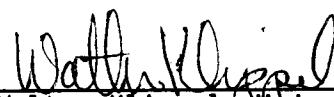


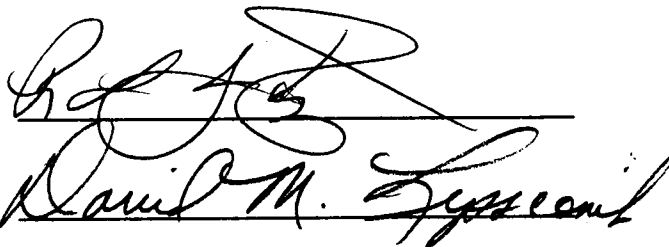
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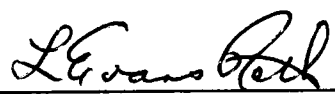

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AN ANALYSIS OF DENTAL STRESS INDICATORS
IN SKELETAL POPULATIONS FROM TENNESSEE

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Kathleen A. Jablonski

June 1983

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ABSTRACT

Skeletal samples from three archaeological periods, the Archaic, Woodland, and Mississippian from the Tennessee River Valley were studied for physiological childhood stress using the following dental stress indicators: mean tooth size, fluctuating dental asymmetry, pathological enamel bands, and microscopic enamel hypoplasias. Two avenues of investigation were taken. The first tested for differences in the frequencies of stress episodes between mature and subadult individuals within each time period. It was predicted that young individuals would exhibit a greater number of dental defects than their surviving cohorts. In the second phase of the research it was hypothesized that physiological stress increased through time from the Archaic to the Mississippian. The prediction was grounded in the assumption that as population density increased through time in the Southeastern United States food resources were depleted and malnutrition and rates of disease increased. Each time period is discussed in reference to population increase, disease rates, and malnutrition.

Younger individuals were found to have more variation in tooth size of certain teeth than older individuals. This is discussed with reference to two viewpoints. The first suggests that a greater amount of variation exists in the younger group because these individuals are composed of two distinct subgroups. One purportedly suffered stress during fetal development when tooth size is fixed,

and the other suffered stress later in their development. Stabilizing selection may also explain these findings. If stabilizing selection was operative then the usefulness of mean tooth size differences between age-at-death groups as a measure of stress is considerably diminished.

There were no differences in the means of younger individuals and older individuals for fluctuating asymmetry, pathological enamel bands, and hypoplasias.

Pathological enamel bands supported the thesis of increased stress through time. However, the results from fluctuating dental asymmetry and microscopic hypoplasias were mixed and difficult to explain. With reservations, the hypothesis of increased stress through time is accepted based on the findings from the pathological bands.

The clinical basis for each dental stress indicator is reviewed. It is concluded that all of the stress indicators need further examination and refinement. Although pathological bands have the best clinical support of all the indicators, modern statistical techniques have yet to be applied in research on their etiology. Hypoplasias are suggested to be of little value, but a refinement of definition may prove them otherwise. Dental asymmetry is suggested to have questionable meaning. Finally, mean tooth size differences between age groups also need further testing.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
II. STRESS AND STRESS MEASURES	4
Physiological Stress	4
Nutrition and Disease	6
Dental Stress Measures	7
Crown size	8
Dental asymmetry	10
Pathological enamel bands	12
Hypoplasias	14
III. ARCHAEOLOGICAL BACKGROUND	17
The Archaic Sample	17
The Cherry site	21
The Big Sandy site	21
Kays Landing	21
The Eva site	21
West Cuba Landing	22
Ledbetter Landing	22
Oak View Landing	22
The Woodland Sample	22
The Mississippian Sample	25
Evaluation of Stress in the Three Time Periods	27
Archaic	27
Woodland	27
Mississippian	28
IV. METHODS	29
Samples and Variables	29
Statistics	35
V. RESULTS	39
Comparisons between Age Groups	39
Comparisons between Time Periods	50
VI. DISCUSSION	61
Comparisons between Age Groups	61
Crown size	61
Fluctuating dental asymmetry	63
Pathological enamel bands	64
Hypoplasias	64
Comparisons between Time Periods	64
Fluctuating dental asymmetry	64
Pathological enamel bands	65

CHAPTER	PAGE
VI. (Continued)	
Hypoplasias	66
General	68
VII. SUMMARY AND CONCLUSIONS	69
LIST OF REFERENCES	73
VITA	84

LIST OF TABLES

TABLE	PAGE
I. Samples	18
II. Sample Sizes for Tooth Measurements	31
III. Sample Sizes for Disturbed Bands and Hypoplasias	34
IV. Results from Tooth Size Comparisons between Young and Old Individuals for the Archaic Sample	40
V. Results from Tooth Size Comparisons between Young and Old Individuals for the Woodland Sample	41
VI. Results from Tooth Size Comparison between Young and Old Individuals for the Mississippian Sample	42
VII. Results from Young and Old Asymmetry Score Comparisons for the Archaic	45
VIII. Results from Young and Old Asymmetry Score Comparisons for the Woodland	46
IX. Results from Young and Old Asymmetry Score Comparisons for the Mississippian	48
X. Results from the Young and Old Comparisons of Pathological Pathological Bands for All Samples	49
XI. Results from the Comparisons between Young and Old Groups for Hypoplasias for All Samples	51
XII. Comparison between Archaic and Woodland for Asymmetry Scores	52
XIII. Comparison between Archaic and Mississippian for Asymmetry Scores	53
XIV. Comparison between Woodland and Mississippian for Asymmetry Scores	54
XV. Analysis of Variance Using Pathological Bands to Test for Time Period Effects	56

TABLE	PAGE
XVI. Analysis of Variance Using Hypoplasias to Test for Time Period Effects	59
XVII. Comparison of Old and Young Individuals for Each Time Period in the First and Second Age Groups for Pathological Enamel Bands	67

CHAPTER I

INTRODUCTION

Paleopathologists have measured physiological stress in a variety of ways such as studies of demographic statistics, developmental defects, and growth rates. Research of this kind is designed to investigate a population's overall "fitness" in its environment. Some of the best skeletal indicators of stress may be found in the dentition. There are three advantages in using teeth to measure stress in populations. The first is that enamel is often the best preserved part of the skeleton. Secondly, enamel is not subject to remodelling, and is therefore a permanent record of individual developmental history. Finally, age of formation can be easily assigned to various tooth components so that the approximate age of defect formation can be obtained.

For these reasons the dentition has been used in a number of paleopathological investigations aimed at studying changes in populational patterns of stress through time. For example, Sciulli (1977) used four Ohio Amerindian populations to study dental defects (enamel hypoplasias) through time. He found higher frequencies of hypoplasias among the later groups. Similarly, Cook and Buikstra (1979) studied prenatally formed dental defects in two skeletal series from the Illinois River Valley. The authors found that the incidence of circular caries was greater in the later group. They concluded that the later time period was more stressful to children due to

increased population pressure on food resources, greater reliance on a carbohydrate diet for weaning, and environmental deterioration. Finally, Rose (1977) found that the incidence of pathological Striae of Retzius increased over time in three Illinois skeletal populations. Rose concludes that the increased pathological striae are associated with increased reliance on maize agriculture.

In this study the frequency of childhood physiological stress will be assessed and compared over three archaeological periods. The skeletal samples are from a single geographical unit, the Tennessee River Valley in the state of Tennessee. The dental variables examined are: tooth size variations over age groups, fluctuating odontometric asymmetry, pathological enamel bands (Striae of Retzius), and hypoplasias. This research is not only the first of its kind from the southeast, but it also is the first to incorporate all of these dental variables into one study. Physiological stress and its purported relationship with each of the dental defects are discussed in Chapter II.

The skeletal series examined are derived from the Archaic, Woodland, and Mississippian Periods. The location of the sites, and what is known of the subsistence strategy, nutrition, and demography of their occupants are briefly discussed in Chapter III. Hypotheses are generated from this information and the discussion in Chapter II.

The hypotheses are divided into two parts. The first set involves within-groups comparisons of young and old individuals for each time period. Young is defined as being less than 17 years of age. The younger individuals are expected to show more dental defects than

older persons. Many young individuals are presumed to have died earlier due to stresses which their surviving cohorts, through physiological strength or chance, were better able to ward off. The second group of hypotheses suggests that the frequency of dental defects increases through time as dependence on agriculture and cultural complexity increases. Therefore, the Archaic group is expected to show the least number of defects, and the Mississippian sample should show the most. The Woodland group is expected to fall between the two.

The growing reliance on agriculture and increased cultural complexity is established in Chapter III for the Tennessee samples. Each hypothesis is stated in Chapter IV. This chapter also includes a summary of the methods used in collecting the dental data, the sample sizes obtained for each measurement, and the statistical procedures used in testing the hypotheses.

The results are reported in Chapter V and discussed in Chapter VI. A summary and conclusions are given in Chapter VII. The final chapter also includes statements regarding future research.

CHAPTER II

STRESS AND STRESS MEASURES

This chapter first examines current thinking on physiological stress. Two potential stressors, malnutrition and infectious disease, are given particular attention because they are deemed to have been active agents in the archaeological populations used in this research. Finally, a summary of the knowledge of stress effects upon tooth development is given and the four dental measures of stress are discussed.

Physiological Stress

A disruption in the biological homeostasis of an organism caused by a maladjustment to its environment produces stress or, more directly, wear and tear on the body. Selye (1976, 1978), from whom this discussion is abstracted, defines stress as "the nonspecific response of the body to any demand" (1978:55). (See also Rose 1973 for a summary of Selye's work and its relevance to dental defects.) In most cases the body adjusts to that demand and homeostasis is re-established. Disease results when homeostasis cannot be achieved.

Stress can cause structural and chemical changes in the organism. The non-specifically induced changes or set of manifestations are caused by the stressor acting on the system. This set of manifestations is called the General Adaptation Syndrome (G.A.S.). The G.A.S. as a physiological process is common to all disease states

regardless of their specific causes. It develops in three stages: the alarm reaction, the stage of resistance, and the stage of exhaustion.

This string of events is initiated when a stressor attacks a localized area of tissues. The body's mobile defense system, including white blood cells and antibodies, acts upon the stressor. This causes a set of changes in the affected area such as inflammation. The set of changes is called the Local Adaptation Syndrome (L.A.S.). If the L.A.S. is unsuccessful in warding off the stressor the first stage of alarm reaction begins. The L.A.S. sends signals to the centers of coordination in the nervous system and consequently to the endocrine glands, most specifically the pituitary and the adrenals. The signal stimulates the endocrine glands to secrete adaptive hormones. The G.A.S. is now fully activated.

The second phase of G.A.S., the stage of resistance, begins as the adaptive hormones coordinate the body's defensive reaction. Though the defense may be proceeding well, the body is at this time more susceptible than usual to attack from other stressors.

There are two points regarding the stage of resistance that are of interest here. One is that the level of intensity of the stressor is a key determinant of how severely tissues are damaged. Thus it can be expected that dental tissues will be more affected by severe, chronic stress than by a mild, short term episode. Another point is that "nonspecific" damages, resulting primarily from toxicoses, may occur in any tissues of the body including those areas

not directly attacked by the stressor. Toxicoses results from noxious dead cell by-products and dangerously high levels of G.A.S.-produced hormones circulating through the blood system. It is therefore possible for enamel development to be disturbed by stressors which have not directly assailed the dentition.

The final stage of G.A.S. is reached when and if the tissues surrender. The organism may die if the stressor is potentially lethal.

Nutrition and Disease

Malnutrition and infection can interact to produce a condition more severe than if one had occurred independently of the other. Thus malnutrition is said to be synergistic with infectious diseases in that the body becomes more susceptible to the affects of bacteria, rickettsia, intestinal helminths, and intestinal protozoa (Scrimshaw et al. 1968).

