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The Effects of Changing Subsistence Strategies on the Degree of Sexual Dimorphism of Skeletons from the Southeastern United States

William Edward Grant
University of Tennessee, Knoxville

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To the Graduate Council:

I am submitting herewith a thesis written by William Edward Grant entitled "The Effects of Changing Subsistence Strategies on the Degree of Sexual Dimorphism of Skeletons from the Southeastern United States." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

William M. Bass, Major Professor

We have read this thesis and recommend its acceptance:

Walter E. Klippel, Richard Jantz, Lyle W. Konigsberg

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Lyle W. Konigsberg

Accepted for the Council:

Associate Vice Chancellor
and Dean of the Graduate School

THE EFFECTS OF CHANGING SUBSISTENCE STRATEGIES ON THE DEGREE OF SEXUAL DIMORPHISM OF SKELETONS FROM THE SOUTHEASTERN UNITED STATES

A Thesis Presented for the
Master of Arts Degree
The University of Tennessee, Knoxville

William Edward Grant
December 1993

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ABSTRACT

This study examines the effects of changing subsistence strategies on the degree of sexual dimorphism for prehistoric skeletal populations from the Southeastern United States. Changes in subsistence from hunting and gathering in the Archaic Period to intensive agriculture in the Mississippian Period caused increased levels of stress that affected growth and development, as well as incidence of disease. Eight long bone measurements were taken from 17 skeletal series (6 Middle/Late Archaic, 8 Early/Middle Woodland, and 3 Late Mississippian) from Tennessee and Alabama. These measurements were subjected to a series of univariate and multivariate statistical tests to determine whether or not significant size- and shape-related changes in sexual dimorphism exist.

Results of these tests indicate that there is a decrease in size-related sexual dimorphism for Mississippian agriculturalists. This is believed to be the result of increased nutritional and disease-related stress. There is also an increase in shape-related sexual dimorphism for this group. A trend for increased size over time also exists for males and females, although Woodland Period males are slightly larger than Mississippian males. These increases are both thought to be caused by heavier workloads associated with intensive maize agriculture.

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OVERVIEW

Introduction

Research in sexual dimorphism has existed for several decades in anthropology, with applications relating to past and present groups of both hominid and non-human primates. In physical anthropology specifically, the term sexual dimorphism has mainly been used to describe the difference in overall body size between males and females, however, according to Hamilton (1975), it is principally meant to signify differences in primary sexual characteristics that exist for reproduction.

Many secondary characteristics also exist that are not size related but are considered sexually dimorphic, for example the distribution of body hair and fat, and the lowering of the male voice. According to Darwin (1871), secondary sex characteristics such as these only become fully developed at the time of sexual maturity. While these types of sex differences are important to some physical anthropologists, it is the distinctions that exist within the human skeleton that are of primary interest. Skeletal elements differ between males and females with regard to size, shape, weight, rugosity, and developmental sequencing.

Attempts at understanding the size and shape differences that occur between males and females have focused on environmental adaptation, nutritional status, behavioral differences, and genetic makeup, among others. Frayer and Wolpoff (1985) state that several of these factors can be viewed in terms of proximate and ultimate causation, with the former explaining sexual dimorphism as being related to nutrition, while the latter accounts for changes in body size as being caused by genetic adaptation.

This study views sexual dimorphism in terms of proximate causation to examine how size and shape differences for males and females within the same geographical region are affected by changing nutritional strategies. The objective here is to determine whether or not the difference in long bone size and shape for the sexes varies significantly, and in what manner, between groups that utilized a hunting and gathering form of subsistence adaptation, compared with a mixed hunter/gatherer horticultural adaptation, and an intensive agricultural adaptation. I propose that there will be changes in the degree of size- and shape-related sexual dimorphism in the agricultural groups, due to an increase in stress. The skeletal remains of individuals from 17 Southeastern archaeological sites have been analyzed in this work. These samples date to the Middle and Late Archaic Periods, the Early and Middle Woodland Periods, and the Late Mississippian Period.

