reason research of this type is undertaken is to evaluate growth patterns obtained from children and adolescents to provide data to answer research questions about prehistoric and modern populations (Johnston and Zimmer 1989). Growth and development investigations of a skeletal sample provide information that goes beyond the subadults being studies. Findings from the analyses of growth may be extrapolated to the entire population being studied. Growth is a reflection of the conditions under which a group lived and the success they had adapting to their environment (Johnston and Zimmer 1989).

5.3 FUTURE RESEARCH

Windover provides the earliest sample of archaic hunter-gatherer skeletal remains found in North America with excellent preservation. Research opportunities at Windover are varied. Potential research opportunities at Windover include: 1) an archaeological overview of burial practices, 2) bone protein analysis, 3) analysis of DNA recovered from brain tissue 4) osteological analysis that focuses on biocultural adaptation and 5) analysis of textiles to provide clues to the environment of Florida during the archaic.

I believe that further research could be done on the growth and development of this population. Assessing the nutritional status of these people by some independent means would be a worthwhile effort to see if nutritional needs were being met sufficiently to allow the full potential of growth and maturation to be expressed. Chemical analysis of the bone could answer questions as to whether this population was receiving adequate amounts of necessary nutrients.

A comparison of the growth rates between the male and female subadults of both populations would be a worthwhile investigation. The question of whether males or females were given preference could lead to some interesting questions about gender, status, and society.

A study of the conservation techniques used to preserve the bone would be interesting. Since this was a wet site, less common methods had to be used in order to preserve the bones adequately. It would be interesting to know whether these preservation methods reduced the amount of shrinking, expansion, or deterioration of the bones.

Assigning age at death in a skeletal sample is a problem in physical anthropology that needs further research. Anthropologists need more comprehensive studies of existing subadult skeletal collections to provide the necessary information for narrowing age intervals to accurately assess growth and maturation.
Re-analyzing collections and employing more modern techniques could provide a myriad of new information.

5.4 FUTURE GOALS

The last several decades have seen explosive growth in the field of skeletal analysis. Further research promises to help resolve issues that are still in question. "The growth in these fields includes not only an enormous increase in the number of studies done, but also a new, ecological, population-oriented approach and the appearance of new techniques" (Cohen 1987:267).

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