Protein deficiency in particular breaks down resistance to traumatic injuries (Selye 1976), and if sufficiently severe, it can have a significant impact on resistance to infection. A protein-deficient diet may inhibit production of antibodies and phagocytes necessary to ward off infections (Scrimshaw et al. 1968). Infections in turn have an adverse affect on an individual's nutritional status. Severe or prolonged illness can interfere with growth and maturation. In sum, malnutrition can increase a population's disease rate and disease can alter a group's nutritional status, thereby exacerbating malnutrition.

Dental Stress Measures

Dental defects can be caused by the G.A.S., however the G.A.S. is not necessarily activated during each disease experience. Therefore, there would not be a one-to-one correspondence between the stress episode and the defect. Variability in the severity of defects between individuals who suffer similar disease experiences can be explained by the factors which influence G.A.S. activation. These factors include nutrition, previous exposure, and genetic make-up.

Although dental defects cannot be related to specific stress episodes (Kreshover 1940, 1960; Kreshover et al. 1958), numerous stressors have been related to dental defects. These include maternal health, the birth trauma, childhood nutrition and disease, hormonal disorders and congenital retardation. Studies suggesting that specific stressors lead to dental defects are outlined below. For further discussion see Jablonski (1981).

Maternal health during pregnancy has been related to dental defects by Evans (1944), Kreshover and Clough (1953), Kreshover et al. (1954), Kreshover and Hanok (1956), Grahnen and Edlund (1967), and Garn et al. (1979). Defects caused by the trauma of birth have been studied by Kreshover (1960) and Schour and Poncher (1937). The relationship between nutrition and dental defects has been explored by Howe (1933), Schour (1938), Garn et al. (1965b), Sobel and Hanok (1948), and Riesenfeld (1970). Shusterman and Fellers (1969), Gustafson (1966), Kreshover (1942), Kreshover et al. (1958), and Brauer and Bahador (1942) have documented the effects of childhood diseases on tooth formation. Garn et al. (1965a), Schour (1936),

Schour and van Dyke (1932), Schour et al. (1934), and Schour and Rogoff (1936) have related dental defects to hormone disorders. Finally, defects in the dentition have been noted to occur more frequently in patients suffering from retardation than normal patients by Watson et al. (1964), Kraus et al. (1968), and Barden 1980a, 1980b.

It can be concluded that many kinds of stressors affect the growth and development of teeth. Enamel is incapable of remodelling, and thus a permanent record of these stress episodes is left on the dentition. Although stressors cannot be directly measured in archaeological populations, the stress end-products (here, dental defects) can be used. The four stress indicators used in this study, tooth size variation between age-at-death categories, asymmetry, pathological Striae of Retzius, and hypoplasias, are discussed below.

Crown size. Tooth crown dimensions have been considered a good way to measure genetic distance between groups (Brace 1980; Brace and Hinton 1981; Hanihara 1979; and Harris and Nweeia 1980) because of the presumed stability of dental tissues. However, research has shown that heritability for tooth size is only a little greater than 50 percent. For example, Townsend and Brown (1978) found heritability among Australian aboriginals to be 64 percent on the average.

Several other researchers have indicated that environmental factors such as hormonal disorders and nutritional deficiencies may affect tooth crown size. In an animal study, Riesenfeld (1970) found

that reduction in tooth size was achieved in rats subjected to nutritional deprivation. In another animal study, Bennett et al. (1981) found that deciduous dental dimensions were reduced in fetuses of diabetic mothers compared to fetuses of non-diabetic mothers.

Research on human groups also indicate environmental influence on tooth crown dimensions. For example, Howe (1933) reports tooth form distortions thus altering crown size in the dentition of patients suffering from Vitamin A deficiency. Tooth size reduction was noted following hypophysectomy (surgical removal of the pituitary) by Schour and van Dyke (1932). Certain deciduous and permanent teeth were found to differ significantly in tooth size for Down syndrome patients compared to normal patients by Barden (1980b). Mesiodistal diameters of the deciduous canine and first molar were significantly greater in the Down's syndrome group than in the normal group, but the first and second incisor as well as the first molar were significantly smaller in the Down's group compared to normal subjects. Garn et al. (1979) report deciduous and permanent crown diameters diminished in size in maternal hypertension, low birth-weight, and small birth-length conditions. Their results suggest that larger teeth may be associated with maternal diabetes, maternal hypothyroidism, and large size at birth. The authors conclude that maternal and fetal conditions may account for as much as a half of permanent and deciduous crown size variability.

Only one study has used dental metrics in measuring stress between two groups in skeletal populations. Guagliardo (1982) compared juveniles and adults for differences in the means and variance

of the bucco-lingual dimension of permanent teeth. Although no significant differences in the variance were found, juveniles exhibited significantly smaller mandibular canines, first premolars, and first molars than adults. Guagliardo concluded that the juvenile teeth failed to reach their maximum genetic potential due to interference from chronic stressors such as malnutrition and disease.

Dental asymmetry. This stress measure is somewhat more controversial than other measures of stress. The problem revolves around the meaning of fluctuating dental asymmetry and whether asymmetry has a genetic basis. Some researchers have suggested that asymmetry measures the degree of canalization or fitness of an individual.

Animal studies indicate that dental asymmetry is affected by environmental stressors. Siegel and Doyle (1975) found that audiogenic stress applied either prenatally or postnatally produced asymmetry in laboratory rats. Heat stress was found to increase fluctuating asymmetry in the teeth and limbs of laboratory rats by Siegel et al. (1977). Another study by Sciulli et al. (1979) found that increased levels of fluctuating asymmetry in laboratory rats could be produced by applying various combinations of heat, cold, noise, and protein deprivation.

Studies using living human populations have assumed or concluded that fluctuating asymmetry is due to environmental stressors. For example, Garn et al. (1967) found in their study based on 118 Ohio adolescents, that boys showed greater levels of fluctuating asymmetry than girls. They concluded that their results were due to

less effective genetic control of tooth size in the males as compared to females. Townsend and Brown (1980) studied Australian Aborigines. They found higher asymmetry scores in males, maxillary teeth, and the mesiodistal dimensions compared to females, mandibular teeth, and the bucco-lingual measure.

Barden (1980a) found that dental asymmetry was higher in children whose mental retardation was produced prenatally than in children whose retardation was caused postnatally. Because of these results and the fact that teeth begin to form prenatally, Barden (1980a:112) concluded that fluctuating asymmetry "reflects the relative success that developmental homeostasis has in countering developmental disturbances."

In studying three skeletal populations, Perzigian (1977) found that populations which show other signs of stress such as enamel hypoplasia and Harris lines, were the most dentally asymmetrical. Doyle and Johnston (1977) found large levels of fluctuating asymmetry in Eskimo and Pueblo skeletal populations compared to Ohio whites. The authors suggest that high levels of asymmetry are due to stress related mechanisms. Also studying a skeletal population, Guagliardo (1980) found that dental asymmetry increased through time within one Tennessee skeletal population. He concluded that the increase was due to chronic stress such as disease and malnutrition. Guagliardo cautions, however, that this measurement may best be reserved for studying stress variation within the same population.

Although the evidence from the above inquiries seems to indicate that fluctuating dental asymmetry can be used to measure stress, a number of problems remain. For instance, the animal research cited above strongly indicates a relationship between stress and fluctuating asymmetry. However, there is no evidence to suggest that results from rat studies are applicable to human populations. Another problem is that the investigations on living populations use dental casts to measure teeth. The amount of error in these measurements could produce false results because the points of maximum tooth diameter are often obscured by the gums, or are otherwise inaccessible. Furthermore, studies which use mesiodistal dimensions to measure fluctuating asymmetry ignore the affects of interstitial wear. Again, faulty results could be obtained.

Finally, other investigations indicate that the meaning of fluctuating dental asymmetry is questionable. Bailit et al. (1970) made such a conclusion in their study of four populations. DiBennardo and Bailit (1978) conducted a regression analysis on the tooth measurements from Japanese children. They attempted to predict asymmetry levels from five factors related to prenatal stress. They concluded that the significance of individual asymmetry is debatable.

For the purposes of this research fluctuating dental asymmetry is assumed to be a valid measure of stress. The implications of this assumption are discussed in Chapter VI.

Pathological enamel bands. A pathological Striae of Retzius, or band, forms in the enamel of teeth which are developing during a

stress episode suffered by an individual. A disturbed striae is defined as any relatively broad band associated with atypical rod forms with a sudden change in rod direction (Wilson and Shroff 1970). For a more thorough discussion of formation of pathological bands see Jablonski (1981). This report also gives a thorough review of the literature on the uses of pathological bands in anthropological research. Some of the more important works will be discussed below.

The first study to use disturbed striae in order to measure stress was carried out by Massler, Schour and Poncher (1941). The authors associated stress episodes, mainly diseases, in childhood with the formations of accentuated bands in the enamel of both permanent and deciduous teeth of American whites.

The first major research using disturbed striae to measure stress in a skeletal population was made by Rose (1973). It was found that the incidence of pathological bands increased as dependence on agriculture and cultural complexity increased. Rose also found that the mean age at death was lower as the number of disturbed bands increased. Therefore, pathological bands can be used to measure the percentage of individuals in a population who are the most susceptible to stressors.

Pathological bands were used by Rose and Boyd (1978) to reconstruct weaning practices in four archaeological samples. The authors concluded that weaning practices and diets in nonagricultural groups were superior to the agricultural groups.

Boyd (1978) reported a low frequency of disturbed bands (22.6 percent) in a skeletal sample from the Libben site, northern Ohio.

It was suggested that this frequency was due to a low level of environmental stress.

Studying enamel defects in a skeletal population from Ohio, Condon (1981) found that tooth morphology influenced the distribution of hypoplasias and pathological Striae of Retzius. He suggested that certain teeth may be more susceptible to hypoplasias. Condon also concludes that bands result from acute stress while hypoplasias are the result of chronic stressors.

Hypoplasias. There are a number of studies in which hypoplasias have been defined. However, the majority of these studies give criteria for identifying hypoplasias macroscopically. Microscopic definitions are relatively rare. Gustafson (1959) defined microscopic hypoplasias as a deficiency of enamel. Rose (1977) adds that the Striae of Retzius are compressed and structureless enamel found along the surface when a hypoplasia is present.

There are numerous studies which suggest that enamel hypoplasias are associated with stress episodes. In living populations some of the stressors associated with hypoplasias are maternal rubella (Evans 1944, Stave 1965), cerebral palsy (Watson et al. 1964; Herman and McDonald 1963), maternal diabetes (Grahnen and Edlund 1967), nephrotic syndrome (Shusterman and Fellers 1969), malnutrition (Enwonwu 1973; Giro 1947; Clement 1963; Baume and Meyer 1966; Grahnen and Selander 1954), measles, scarlet fever, and diphtheria (Giro 1947), congenital heart disease (Pindborg 1970), neonatal asphyxia (Grahnen et al. 1969), congenital allergies (Pindborg 1970),

hypoparathyroidism (Sarnat and Schour 1942), lymphocytic choriomeningitis (Kreshover and Hancock 1956), nonspecific diarrhea (Sweeney et al. 1969), syphilis (Giro 1947), and tuberculosis (Stave 1965).

Other stressors associated with hypoplasias include genetic disorders such as amelogenesis imperfectus, phenylketonuria, and Down's syndrome (Pindborg 1970, Johnson et al. 1965).

Because of the apparent association between stress and hypoplasias, the dental defect has been used to measure stress in skeletal populations. For example, Sciulli (1977) studied four skeletal populations and found that the incidence of hypoplasias was greater in the agriculturalists. Sciulli concluded that changes in diet and food preparation techniques caused an increase in stress episodes in the agricultural population. Cook and Buikstra (1979) found that the incidence of hypoplastic defects in children increased as one moved from the Middle to Late Woodland periods. The authors concluded that the Late Woodland was more stressful than the Middle because of increased population pressure on food resources as well as a greater reliance on a carbohydrate diet and environmental deterioration.