Determination of Sex

Analyzing the degree of sexual dimorphism in the fields of hominid evolution and bioarchaeology requires that the gender of individuals first be determined through the analysis of skeletal remains. The accuracy of sex assessment depends on numerous factors, the most important of which being the completness of the remains under study. One must also take into consideration certain taphonomic factors that can potentially cause a bias to occur within the sample(s) being analyzed.

Sexing of human skeletal remains is possible using a variety of gross and anthropometric techniques, some of which are more accurate than others. The accuracy of these techniques and the skill with which they are applied will determine the degree of error that is introduced into the assessment of sexual dimorphism for skeletal assemblages.

The best area with which to determine the sex of skeletal remains is the pelvis. The pelvis provides certain nonmetric features (i.e., shape dimorphism) that can be used as accurate indicators of sex, unlike the rest of the skeleton which relies on size and therefore varies from one population to the next (Hamilton, 1982). Although numerous techniques have been discussed for differentiating sex using the pelvis (Bass, 1987; Houghton, 1974; Iscan and Derrick, 1984; Kelley, 1979; Krogman and Iscan, 1986; MacLaughlin and Bruce, 1986; Schulter-Ellis and Hayek, 1988; Suchey et al., 1979; Washburn, 1948), the best overall method was developed by Terrell Phenice in 1969.

Phenice (1969) uses gross observation of three criteria on the pubic bone (ventral arc, subpubic concavity, and medial aspect of the ischio-pubic ramus) to determine sex. This method was developed using the Terry Collection, a "modern" collection of skeletons of known sex. Recently, Sutherland and Suchey (1991) tested the ventral arc alone on a large number (n=1284) of known forensic cases, and correctly sexed 96% of the individuals. Also, Kelley (1978) has applied Phenice's technique to a sample of 362 prehistoric Amerindians from California, and has obtained what he believes are extremely reliable results.

Houghton's (1974) study of the preauricular groove and its relationship to pregnancy provides another good indication of gender for skeletal remains. According to the author, two types of grooves can form on the preauricular surface of the ilium: A groove of pregnancy, or a groove of ligament. A groove of pregnancy consists of deep elongated pits on the surface of the bone. This appears to be caused by osteoclastic resorption of bone adjacent to the attachment for the ventral sacroiliac ligament. A groove of ligament, on the other hand, is shallow, narrow, and tends to be short and straight-edged. While both males and females can have a groove of ligament, only females will have a groove of pregnancy. Thus its presence indicates that an individual is female.

The presence or absence of a postauricular sulcus is also a relatively good indicator of sex. Iscan and Derrick (1984) write that females uniformly exhibit a postauricular sulcus, whereas in males this feature is hardly ever present. Also, females have a wide postauricular space compared to males. Finally, the authors state that males have a mound-shaped iliac tuberosity, while in females this structure is usually pointed.

Bass (1987) states that the next best area to determine the sex of skeletal remains is the skull. Numerous morphological criteria have been used over the years, including the presence or absence of a supraorbital torus, and suprameatal crest; the size of the nuchal muscle attachments, and mastoid processes; and the shape of the chin, and forehead (Bass, 1987; Krogman and Iscan, 1986). Osteometric techniques have also been developed to sex the cranium (Giles and Elliot, 1963; Holland, 1986; Jantz and Ousley, 1993; Keen, 1950), mandible (Giles, 1964), and teeth (Garn et al., 1979).

Aside from the pelvis, a variety of postcranial techniques have been developed and tested for sexing skeletal material. The vast majority of these criteria involve measurements, such as the diameter of the femoral head (Dittrick and Suchey, 1986; Pearson, 1917-1919, Stewart, 1979), femoral circumference at midshaft (Black, 1978a; DiBennardo and Taylor, 1979, Spruiell, 1984), the proximal tibia (Holland, 1991) and tibial shaft (Iscan and Miller-Schaivitz, 1984), the humerus (Dittrick and Suchey, 1986), the head of the radius (Berrizbeitia, 1989), and a technique using measurements from the humerus, radius, and ulna (Holman and Bennett, 1991). Jantz and Moore-Jansen (1988) have devoted an entire volume to the discrimination of sex and race using measurements.