Goodman et al. (1980) studied four skeletal groups from Dickson Mounds, Illinois dating to the Late Woodland, the Mississippian Acculturated Late Woodland, and the Middle Mississippian period. The authors found a greater number of hypoplastic defects in later samples. The increase was suggested to be due to a greater reliance on maize agriculture.

Other research on skeletal populations has centered around correlating hypoplasias with some other stress measures. For example, Clarke (1978, 1982) found a statistically significant association between the occurrence of radio opaque lines and hypoplasias in a prehistoric skeletal group. However, McHenry and Schultz (1976) found no such correlation. Finally, Condon (1981) correlated pathological bands in canines with hypoplastic defects of the first premolar.

CHAPTER III

ARCHAEOLOGICAL BACKGROUND

This chapter discusses the archaeological aspects of the skeletal materials. The archaeological sites are listed in Table I and their locations are mapped in Figure I. General information about each time period is given, followed by a description of each site. The last section evaluates what is known of the nutritional status and disease conditions for each time period.

The Archaic Sample

In order to obtain sufficient sample sizes for statistical analysis it was necessary to use seven archaeological sites from western Tennessee. These are the Cherry site (84BN74), Big Sandy site (25HY18), Kays Landing site (15HY13), Eva (6BN12), West Cuba Landing (13BN17), Ledbetter site (9BN6), and Oak View Landing site (1DR1). These sites were excavated in the 1930s and 1940s by the Works Project Administration under the directorship of The University of Tennessee Department of Anthropology. The skeletal material is now housed at the McClung Museum of The University of Tennessee, Knoxville.

The Archaic period in eastern Tennessee began at about 6000 B.C. and lasted until 500 B.C. (Lewis and Kneberg 1959). Settlements of this early period are often located near permanent streams. Usually they were small, sedentary settlements occupied for long

TABLE I

SAMPLES

Time Period	Sites
Archaic	Cherry (84BN74) Big Sandy (25HY18) Kays Landing (15HY13) Eva (6BN12) West Cuba Landing (13BN17) Ledbetter (9BN6) Oak View Landing (1DR1)
Woodland	Hiwassee Island (46MG31 and 42MG31)
Mississippian	Toqua (40MR6)

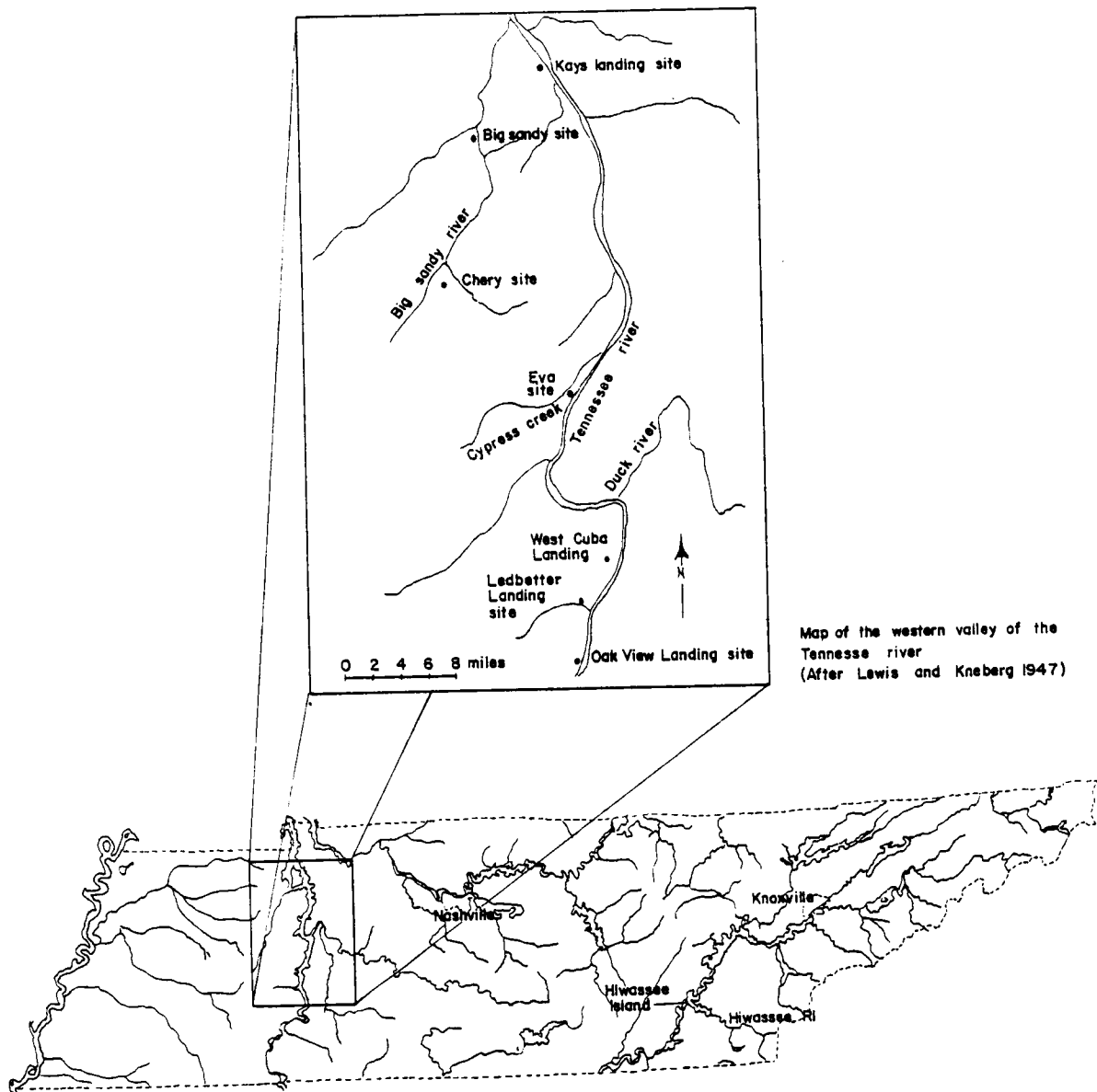


Figure I. Map of the sites used in the research.

periods of time (Lewis and Kneberg 1958, 1959). In the Late Archaic sites are characterized by large shell middens with depths ranging from a few feet to nearly 20 feet (Lewis and Kneberg 1946, 1958, 1959). The use of shellfish has been suggested to indicate an increase in stress on resources (Cohen 1975).

Osteological evidence indicates that deer were utilized more frequently than other vertebrates. The use of a variety of other animals are indicated as well, including elk, bear, rabbit, wild cat, fox, wolf, squirrel, raccoon, opossum, beaver, wild turkey and other large birds (Chapman 1976; Crites 1978a; Faulkner 1977; Lewis and Kneberg 1946, 1958, 1959; Lewis and Lewis 1961). In addition, fishing and collecting mussels was important, as is evidenced by the large shell mounds.

The floral remains indicate that a great variety of plants were heavily exploited. Seeds, nuts, fruits and roots were used extensively (Chapman 1976; Faulkner 1977; Lewis and Kneberg 1946, 1958, 1959; and Lewis and Lewis 1961). However, no other evidence of cultigens has been found (Chapman 1976; Faulkner 1977), except perhaps for the indigenous sunflower in the Terminal Archaic of the eastern part of the Tennessee River Valley (Brewer 1973).

Lewis and Kneberg (1959) describe the Archaic burials as fully flexed although there is variation. Burials tended to be in circular pits and often occurred in the shell middens. Dogs were frequently found with the human remains.

Individual site descriptions are paraphrased from Lewis and

Kneberg (1946). All site locations refer to the original course of the Tennessee River prior to inundation by modern dams.

The Cherry site. Located far up the Big Sandy River, the Cherry site is found on the bank of a small tributary about a mile from its confluence with the Big Sandy River. Shell debris is sparse, but animal bones were found in abundance with deer being the prominent species represented. Several trade items were found such as *Busycon perversum* shell and copper. The living quarters were spatially separated from the refuse and burial areas. The refuse dump contained 70 burials with some grouped in twos and threes in one pit. Most burials were fully flexed.

The Big Sandy site. This site is found on the left bank of the Big Sandy River near its confluence of the West Sandy Branch. Shell was found in abundance. Sixty-two burials were found in a refuse dump. Most individuals were fully flexed.

Kays Landing. On the west bank of the Tennessee River a few miles south of the Big Sandy is the Kays Landing site. A series of floods at the site was indicated. The site contained a shell mound and village area. Eighty-three burials were found. All but one were fully flexed.

The Eva site. The Eva site was located one mile west of the Tennessee River on the right bank of Cypress Creek about four miles above its junction with the Tennessee River. An abundance of mussel shell was found. Lewis and Kneberg (1961) concluded that shellfish

was a food supplement rather than a staple of these people. A great number of animal bones were recovered. Deer seems to have been a primary food source. Although Lewis and Kneberg report a lack of plant foods, this is probably due to the recovery techniques used at the time of excavation. Modern methods usually include the fine screening of materials in order to recover small objects such as plant seeds. About 198 burials were recovered, the majority of which were in the flexed position.

West Cuba Landing. This site began at the west bank of the Tennessee River several miles south of the mouth of the Duck River and stretched to the mouth of Morgan's Creek. West Cuba Landing site is typical of Archaic sites in that it had a large shell midden. Only seven burials were excavated.

Ledbetter Landing. This site is located between Morgan's Creek and the Tennessee River. Plenty of shell was found. Most of the 118 burials were found in a flexed position. Nine redeposited cremations were also found.

Oak View Landing. A little more than four miles south of the Ledbetter Landing site is the Oak View site. This site contained an enormous amount of mussel shell debris. Implements such as flat hoes suggests an agricultural use. Eighty-one burials were found.

The Woodland Sample

The Woodland sample is comprised of skeletons from one site, Hiwassee Island (46MG31 and 42MG31). The Late Woodland occupation

from Hiwassee Islands dates to the Hamilton complex (A.D. 700-1150, Schroedl (1973)), and is known almost solely from burial mounds. Little is known about food procurement or occupation sites. Therefore, the general discussion of the Woodland comes from knowledge about subsistence and occupation from the Middle Woodland dating between 200 B.C.-A.D. 500 (Faulkner et al. 1976). It is assumed that the Late Woodland Hamilton complex was not much different, except for some increase in the intensity of plant cultivation. Hunting of small and large game was still important as was the collection of wild flora (Crites 1978b; Faulkner 1977; and Faulkner et al. 1976). However, there is evidence for incipient cultivation of sunflower, squash, and maize (Crites 1978b). These cultigens probably made up only a small percentage of the diet.

Excavations of Hiwassee Island began in April 1937 and ended in March 1939. It was excavated through federal aid from the Work Projects Administration. Sponsorship and direction of the work was by The University of Tennessee, Department of Anthropology.

The site is located in Meigs County, Tennessee, seven miles south of the town of Dayton. It lies near the left bank of the Tennessee River at its confluence with the Hiwassee. The following description is extracted from Lewis and Kneberg (1946).

The sizeable settlements tended to be spread out. It is suggested that each household was a fairly independent unit. The straggling pattern of households suggest little fear of invasion. Each community had a group of households associated with a group of

burial mounds. The mounds indicate social integration of the households.

There is evidence of trade. Certain traits link the Hamilton focus to Copena in northern Alabama and others which suggest affiliations with Adena (for example, conical burial mounds, log tombs, important central graves, sub-floor graves, flexed burials, shell beads as burial accompaniments, disk-shaped shell beads, stone gorgets, stone celts, stemmed projectile points, flint drills, and flint scrapers).

Because the modern techniques of water screening and flotation were not available at the time of excavation, there is no tangible evidence that indicates the use of cultigens in the diet, but Lewis and Kneberg (1946) suggest that agriculture was practiced. No stone agricultural implements were found, but bone or wood could have been used because the soil is soft. The presence of flint projectile points suggests that wild game was actively pursued. There were only fragmented bones of unidentified species recovered. Fresh water mussel were used extensively. Although plant remains were not found, it is suggested to have remained an important part of the diet. In sum, the subsistence indicated from earlier Woodland samples and the evidence found at the Hiwassee site suggest these late Woodland peoples practiced some agriculture, but hunting and gathering of fauna and floral species remained the primary mode of subsistence.

Burials were found in mounds which usually began with a single body placed on a prepared spot and covered with soil. Mounds increased by additional burial until a height of 10-12 feet was reached.

Burial position tended to be tightly flexed. A total of 173 burials were recovered. Lewis and Kneberg (1946) suggest that the infant mortality rate was low in comparison with later cultures, because few infant burials were recovered.

The Mississippian Sample

The Mississippian sample is also represented by one site, Toqua (40MR6), located in the Tellico Reservoir in east Tennessee. The site dates to the Late Mississippian Dallas focus, ca. A.D. 1300 until A.D. 1550 (Schroedl and Polhemus 1977).

Mississippian sites are characterized by maize horticulture and sedentary villages (Lewis and Kneberg 1946). Settlements were most often located within the valley of a major river (Smith 1978). The most common sites from this time period were villages with palisades for fortification and large truncated mounds placed near a central plaza (Jennings 1968; Goldstein 1976). Hunting was still practiced as indicated by faunal remains of deer, woodchuck, raccoon, rodents, turkey, frog, opossum, fish, and migratory waterfowl (Smith 1978; Ferguson 1972). But fewer remains of deer were found than of smaller animals (Ferguson 1972). Maize, beans, and squash were the primary cultigens and sunflower, marsh elder, and gourd were secondary (Smith 1978; Ferguson 1972). However, Kline and Crites (1979:96) in their analysis of the Ducks Nest Site (40WR4), suggest that not all Mississippian systems "represent agricultural farmsteads." The collection of wild foods continued to be of some importance.

The infant mortality rate was extremely high according to Lewis and Kneberg (1946), who attributed the high death rate among later Mississippian peoples to the introduction of European diseases.

The Toqua site was located about 4.5 miles west of Vonore, Tennessee on the south bank of the Little Tennessee River. Excavations began in 1975 and continued until late 1977. Work was done by The University of Tennessee, Department of Anthropology. The site is now completely inundated by the Tellico Reservoir.

Toqua is one of some 20 late Mississippian Dallas sites from the Great Valley of Eastern Tennessee. It is unique, however, in that it contains the largest skeletal sample from this time period known. There were 477 burials recovered. About 500 individuals are represented.

Bogan (1980) found that white-tailed deer was the primary source of animal protein followed by bear and turkey. However, Parham and Scott (1980) suggest that animal protein was deficient in the diet, which primarily consisted of maize.

In studying this material, Parham (1982) found high frequencies of cribra orbitalia and calvarial porotic hyperostosis. Parham surmised that the high levels were due to iron deficiencies caused by reliance on maize agriculture. In addition, Parham reports an extremely high infant and childhood mortality rate. Also, younger individuals were reported to have significantly higher periosteal lesions than older individuals, probably due to acute infectious diseases in early life.

Evaluation of Stress in the Three Time Periods

Rose (1973) evaluated physiological stress in three archaeological populations by describing population size and resource availability. Stress will be evaluated for each of the three time periods used in this research in the same manner.

Archaic. In the Archaic, a large variety of foods were utilized. Both animal and vegetable protein sources were available. The wide variety of foods supplied essential nutrients to the diet. As mentioned earlier, the populations were small and probably insufficient to maintain most infectious diseases on an endemic level (Cockburn 1967). Crites (1978a) suggests that population pressure in the Terminal Archaic provided the incentive for change to a more agriculturally based economy. However, Crites also notes that the subsistence strategy in the Late and Terminal Archaic was a continuation of an adaptive strategy established as early as 5000 B.C. Nevertheless, the size of the population was smaller than later groups and therefore less likely to cause environmental pressures on food sources or to produce sanitary problems. Therefore, a limited exposure to pathogens is hypothesized. For a thorough discussion of population demography and archaeology, see Hassan (1978).

Woodland. With the Woodland Period came a population increase. The diet, although still including many of the kinds of food the Archaic peoples consumed, also began to include the domesticate, maize. In addition, smaller species of animals were being exploited than in the earlier period. This was possibly due to pressures on

the larger game (e.g. deer) caused by a growing Woodland population. A general decrease in protein is indicated. The large population size allowed for the spread of disease caused by an increase in waste which served to foster the disease process.

Mississippian. Population size continued to grow.

Palisaded villages indicate increased warfare. An increase in population means an increase in disease. These people depended heavily on maize agriculture. The largely carbohydrate diet was deficient in several important amino acids. Protein was no longer as available as in the past because game was scarce. There was a decrease in projectile points and scrapers with an increase in agricultural implements. The decline in animal protein came at a time when disease rates were high. Low animal protein consumption could have increased the incidence of diarrhea in infants. It is not surprising that a high childhood mortality rate is found. As population size increases so does human waste. Again this provided a mechanism for the spread of disease.

CHAPTER IV

METHODS

Samples and Variables

Sample sizes differed for each of the purported stress variables because each variable necessitated different criteria as to which individuals could be included in an analysis. First, the teeth were measured. Any tooth that had excessive amounts of preservative, dirt, or calculus adhering to the enamel surface that could not be removed without damaging the tooth was excluded. Mesio-distal dimensions were not used due to the effect that interstitial wear has in altering this dimension (see Wolpoff 1971).

Measurements were taken with Helios-dial calipers and recorded to the nearest tenth of a millimeter. Measurements were made according to the following procedures outlined by Guagliardo (1980: 15):

. . . for measuring incisors and canines, the measuring arms of the caliper are held parallel to the vertical axis of the tooth in the mesiodistal and labiolingual planes. The measurement was the maximum reading found by moving the caliper in the mesiodistal dimension.

For premolars and molars, the measuring arms of the calipers were held in or near the occlusal plane and perpendicular to a line bisecting the angle formed by the mesial and distal surface. The arms were held perpendicular to the distal surfaces if those surfaces were parallel to each other. The maximum reading was recorded.

Furthermore, the measurements obtained using this method are easily duplicated. In order to examine asymmetry, correlation

coefficients (SAS Proc Corr) were computed for all antimeric pairs of teeth.

The final sample sizes for each tooth are given in Table II for the Archaic, Woodland, and Mississippian, respectively. These samples will be used to compare young and old individuals for tooth size and fluctuating asymmetry differences within each time period. These are also the samples used to compare fluctuating asymmetry scores between each of the three archaeological periods.

The following procedures were used in the collection of pathological Striae of Retzius and hypoplasia data. The left permanent mandibular canine was removed from each individual if at least half of its enamel apex was present. If the left side was absent or damaged the right side was removed.

The canines were cast to preserve their morphological information for future research. They were then embedded in Ward's Bioplastic. A thin-section of 125-150 microns was made using a Buehler isomet low speed saw according to the methods of Jablonski (1981). Each section was numbered so that in the analysis, the origin of the tooth remained unknown. Sections were then analyzed for the presence of pathological bands and hypoplasia on an Olympus microscope in the following way. First, under low power the height of each thin-sectioned crown was divided into eight equal intervals, each of which approximates one half year of enamel development. Half year intervals were determined with the aid of a micrometer fitted into the eyepiece of the microscope. Age intervals ranged from about .3 years to crown completion at 4.5 years. These approximate ages are based

TABLE II (Continued)

Site	Mandible							Maxilla								
	I1	I2	C	P1	P2	M1	M2	M3	I1	I2	C	P1	P2	M1	M2	M3
Archaic (continued)																
9BN6																
Male	6	6	5	6	7	4	7	7	4	4	6	5	6	4	6	5
Female	5	5	6	5	3	1	5	4	5	4	5	5	5	3	4	3
Indet.																
Subadult	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
84BN74																
Male	3	3	3	2	2	1	1		3	4	3	2	2			1
Female	2	2	2	1							1					
Indet.																
Subadult																
Woodland																
42MG31 and																
46MG31																
Male	11	12	18	21	21	22	19	15	16	17	18	13	12	12	14	12
Female	8	7	12	13	12	9	11	11	7	10	11	11	11	10	11	7
Indet.	4	7	8	8	8	8	7	5	6	8	8	6	6	8	7	7
Subadult	18	22	20	15	16	26	20	7	22	22	18	21	16	27	19	6
Mississippian																
40MR6																
Male	17	16	22	19	17	14	10	7	12	14	18	16	15	12	15	17
Female	12	16	16	15	15	13	12	10	12	13	13	15	18	18	14	12
Indet.			1													
Subadult	18	17	20	22	20	23	20	11	21	21	18	21	17	21	17	10

on the timing of lower canine development reported by Schour and Massler (1940) for white children. This method of approximating ages is taken from Massler et al. (1941) and followed by other researchers (for example Rose 1973). Intervals were approximated in the sections affected by occlusal wear. The first age interval (.3-1.0 years) was the most affected. This approximation will be discussed in greater detail in Chapter VI. The number of pathological striae and hypoplasias were recorded for each half-year unit.

To be counted as a pathological band the line must run from the dentino-enamel junction to the enamel surface. Further criteria are summarized by Jablonski (1981:31) as follows:

A pathological band has darkly pigmented enamel and rod structure. Although normal rod structure may occur before and after the suspect striae, only abnormal rod structure may occur along the length of a pathological band. Abnormal rod structure appears to be very erratic and randomly oriented nonlinear rod outlines associated with a change in rod direction. Furthermore, under X400 magnification the prisms of the disturbed band must bend into or out of the plane of section giving the appearance of ridges or troughs. The same features of pathological striae should be observed in the contralateral enamel of the dental section.

Hypoplasias were defined using Gustafson's (1959) criteria for microscopic analysis of these defects. A hypoplasia is described as a deficiency of enamel exhibiting compressed Striae of Retzius and structureless enamel along the surface.

The sample sizes obtained for these two stress measures are found in Table III. These samples were used for both between and within-archaeological period comparisons.

TABLE III
SAMPLE SIZES FOR DISTURBED BANDS AND HYPOPLASIAS

Time Period (Site)	Male	Female	Indet.	Subadult	Total
Archaic					
13BN17		2			
15HY13	3	4			
1DR1	1				
25HY18	2	1			
6BN12	2	4	1	10	
9BN6	5	4	1	1	
84BN74	4				
Total	17	15	2	11	45
Woodland					
46MG31 and 42MG31	16	8	5	21	50
Mississippian					
40MR6	19	15	2	15	51

Statistics

The following discussion is broken into two parts. First, statistical analyses comparing stress measures between young and old individuals for each of the three time periods (Archiac, Woodland, and Mississippian) are covered. The young group contains those individuals who are less than approximately 17 years of age, while the older group is comprised of individuals aged greater than or equal to 17 years. This was an arbitrary cutoff point which was intended to include skeletally mature individuals in the old group and skeletally immature individuals in the young group. Next the statistical analyses comparing physiological stress between the Archaic, Woodland, and Mississippian time periods are explained.

The first statistical tests compare the bucco-lingual diameters of permanent teeth of the young group and the old group for each time period. Heterogeneity of variances between age-at-death groups was tested for each tooth, and when appropriate, t-tests were computed using SPSS T-test procedure (Nie et al. 1975). Tests were only made if the sample sizes for both groups exceeded seven. Seven is an arbitrary cutoff point for minimum sample size. Two alpha-levels of significance were used. The first was 0.05, and the second was computed by dividing 0.05 by the number of tests conducted for each archaeological period. The establishment of this second alpha level, referred to as Bonferonni's correction (Neter and Wasserman 1974) is a conservative measure that should be used when a number of tests using different variables are made using the same samples. This approach reduces the chance of obtaining significant results by

chance alone. The Bonferonni procedure may be excessively conservative here because each individual test (per tooth) does not necessarily involve all of the individuals that the other tests use. Therefore, both alpha-levels are reported for this and all further tests when applicable. Emphasis will be given to the Bonferonni results during the interpretative phase of this study.