The accuracy of sex assessments using these techniques depends on the population being analyzed. It is best when using any such techniques on a skeletal series to first sex individuals using the pelvis, then use the information obtained from these "known" individuals to help sex the remainder of the series since the degree of sexual dimorphism varies from population to population.

The importance of accurately determining the sex of skeletal material cannot be overstated. By using size differences and degree of rugosity to sex skeletal material, researchers increase their risk of obtaining a biased sample. According to Weiss (1972), past analysis of skeletal populations for sex carried a male bias of up to 12%. While Bone's (1993) research on sex bias within skeletal populations confirms this, she has also found that since Weiss' publication the ratio of males to females from skeletal series has come closer to being 1:1. This is likely due to the increased use of the Phenice technique, as well as a conscious effort on the part of researchers to avoid biasing their samples.

Factors Affecting Sex Determination

Several factors exist that can affect the determination of sex from skeletal remains, thus obscuring the degree of sexual dimorphism. The age of an individual is possibly the most important of these. Numerous authors have discussed the problems and possibilities of establishing the gender of infant and subadult skeletal remains (Bailit and Hunt, 1964; Hunt, 1990; Hunt and Gleser, 1955; Sundick, 1977; Weaver, 1980), and while some believe there to be promise, the results are less than adequate. The major problem is that while some sexual dimorphism does exist in immature individuals (Boucher, 1955; Holcomb, 1992; Moss, 1978; Moss and Moss-Salentijn, 1977; Reynolds, 1945, 1947; Stini, 1985), it is not until secondary sex characteristics manifest themselves at puberty that skeletal differences can be relied upon with any degree of accuracy.

Problems can also exist with differentiating the sex of older adults due to changes in skeletal dimensions that occur with age. It has been shown that remodeling of bone continues throughout life and can affect certain dimensions of the skull (Hunter and Garn, 1972; Israel, 1967, 1973, 1977; Ruff, 1980), as well as postcranial bones such as the humerus (Pfeiffer, 1980), femur (Smith and Walker, 1964), tibia (Ruff, 1992) and metacarpal (Garn et al., 1967b, 1972). Although both Israel (1967, 1977) and Ruff (1980) feel that since the bones of males and females remodel in the same manner with age, the sex difference factor might not be very important, the use of older individuals in sexual dimorphism studies should be avoided. This is because the use of these individuals, whose bones have sufficiently remodeled, can affect the size differences that exist between younger adult males and females within a population.

Aside from age-related changes in skeletal material, sex determination can be affected by the state of preservation of bones within soil. Gordon and Buikstra (1981) write that the degree of acidity in soil is directly correlated with the preservation of bone. The authors found that while the bones of young adults were affected by acidic soil, the remains of both mature individuals and subadults were especially succeptible.

Walker et al. (1988) analyzed the degree of preservation of skeletal material from two cemeteries in California in an attempt to determine whether sex and age biases were present that could be attributed to soil conditions. The authors felt that the bones of females would not preserve as well, due to their lighter build. Although they did not find there to be differential preservation of female remains, the remains of older individuals were found to be poorly preserved.

Human skeletal remains located within soils having a basic pH, on the other hand, are often in an excellent state of preservation. Soils of this nature are usually associated with shell middens, as shells are rich in calcium carbonate. Several of the skeletal series that will be analyzed in this work were found within shell middens. The quality of bone preservation was thus greatly improved, allowing for a more accurate determination of both sex and age of the skeletons.

Sexual Dimorphism in Human Evolution

Some studies in hominid evolution have focused on sexual dimorphism. For instance, in the late 1960s and throughout the 1970s debate existed regarding the taxonomic classification of australopithecine fossils discovered in Africa (Brace, 1969, 1970, 1973; Howell, 1967; Le Gros Clark, 1967; Robinson, 1972; Wolpoff, 1971, 1974, 1975, 1976a, 1976b). Both Howell (1967) and Le Gros Clark (1967) hypothesized that robust and gracile forms of hominids represented two distinct species within the common genus Australopithecus, while Robinson (1972) felt that two or more separate genera were represented by these fossil remains.