It is expected that, for each time period, younger individuals will have larger variances and have smaller teeth than the older individuals. It is also predicted that the latest, and presumably most stressed time period, the Mississippian, will show these differences for a greater number of teeth than in either the Woodland or Archaic. The Archaic group is expected to show some differences between tooth sizes of young and old individuals but this pattern will not be as strong as in the Mississippian. The Woodland pattern is expected to fall somewhere in between the Archaic and Mississippian as far as frequency of significant differences is concerned.

In order to test for significant differences between young and old individuals for each time period, the correlation coefficients were converted to Z scores by Fisher's Z-transformation and a Z test was then done (Hays 1973). Young individuals are expected to show more mean asymmetry with greater asymmetry variances due to increased stress than older individuals. Again, as with tooth size this pattern is expected to be clearer for the later, more stressed group, the Mississippian. This pattern is expected to be least apparent for the Archaic, with the Woodland sample falling somewhere in between.

Statistical tests of variance and mean differences were also performed between young and old individuals for the frequency of pathological Striae of Retzius. Hypoplasia frequencies were also compared, for each time period, between young and old individuals, by using both F-tests for variance and a t-test for means.

Between-time period comparisons using combined age group samples were made for asymmetry, pathological bands, and hypoplasias. Asymmetry was contrasted over time periods by using Fisher's Z test. Each tooth was analyzed separately for asymmetry. It is expected that the Mississippian time period will show more asymmetry followed by the Woodland, with the Archaic group showing the least.

Analysis of variance (SAS; Barr et al. 1979) was used in order to compare the number of pathological bands between the time periods. The statistical model used time period, sex, age, and their interactions as independent variables with the total number of disturbed bands as the dependent variable. Terms were subsequently dropped from the model if this was deemed appropriate based on lack of significance for that term's F value.

In order to discern similarities or differences between the time periods for the distribution of disturbed bands over age of band formation graphs for each time period were plotted with age on one axis and number of bands on the other. The more stressed group, the Mississippian, is expected to show earlier formation of disturbed bands as well as more frequent formation later in life than in the other two groups. The Archaic should show a peak at a later age than the Woodland.

The occurrence of hypoplasias on the canine was also compared between the three time periods using analysis of variance. The independent variables included age, sex, time period, and their interactions. The dependent variable was the total number of hypoplasias. As before, terms were dropped out of the model when indicated and the analysis was re-run until all terms remaining in the model were significant. Graphs were also plotted for each of the three time periods. The plots show the number of hypoplasias versus age of occurrence. This depicts similarities and differences between time periods for the age distribution of hypoplasias.

As with pathological striae, the frequency of hypoplasias is hypothesized to be greater in the Mississippian group than the Archaic. The number of hypoplasias in the Woodland group is expected to fall somewhere in between the two. In addition, the Mississippian group should show hypoplastic defects at an earlier age and persisting longer than in the Archaic group. The Woodland group is expected to show frequencies at a level between the Mississippian and Archaic.

CHAPTER V

RESULTS

First, the results from the young and old comparisons within each archaeological grouping will be reported. This is followed by the results from the tests directly comparing the three groups for amounts of physiological stress.

Comparisons between Age Groups

The results for tooth size analyses comparing young individuals can be found in Tables IV, V, and VI for the Archaic, Woodland, and Mississippian time periods, respectively. In the Archaic group, significant differences ($\alpha = .05$) were found in the variances between young and old individuals for two teeth: the upper first incisor and upper second incisor. The variance difference for the two teeth was in opposite directions. The variance of the upper first incisor for the younger group was greater than for the older group as was predicted. The older group, however, showed greater variance for the second upper incisor. Using Bonferonni bounds ($\alpha = .005$) only the upper first incisor showed significant differences in the variances of young and old individuals. As noted above, the young group had a greater variance for this tooth than the older group. Eight t-tests were computed with no statistical differences noted in tooth size ($\alpha = .05$; see Table IV).

For the Woodland sample, a comparison between young and old groups for tooth size shows statistically significant differences in

TABLE IV
RESULTS FROM TOOTH SIZE COMPARISONS BETWEEN YOUNG AND OLD
INDIVIDUALS FOR THE ARCHAIC SAMPLE

Variable (Group)	N	Mean Tooth Size	S.D.	F.	.05	.05/K	T	.05	.05/K
L11 Old	9	58.722	2.938	1.29			0.40		
Young	34	58.265	3.340						
LC Old	8	76.375	4.042	1.92			0.69		
Young	52	77.500	5.599						
LP1 Old	8	81.563	5.609	1.19			0.45		
Young	37	82.527	5.145						
LP2 Old	8	86.438	5.447	1.48			0.81		
Young	33	84.758	4.481						
LM1 Old	8	109.375	5.896	1.08			1.28		
Young	22	112.568	6.119						
U11 Old	30	71.900	5.184	4.47	*	*	1.88		
Young	8	66.875	10.957						
U12 Old	29	64.931	5.735	5.45	*		0.96		
Young	8	66.938	2.456						
UC Old	35	84.171	6.461	1.22			0.17		
Young	8	83.750	5.843						
UP1 Old	31	97.226	4.586	1.30			0.72		
Young	8	98.500	4.018						
UM1 Old	22	118.591	6.615	4.09			1.04		
Young	9	116.167	3.269						

TABLE VI

RESULTS FROM TOOTH SIZE COMPARISON BETWEEN YOUNG AND OLD
INDIVIDUALS FOR THE MISSISSIPPIAN SAMPLE

Variable (Group)	N	Mean Tooth Size	S.D.	F.	Sig.		T	Sig.	
					.05	.05/K		.05	.05/K
L11 Old	13	56.115	4.058	1.57			0.36		
Young	34	56.632	5.083						
L12 Old	13	59.423	4.300	1.05			1.06		
Young	36	60.903	4.411						
LC Old	15	77.133	5.146	1.16			0.19		
Young	44	76.841	4.774						
LP1 Old	16	81.500	5.526	1.10			0.21		
Young	40	81.150	5.260						
LP2 Old	16	87.937	8.290	2.39	*		1.03		
Young	36	85.611	5.357						
LM1 Old	18	108.278	6.512	2.09			0.68		
Young	32	107.110	4.506						
LM2 Old	13	106.770	7.328	1.72			1.37		
Young	29	103.638	5.593						
U11 Old	30	71.017	4.517	1.26	*		1.00		
Young	15	69.533	5.080						
U12 Old	32	63.984	5.044	2.57	*		0.60		
Young	16	63.156	3.145						
UC Old	37	84.041	5.662	1.34			1.02		
Young	12	86.042	6.566						
UP1 Old	35	96.386	5.321	1.23			1.53		
Young	17	98.882	5.902						
UP2 Old	36	96.431	4.403	3.53	*	*	1.92		
Young	14	99.893	8.275						
UM1 Old	35	116.671	6.056	1.18			1.67		
Young	16	119.656	5.582						
UM2 Old	33	114.409	6.649	1.52			1.38		
Young	13	117.615	8.191						

the variance of seven teeth and no statistical differences in mean tooth size (see Table V). For all five teeth (upper first incisor, upper second incisor, upper second premolar, upper first molar, and upper second molar) the younger group had a significantly ($\alpha = .05$) greater variance than the older group for these teeth. When Bonferonni bounds are applied to the F-tests only two teeth show statistically significant differences in their variance ($\alpha = .0036$) between young and old. These teeth are the upper first molar and upper second molar. Both these teeth show that the younger group has a larger variance, which is in the direction predicted.

The Mississippian sample shows statistically significant differences ($\alpha = .05$) in the variances between young and old individuals for two teeth (Table VI). The upper second premolar shows this difference in the predicted direction, with the younger individuals having more variation. This relationship also holds when Bonferonni bounds are applied ($\alpha = .0036$). The tooth, the upper second incisor, shows that older individuals have more variation in the bucco-lingual dimension. This relationship does not hold when the more conservative alpha level is applied.

One t-test was significant for the Mississippian group. The means between the young and old individuals in tooth size for the upper, first molar are significantly different ($\alpha = .05$). The younger group has a larger mean tooth size than does the older group. Applying Bonferonni bounds, the difference is found not to be statistically significant ($\alpha = .0036$).

The comparisons for young and old individuals from the Archaic for fluctuating asymmetry are given in Table VII. Five teeth show statistically significant differences in asymmetry ($\alpha = .05$). Four of these are in the predicted direction with the young group having greater asymmetry between teeth. These teeth are the mandibular canine, and in the maxilla, the second incisor, canine, and first premolar. One tooth, the upper second premolar showed that the older group had a greater amount of asymmetry for these teeth.

Using the more conservative alpha level of .0035, one tooth remains statistically significant different for fluctuating asymmetry. The older group shows statistically more asymmetry in the upper second premolar.

The tests comparing asymmetry between young and old groups in the Woodland period are found in Table VIII. Four teeth show statistically significant differences ($\alpha = .05$). Of these two are in the predicted direction with the young having more dental asymmetry. These teeth are the lower canine and the upper first incisor. The lower second premolar and the upper second molar show that the older group had more dental asymmetry. After applying a stricter alpha level, statistically significant differences remain in only two teeth. Both teeth show that the younger group had more dental asymmetry. These teeth are the lower canine and the upper first incisor.

TABLE VII
RESULTS FROM YOUNG AND OLD ASYMMETRY SCORE COMPARISONS FOR THE ARCHAIC

Variable (Group)	N	Correlation Coefficient	Z Transform	Variance	Z Ratio*	Sig.	
						.05	.0035
L11 Young	12	0.58944	0.67687	0.19444	-1.16170		
Old	15	0.83029	1.18907				
L12 Young	13	0.83627	1.20864	0.1901	0.17044		
Old	14	0.81244	1.13417				
LC Young	12	0.95036	1.83546	0.16667	2.04175	*	
Old	21	0.76241	1.00195				
LP3 Young	14	0.73587	0.94141	0.14973	-0.06173		
Old	20	0.74663	0.96530				
LP4 Young	13	0.67403	0.81809	0.17143	-1.22242		
Old	17	0.86783	1.32422				
LM1 Young	10	0.89516	1.44731	0.25397	0.26409		
Old	12	0.86534	1.31422				
LM2 Young	15	0.84892	1.25227	0.16026	-0.67097		
Old	16	0.90885	1.52087				
U11 Young	13	0.84935	1.25382	0.22500	0.41784		
Old	11	0.78398	1.05562				
U12 Young	9	0.96166	1.96166	0.29167	2.11213	*	
Old	11	0.67878	0.82685				
UC Young	13	0.97016	2.09501	0.17692	1.68935	*	
Old	16	0.88194	1.38443				
UP1 Young	15	0.94393	1.77293	0.15476	2.59580	*	
Old	17	0.63554	0.75066				
UP2 Young	15	0.33920	0.35319	0.15476	4.13816	*	*
Old	17	0.96267	1.98113				
UM1 Young	14	0.90595	1.50445	0.23377	0.48498		
Old	10	0.85379	1.26997				
UM2 Young	12	0.95340	1.86786	0.18803	0.71187		
Old	16	0.91529	1.55920				

*Z Ratio = S.D.(Young) - S.D.(Old).

TABLE VIII
RESULTS FROM YOUNG AND OLD ASYMMETRY SCORE COMPARISONS FOR THE WOODLAND

Variable (Group)	N	Correlation Coefficient	Z Transform	Variance	Z Ratio*	Sig.	
						.05	.0035
L11 Young	9	0.94432	1.77652	0.41677	-0.00373		
Old	7	0.94458	1.77893				
L12 Young	14	0.96711	2.04558	0.25758	1.20157		
Old	9	0.89284	1.43576				
LC Young	17	0.98508	2.44536	0.13810	3.14647	*	*
Old	18	0.85544	1.27609				
LP3 Young	10	0.97181	2.12387	0.18452	0.40265		
Old	27	0.96039	1.95091				
LP4 Young	10	0.09177	0.90203	0.20168	-2.47437	*	
Old	20	0.83464	1.20324				
LM1 Young	18	0.42993	0.45981	0.11212	-1.95855		
Old	25	0.80604	1.11562				
LM2 Young	13	0.68627	0.84087	0.16667	0.97149		
Old	18	0.41717	0.44426				
U11 Young	14	0.93516	1.69801	0.16234	2.77870	*	*
Old	17	0.52153	0.57844				
U12 Young	14	0.85571	1.27710	0.15758	-0.35880		
Old	18	0.88950	1.41953				
UC Young	11	0.80481	1.11212	0.17763	-1.25381		
Old	22	0.92755	1.64055				
UP1 Young	11	0.83993	1.22094	0.20833	0.30735		
Old	15	0.79344	1.08065				
UP2 Young	9	0.93479	1.69507	0.27778	0.51102		
Old	12	0.89079	1.42574				
UM1 Young	17	0.76431	1.00650	0.13393	1.14930		
Old	19	0.52694	0.58590				
UM2 Young	13	0.36957	0.38792	0.38792	-2.57395	*	
Old	20	0.88828	1.41370				

*Z Ratio = S.D.(Young) - S.D.(Old).

A total of three teeth show statistically significant differences in fluctuating dental asymmetry between the young and old groups during the Mississippian (see Table IX). Of these, the following two teeth show that the younger group has more asymmetry: the lower first premolar and the lower second molar. One tooth, the upper first incisor, shows statistically significant differences with the older group displaying more asymmetry. After applying a stricter alpha level only one tooth shows statistically significant differences, the upper second incisor. This was in the opposite direction with the older group showing more asymmetry than the younger group.

Tests for differences in the number of pathological bands between the young and old groups for the Archaic, Woodland, and Mississippian samples can be found in Table X. Although the Archaic samples may not meet sample size requirements of many statisticians (the young group totals six individuals) it is reported here for the sake of completeness. Not one of the F-tests for variance or t-tests for mean differences were significant for any of the three samples.

The tests for differences in the number of hypoplasias between young and old individuals for all time periods are reported in Table XI. The Archaic sample fails to meet minimum sample requirements. The Woodland group shows that the older individuals have a greater variance than the

TABLE IX
RESULTS FROM YOUNG AND OLD ASYMMETRY SCORE COMPARISONS FOR THE MISSISSIPPIAN

Variable (Group)	N	Correlation Coefficient	Z Transform	Variance	Z Ratio*	Sig.	
						.05	.0035
L11 Young Old	14	0.77712	1.03806	0.174242	0.94909		
	15	0.89253	1.43423				
L12 Young Old	13	0.84857	1.25102	0.16250	0.23664		
	19	0.81961	1.15563				
LC Young Old	14	0.95338	1.86764	0.15341	-0.04042		
	19	0.95480	1.88347				
LP3 Young Old	15	0.96967	2.08674	0.13333	2.46866	*	
	23	0.82912	1.18531				
LP4 Young Old	13	0.60152	0.69553	0.18333	-1.32203		
	15	0.85150	1.26158				
LM1 Young Old	13	0.75720	0.98962	0.19091	0.50885		
	14	0.64535	0.76729				
LM2 Young Old	13	0.93718	1.71436	0.19091	2.29580	*	
	14	0.61146	0.71125				
U11 Young Old	13	0.95669	1.90531	0.17143	0.08833		
	17	0.95348	1.86874				
U12 Young Old	15	0.24534	0.25045	0.15000	-2.72492	*	*
	18	0.86321	1.30580				
UC Young Old	11	0.96107	1.95974	0.19643	0.26062		
	17	0.95120	1.84423				
UP1 Young Old	14	0.82763	1.18057	0.15341	-1.18267		
	19	0.92800	1.64379				
UP2 Young Old	9	0.96217	1.97435	0.23333	0.95825		
	18	0.90720	1.51147				
UM1 Young Old	18	0.95649	1.90296	0.15758	1.32024		
	14	0.88070	1.37888				
UM2 Young Old	11	0.93855	1.72574	0.20833	1.28507		
	15	0.81414	1.13919				

*Z Ratio = S.D.(Young) - S.D.(Old).

TABLE X
RESULTS FROM THE YOUNG AND OLD COMPARISONS OF PATHOLOGICAL
BANDS FOR ALL SAMPLES

Time Period (Group)	N	Mean Band Number	S.D.	F	Sig. .05	T	Sig. .05
Archaic							
Old	39	1.97	1.99	1.58		0.40	
Young	6	2.33	2.50				
Woodland							
Old	31	2.26	2.42	1.99		0.83	
Young	19	2.79	1.72				
Mississippian							
Old	39	3.03	2.17	1.10		0.55	
Young	12	3.42	2.07				

TABLE XI

RESULTS FROM THE COMPARISONS BETWEEN YOUNG AND OLD GROUPS
FOR HYPOPLASIAS FOR ALL SAMPLES

Time Period (Group)	N	Mean No. of Hypoplasias	S.D.	F	Sig. .05	T	Sig. .05
Archaic							
Old	39	1.41	1.71	4.40		0.11	
Young	6	1.33	.82				
Woodland							
Old	31	1.06	1.46	2.33	*	1.15	
Young	19	.63	.96				
Mississippian							
Old	39	.46	.79	2.33	*	1.81	
Young	12	1.00	1.21				

younger individuals. This is not in the predicted direction. The younger group in the Mississippian sample displays a significantly greater variance in hypoplasia number.

Comparisons between Time Periods

The results of the tests for differences in asymmetry scores between the three time periods are given in Tables XII-XIV. Seven teeth showed statistically significant differences ($\alpha = .05$) in asymmetry between the Archaic and Woodland groups (Table XII). Three of these showed that the Archaic had more fluctuating asymmetry (in the mandible these are the second premolar and the first molar and in the maxilla the second molar. Four other teeth showed that the Woodland had greater asymmetry values. These are the lower second incisor and canine, the upper first incisor, and first premolar. After applying a stricter alpha level, three teeth remained significant. Two, the lower first premolar and upper second molar, showed that the Archaic had more asymmetry than did the Woodland. The lower canine, however, showed that the opposite is true.

The comparisons from the Archaic and Mississippian time periods (Table XIII) show significant differences in four teeth. The lower canine, lower first premolar, upper first incisor, and upper second premolar show statistically significant differences in asymmetry with the Mississippian having higher asymmetry scores than the Archaic. However, after applying

TABLE XII
COMPARISON BETWEEN ARCHAIC AND WOODLAND FOR ASYMMETRY SCORES

Variable (Group)	N	Correlation Coefficient	Z Transform	Variance	Z Ratio*	Sig.	
						.05	.0035
L11 Archaic	27	0.72565	0.91948	0.11859	-0.48496		
Woodland	16	0.79559	1.08648				
L12 Archaic	29	0.79694	1.09017	0.08846	-2.51390	*	
Woodland	23	0.95059	1.83787				
LC Archaic	33	0.85296	1.26692	0.06458	-3.91360	*	*
Woodland	35	0.97852	2.26149				
LP3 Archaic	34	0.74500	0.96162	0.06167	-1.31930		
Woodland	37	0.85893	1.28925				
LP4 Archaic	30	0.81207	1.13308	0.07407	2.25312	*	
Woodland	30	0.47759	0.51986				
LM1 Archaic	22	0.87959	1.37395	0.07763	3.01216	*	*
Woodland	43	0.48896	0.53469				
LM2 Archaic	31	0.88477	1.39732	0.07143	0.86464		
Woodland	31	0.82306	1.16623				
LM3 Archaic	19	0.83862	1.21650	0.11513	1.11112		
Woodland	22	0.68553	0.83947				
U11 Archaic	24	0.80594	1.11533	0.08333	-2.09886	*	
Woodland	31	0.93801	1.72122				
U12 Archaic	20	0.81238	1.13399	0.09331	-0.56995		
Woodland	32	0.86379	1.30808				
UC Archaic	29	0.90695	1.51006	0.07179	1.45209		
Woodland	33	0.80791	1.12098				
UP1 Archaic	32	0.75105	0.97536	0.07796	-1.72850	*	
Woodland	26	0.89726	1.45798				
UP2 Archaic	32	0.66919	0.80927	0.09004	-1.55672		
Woodland	21	0.85552	1.27639				
UM1 Archaic	24	0.88230	1.38606	0.07792	1.54801		
Woodland	36	0.74156	0.95394				
UM2 Archaic	28	0.92351	1.61237	0.07333	4.54819	*	*
Woodland	33	0.36333	0.38072				
UM3 Archaic	18	0.80769	1.12035	0.15758	-0.29943		
	14	0.84523	1.23921				

*Z Ratio = S.D.(Archaic) - S.D.(Woodland).

TABLE XIII
COMPARISON BETWEEN ARCHAIC AND MISSISSIPPIAN FOR ASYMMETRY SCORES

Variable (Group)	N	Correlation Coefficient	Z Transform	Variance	Z Ratio*	Sig.	
						.05	.0035
L11 Archaic	27	0.72565	0.91948	0.08013	-1.25850		
Mississippian	29	0.85534	1.27572				
L12 Archaic	29	0.79694	1.09017	0.07294	-0.48229		
Mississippian	32	0.83978	1.22043				
LC Archaic	33	0.85296	1.26692	0.06667	-2.35271	*	
Mississippian	33	0.95399	1.87438				
LP1 Archaic	34	0.74500	0.96162	0.06083	-2.03131	*	
Mississippian	38	0.89816	1.46262				
LP2 Archaic	30	0.81207	1.13308	0.07704	1.21224		
Mississippian	28	0.66214	0.79661				
LM1 Archaic	22	0.87959	1.37395	0.09430	1.53382		
Mississippian	27	0.71773	0.90295				
LM2 Archaic	31	0.88477	1.39732	0.07738	1.21180		
Mississippian	27	0.78574	1.06020				
LM3 Archaic	19	0.83862	1.21650	0.13393	1.15730		
Mississippian	17	0.66010	0.79299				
U11 Archaic	24	0.80594	1.11533	0.08466	-2.30967	*	
Mississippian	30	0.94548	1.78735				
U12 Archaic	20	0.81238	1.13399	0.09216	1.36036		
Mississippian	33	0.61754	0.72102				
UC Archaic	29	0.90695	1.51006	0.07846	-1.36528		
Mississippian	28	0.95559	1.89249				
UP1 Archaic	32	0.75105	0.97536	0.06782	-1.59623		
Mississippian	33	0.88340	1.39104				
UP2 Archaic	32	0.66919	0.80927	0.07615	-2.94558	*	*
Mississippian	27	0.92493	1.62211				
UM1 Archaic	24	0.88230	1.38606	0.08210	-0.92504		
Mississippian	32	0.92901	1.65111				
UM2 Archaic	28	0.92351	1.61237	0.08348	0.98156		
Mississippian	26	0.86895	1.32886				
UM3 Archaic	18	0.80769	1.12035	0.12917	1.20585		
Mississippian	19	0.59603	0.68697				

*Z Ratio = S.D.(Archaic) - S.D.(Mississippian).

TABLE XIV
COMPARISON BETWEEN WOODLAND AND MISSISSIPPIAN FOR ASYMMETRY SCORES

Variable (Group)	N	Correlation Coefficient	Z Transform	Variance	Z Ratio*	Sig.	
						.05	.0035
L11 Woodland	16	0.79559	1.08648	0.11538	-0.55710		
	29	0.85534	1.27572				
L12 Woodland	23	0.95059	1.83787	0.08448	2.12428		
	32	0.83978	1.22043				
LC Woodland	35	0.97852	2.26149	0.06458	1.54934		
	33	0.95339	1.87438				
LP1 Woodland	37	0.85893	1.28925	0.05798	-0.71998		
	38	0.89816	1.46262				
LP2 Woodland	30	0.47759	0.51986	0.07704	-0.99712		
	28	0.66214	0.79661				
LM1 Woodland	43	0.48896	0.53469	0.06667	-1.42624		
	27	0.71773	0.90295				
LM2 Woodland	31	0.82306	1.16623	0.07738	0.38117		
	27	0.78574	1.06020				
LM3 Woodland	22	0.68553	0.83947	0.12406	0.13197		
	17	0.66010	0.79299				
U11 Woodland	31	0.93801	1.72122	0.07275	-0.24516		
	30	0.94548	1.78735				
U12 Woodland	32	0.86379	1.30808	0.06782	2.25435		*
	33	0.61754	0.72102				
UC Woodland	33	0.80791	1.12098	0.07333	-2.84899	*	*
	28	0.95559	1.89249				
UP1 Woodland	26	0.89726	1.45798	0.07681	0.24153		
	33	0.88340	1.39104				
UP2 Woodland	21	0.85552	1.27639	0.09722	-1.10878		
	27	0.92493	1.62211				
UM1 Woodland	36	0.74156	0.95394	0.06479	-2.73906	*	*
	32	0.92901	1.65111				
UM2 Woodland	33	0.36333	0.38072	0.07681	-3.42105	*	*
	26	0.86897	1.32886				
UM3 Woodland	14	0.84523	1.23921	0.15341	1.40995		
	19	0.59603	0.68697				

*Z Ratio = S.D.(Woodland) - S.D. (Mississippian).

conservative Alpha levels, only the upper second premolar remains significant.

The remaining comparison, between the Woodland and Mississippian groups (Table XIV), shows that five teeth have significantly different amounts of fluctuating asymmetry. Only two, the lower second incisor and the upper second incisor, show that the Woodland had a greater amount of asymmetry. The remaining three teeth show that the Mississippian group had more asymmetry than the Woodland. These teeth are the maxillary canine and first and second molars. These three teeth were also significant after applying a stricter Alpha level.

The analysis of variance tests using pathological striae to test sex, age, and period effects demonstrated that only period had a statistically significant effect. This model is reported in Table XV. The results are in the order predicted by the hypothesis of increasing stress through time with the Archaic group showing the least and the Mississippian sample the most pathological bands with the Woodland group falling between the two. Figure II shows the distribution of bands over age of formation for each archaeological time period. The figure shows no obvious difference in band distribution other than that of overall number. All three graphs show peak band occurrence between 1.5-3.0 years.

The analysis of variance tests of sex, age, and time period effects in hypoplasia frequency show that only time

TABLE XV
ANALYSIS OF VARIANCE USING PATHOLOGICAL BANDS TO TEST
FOR TIME PERIOD EFFECTS

Source	D.F.	Sums of Squares	F-Value	PR > F
Time period	2	29.3699	3.267	.0410
<u>Mean Pathological Bands</u>				
		Archaic	2.0222	
		Woodland	2.4600	
		Mississippian	3.1176	

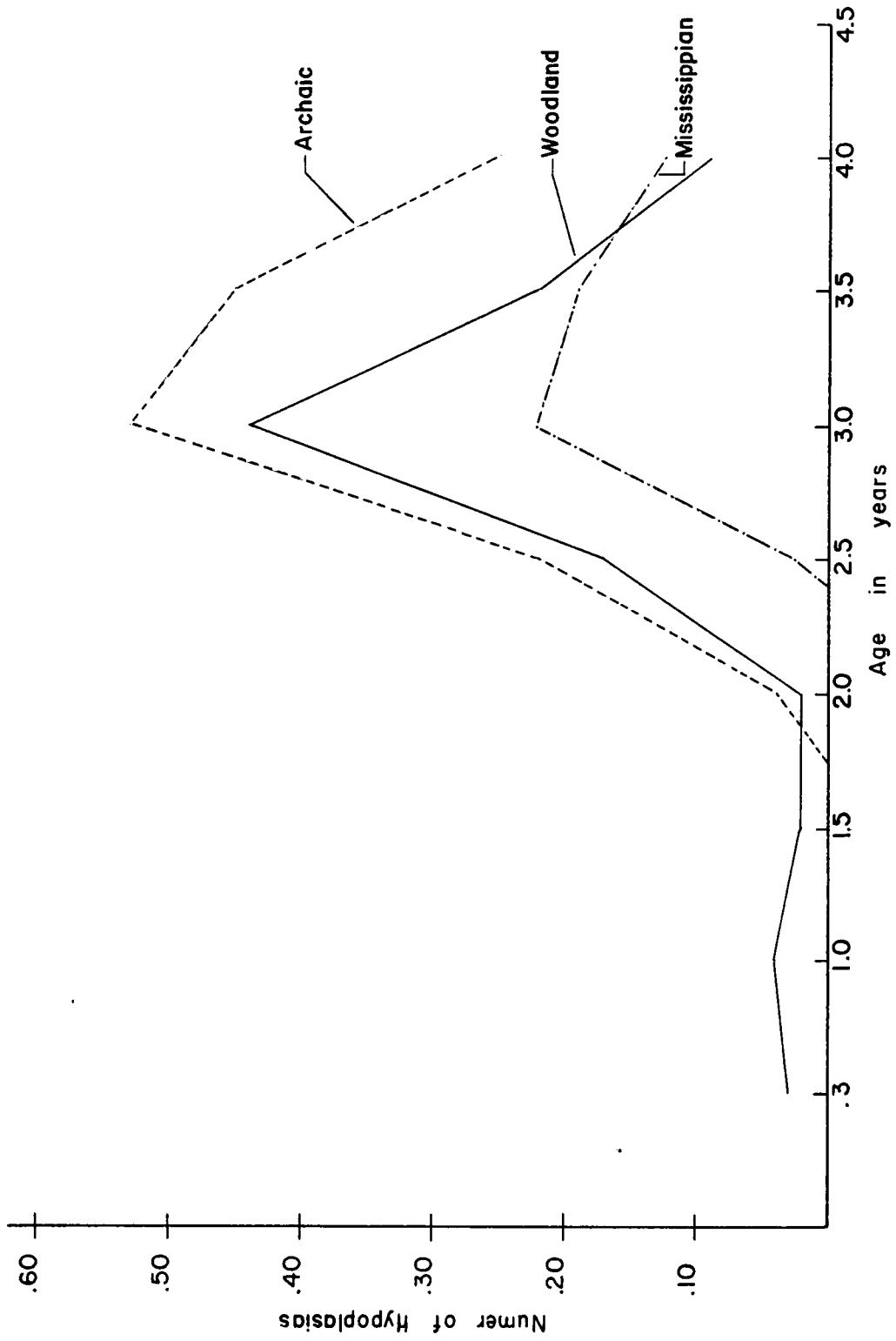


Figure II. Plots of the number of pathological bands and the age of occurrence.

period has a statistically significant effect. The Archaic sample shows the most hypoplasias with the Mississippian showing the least. The Woodland group fell in between. This is in the opposite direction predicted by the hypothesis of increasing stress through time. Table XVI gives these results. The distribution of hypoplasias over age of formation is given for each time period in Figure III. The number of hypoplasias peaks at 3.0-3.5 years for each time period. The only difference suggested is that the Archaic and Woodland show hypoplasias forming at an earlier age than in the Mississippian sample.

TABLE XVI
ANALYSIS OF VARIANCE USING HYPOPLASIAS TO TEST
FOR TIME PERIOD EFFECTS

Source	D.F.	Sums of Squares	F-Value	PR > F
Time period	2	7.9544	4.746	.0101
		<u>Mean Hypoplasias</u>		
		Archaic	1.4000	
		Woodland	.9000	
		Mississippian	.5882	

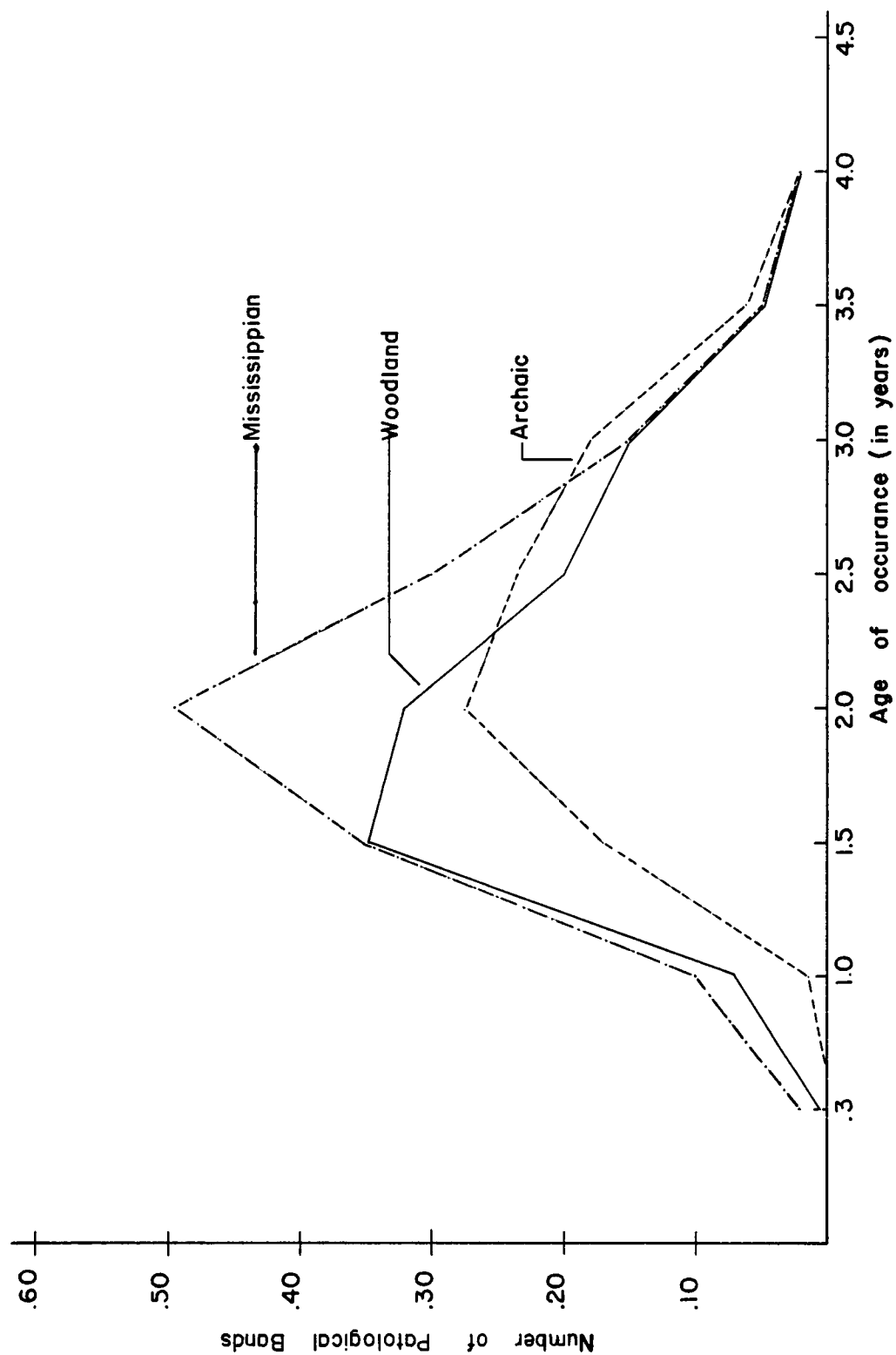


Figure III. Plot of the number of hypoplasias and the age of occurrence.

CHAPTER VI

DISCUSSION

The following discussion is divided into two parts in the same way as the previous chapters. The results from the young-old comparisons within time periods will be discussed first. This is followed by a discussion of the between-time period comparisons. Only the more conservative test results, those from the Bonferonni procedure, will be considered in this discussion.

Comparisons between Age Groups

Crown size. Although none of the t-tests between young and old groups were statistically significant for any time period, a number of F-tests were. The Archiac group only had one tooth which showed statistically significant differences in size variance between young and old individuals. The Woodland had two, and the Mississippian only had one. All of these variances were in the direction predicted, with the younger group showing the most variance.

One possible explanation for the younger groups exhibiting higher variance is that they were composed of two types of children. One type would have suffered stress during fetal development while teeth were in their initial stages of formation. It is during fetal development that the dimensions of teeth are fixed. Therefore, any stress episode suffered in utero could reduce tooth size. These individuals died in childhood for the same reason that their teeth

were smaller--because their natural defenses against childhood diseases and other stressors were weakened by severe stress during fetal development. The second group of subadults would be those who did not suffer stress episodes during fetal development. Their tooth dimensions reached or nearly reached their full genetic potential.

In contrast to the two groups of subadult skeletons, cohorts surviving to adulthood were less likely to have been among those who suffered any debilitating stress. As the theory goes, it is also more likely that the teeth of these survivors all developed so as to approach the genetic norm of the breeding population. Thus the survivors (i.e. adult skeletons) would show less variation in tooth size because there would be less variation in their developmental histories.

This theory is not especially damaged by the fact that different dental elements are involved in the young-old variance inequality for the various archaeological periods. Teeth develop at different times, and it may be that, for sociocultural or ecological reasons, fetuses and children of the various periods may have been exposed to peaks of stress intensity occurring at different times in their lives. Indeed, a major assumption throughout has been that living conditions changed from the Archaic to the Mississippian.

Another possible explanation is that of stabilizing selection. The variance of the young group is suggested to be due to the possibility that both extremes of the tooth size distribution are removed from the surviving population. This would then produce larger variances for the young group and smaller variances for the surviving

older group. In this interpretation, mean tooth size cannot be used to measure differences between groups as large and small teeth are selected out. There is evidence supporting the supposition that certain stressors can cause large teeth, for example maternal diabetes (see Garn et al. 1979). Therefore, the assumption that only individuals with small teeth are stressed may be invalid.

Even though all groups were expected to show some old-young inequalities of size variance, in Chapter III it was predicted that the Archaic sample would exhibit the least number of differences and the Mississippian the most. No support can be found for this expectation because so few teeth were involved in any time period.

Fluctuating dental asymmetry. The results for this variable are difficult to interpret. There seems to be no clear cut pattern of dental asymmetry for any of the young and old comparisons for any archaeological period. The comparisons done here were within one biological population. As noted previously, Guagliardo (1980) suggested that asymmetry should only be studied within one breeding population. These results cast doubts on the meaning of dental asymmetry. It should be noted, however, that sample sizes were small. If larger sample sizes could have been reached the results may have been different. Smith et al. (1980) suggests that very large sample sizes (in the thousands) are needed in order to detect differences in tooth size. These sample sizes were not obtainable for this study and probably would not be for any archaeological study.

Pathological enamel bands. Comparisons of disturbed bands in the tooth enamel revealed no significant differences in variances and no differences in the means between young and old groups for either of the archaeological samples. (The Archaic was not used.) It could be that this measurement is not sensitive enough to the amount of stress the younger group suffered. It may also be that the differences in stress suffered between young and old individuals is not so great that a difference in disturbed bands could be detected. Again the option remains open that the hypothesis is wrong, and that the younger group did not suffer any more stress episodes than the older group did.

Hypoplasias. Here again, only the Woodland and Mississippian samples were analyzed. The Woodland sample showed that older individuals had significantly more hypoplasias than the younger group. The Mississippian sample showed that the younger group had a greater variance than the older group in the predicted direction. The results from the Woodland sample are difficult to interpret. It may be that the criteria used to identify hypoplasias are too vague. This is discussed in the last section. A possibility that can not be dismissed is that the hypothesis that the younger group suffered more stress than their older counterparts is invalid.

Comparisons between Time Periods

Fluctuating dental asymmetry. As in the young-old comparisons, the results for this variable are difficult to interpret.

Again, there is no pattern defined. A conclusion about the hypothesis of increased stress through time cannot be made. The meaning of fluctuating asymmetry is questionable. However, it should be pointed out once again that Smith et al. (1982) suggest that very large sample sizes must be obtained before testing this variable. Such large sample sizes were simply not attainable here, and probably would not be in most archaeological skeletal studies.

Pathological enamel bands. This was the only stress indicator whose results were in the predicted direction with the Archaic having the least, the Mississippian the most, and the Woodland falling between these two. Thus, the hypothesis of increasing stress through time is supported. Although this variable does support the hypothesis, using pathological bands in stress studies is not without its problems. Clinical investigations are needed to evaluate the usefulness of this measure. Clinical studies such as Massler, Schour, and Poncher (1941) have not used adequate statistical procedures or have not reported these procedures.

The plots of disturbed striae over age-at-formation categories for each time period do not show any obvious differences between periods. It can be concluded that stress episodes peaked at about the same age for all three archaeological samples (age 1.5 to 2.0 years). The peak at this time during childhood development may be related to weaning. Rose and Boyd (1978) make a similar conclusion in their comparison of Middle and Late Woodland, and Mississippian tradition samples in the Illinois Valley.

As mentioned earlier, attrition may have affected the estimation of age intervals. It may also have obscured the presence of bands in the first and second age groups (0.3 to 1.0 years and 1.0 to 1.5 years). Although this could have affected the results it is probably not significant. The younger age-at-death group had less attrition but did not have any more bands in this age category than did the older group (see Table XVII). In fact, the older group exhibited significantly more defects in the Archaic sample than the younger group for the age range of 1.0-1.5 years.

Hypoplasias. It was found that the Archaic had the most hypoplasias, the Woodland next, and the Mississippian sample the least. This is exactly opposite from the direction predicted. Three possible reasons for this finding are given. First, hypoplasias may not be adequately defined. Personal experience suggests that researchers vary a great deal in what they do and do not accept as a case of enamel hypoplasia. Condon (1981) supports this view. He suggests that microscopic hypoplasias should be broken down into at least five categories. Theoretically these categories would correspond to different degrees of stress severity. Upon refinement of Condon's techniques, the use of such a system would improve the sensitivity of statistical analyses in detecting stress variables between groups.

The other explanation for the results of the hypoplasia analysis is that the hypothesis of increasing stress through time is wrong. This would be a premature conclusion because of the

TABLE XVII
COMPARISON OF OLD AND YOUNG INDIVIDUALS FOR EACH TIME PERIOD
IN THE FIRST AND SECOND AGE GROUPS FOR
PATHOLOGICAL ENAMEL BANDS

Time Period (Age in Years)	No. of Individuals		F-Value	Sig. .05	T-Value	Sig. .05
	Old	Young				
Archaic						
0.3-1	1	0	0		0	
1-1.5	3	0	0		5	*
Woodland						
0.3-1	1	1	0		0	
1-1.5	4	0	0		0	
Mississippian						
0.3-1	1	1	0		0	
1-1.5	3	2	1.5		0.29	

uncertainty of the definition of what a hypoplasia is, morphologically and historically speaking.

General. The lack of consistency of results among the analyses of the various "stress" indicators could indicate that most or all of them do not measure stress. From the literature review of Chapter II it appears more likely that formation of these dental defects is in part a function of stress, but that each kind of defect is also a function of a different set of other, as yet unknown, factors. For example, pathological Striae of Retzius may result from chronic stress but hypoplasias from acute stress episodes.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The purpose of this research was to measure physiological stress using dental stress indicators in skeletal populations from Tennessee from three time periods, the Archaic, Woodland, and Mississippian. The dental stress indicators used were mean tooth crown size, dental asymmetry, pathological enamel bands, and enamel hypoplasias. Two hypotheses were tested. The first was that younger individuals (aged 16 years or less at death) would show a greater amount of physiological stress than their older, surviving cohorts. One stress indicator supported this hypothesis. It was found that dental crown size varied more in younger individuals than older individuals.

The second hypothesis was that an increase in physiological stress, as measured by the dental stress indicators, increased from the Archaic to the Mississippian. This hypothesis was based on the assumption that as population density increased through time food resources were depleted and malnutrition and disease rates increased. It was found that statistically significant differences in the number of pathological bands exists in the three time periods with Archaic having the least and the Mississippian having the most. It was also found that a statistically significant difference in the number of hypoplasias exists through time. However, the Archaic had the most and the Mississippian had the least. This is in the opposite

direction than that predicted. Dental asymmetry did not support the hypothesis either. However, no discernible pattern could be detected for this variable.

Although this study was not designed to test the validity of the dental stress variables, given the assumption that stress increased through time, some points can still be made about the variables themselves. One is that more clinical evaluation is certainly necessary before the hypothesis of stress changes during the pre-history of Tennessee or anywhere else can be completely tested. This point would be less important if the dental stress indicators had been consistent among themselves in their results.

Fluctuating dental asymmetry is probably the most questionable of the stress indicators. It was included in this research because there have been reports that fluctuating asymmetry is related to periods of physiological stress. These include clinical studies such as Barden (1980a) and skeletal studies such as Guagliardo (1980). However, dental asymmetry data supported neither the supposition that within a group younger individuals will show more asymmetry, nor that levels of asymmetry increase through time. A rejection of either hypothesis is not warranted on the basis of these findings alone, especially in the face of questionable results reported by other researchers. The conclusion here is that the equivocal status of dental asymmetry as a stress indicator is well deserved.

The results from hypoplasia comparisons between time periods certainly do not support the hypothesis. They might suggest that the opposite is true, namely, stress decreases through time. However,

the fact that the young-old comparisons did not show a clear cut patterning may indicate that there are problems in using this stress indicator, also. As previously noted, the relationship between stress and hypoplasias is well documented. However, it is concluded that hypoplasias must be more clearly and consistently defined in clinical as well as skeletal studies. Particular kinds of stress episodes must be more clearly related to particular types of hypoplastic bands. For example, most dentists feel that hypoplasias in general are caused by high fever or similar acute stresses. The kind of stress most associated with increased population pressure and sedentary maize agriculture is chronic malnutrition. Therefore, it remains to be seen if hypoplasias were an acceptable choice to test the hypothesis of increasing "stress" through time.

The method of tooth size comparisons between young and old subsamples seems to be theoretically sound. Unfortunately, the sample sizes employed by Guagliardo (1982) could not be obtained here. Small sample sizes often may lead to spurious conclusions. Nevertheless, there were some interesting results. Significant differences in the variances of certain teeth were found in all three time periods. Each indicated that younger individuals had greater tooth size variation than older individuals, as was predicted. It would be of great interest to subject this indicator to clinical tests beyond those of Garn et al. (1979).

Pathological Striae of Retzius is the most clinically documented and the least controversial of all the dental stress indicators used in this research. It is significant, therefore, that

the analysis of pathological bands does support the hypothesis of increasing stress through time for the prehistoric periods in Tennessee. However, there are as yet no statistically sound clinical studies to support its status as an indicator of physiological stress.

In conclusion, dental stress indicators need to be more clearly defined and tested before being accepted as absolute indicators of stress in skeletal series. Of the dental stress indicators used, dental asymmetry is regarded as the most controversial. Pathological bands are accepted as being the most sound indicator. After taking into account the questionable status of the stress indicators, the hypothesis of increasing stress through time for the prehistoric periods in Tennessee is tentatively accepted, primarily on the basis of the Striae of Retzius analysis.

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