C. Loring Brace (1969, 1970, 1973) and Milford Wolpoff (1971, 1974, 1975, 1976a, 1976b) however proposed a "single species hypothesis" in which the robust and gracile forms were explained as being males and females (respectively) from the same species. Brace (1973) writes that the advent of culture altered the degree of sexual dimorphism in Homo sapiens and that prior to this hominid species had a marked degree of sexual dimorphism comparable to modern gorillas. Later research (Johanson and White, 1979; White and Harris, 1977) suggests it is much more likely that the robust and gracile australopithecine specimens are separate species.

Sexual Dimorphism in Skeletal Populations

Changes in the degree of sexual dimorphism in skeletal populations have been analyzed using recent, as well as prehistoric skeletal material. Studies using the skeletal remains of modern individuals have tended to focus on developing methods of determining gender (see above section), and stature (e.g., Jantz and Moore-Jansen, 1990; Trotter, 1970; Trotter and Gleser, 1952, 1958). Research in sexual dimorphism using skeletal data from prehistoric groups has been more concerned with determining the phenotypic response of males and females to environmental factors (Boyd and Boyd, 1989; Bridges, 1989, 1991; Hamilton, 1975, 1982; Larsen, 1982; Ruff, 1987, 1992).

Margaret Hamilton (1975, 1982) has conducted research on sexual dimorphism for size using skeletal populations from Archaic, Woodland, and Mississippian sites in the Midsouth as well as two agricultural sites in Mexico. Hamilton utilized a variety of measurements from the pelvis, femur, humerus, clavicle, and first metatarsal (the latter measurement being used in her 1982 article only), to compare these groups. Her results show that for groups within these two regions, the change to an intensive agricultural subsistence base led to a decrease in the degree of sexual dimorphism for size. The author attributes the findings of her study to nutritional and disease-related stress associated with intensive agriculture.

In Larsen's (1982) analysis of pre-agricultural and agricultural Amerindian populations from St. Catherines Island, the author compares the percentage of sexual dimorphism between the two groups for cranial, postcranial, and tooth measurements (see also Larsen, 1984 for a similar study). For the postcranial skeleton, Larsen's results, in contrast to the previous study, indicate that 24 out of 27 measurements have a higher percentage sexual dimorphism for the agricultural population. Similar results exist for the other measurements. Analysis of mean measurements for males and females shows an overall size decrease in the agricultural group as well, with females experiencing the greatest amount of reduction. Larsen believes these results show that males in the agricultural group were consuming a higher percentage of protein than were females, since they most likely ate more meat while on hunting trips while females stayed back at the village and predominantly ate corn. Although the results for the percentage of sexual dimorphism are directly opposed to Hamilton's (1975) results, Larsen (1982) uses the lower caries rate and higher rate of degenerative joint disease among agricultural males to support his results.

Boyd and Boyd (1989) have compared femur size variability among Archaic and Mississippian males and females to changes in subsistence patterns. The authors used 524 individuals from 10 sites, all of which are located in Tennessee. They believed that the overall size of femora would decrease over time due to a change in subsistence practices from hunting and gathering to maize agriculture (as was the case with the St. Catherines Island groups), however this did not occur. Their results also show there to be a lack of significant change in the degree of sexual dimorphism for the two groups.

Research in long bone shape variation has also been used to help understand skeletal changes taking place as a result of a shift from hunting and gathering to intensive maize agriculture (Bridges, 1991; Ruff, 1987, 1992). Ruff (1987, 1992) has found that shape changes occur in both the femur and tibia midshaft between prehistoric hunter/gatherers and agriculturalists. The shape changes that have occurred correspond to a decrease in sexual dimorphism for agriculturalists in the relative bending strength of these bones. The author has attributed these changes to an increase in sedentary tasks for males in agricultural groups.

Bridges (1989, 1991) writes that comparisons of overall long bone size is greater in Mississippian agriculturalists than in Archaic hunter/gatherers. This size increase corresponds to a shape change that the author attributes to changes in the division of labor among these groups. For instance, Mississippian females show an increase in size and cortical bone thickness of both upper and lower limbs that is likely the result of increased workloads associated with agriculture (the grinding of corn being an excellent example). Long bone shape changes occurred to a lesser degree among Mississippian males, possibly due to a decreased role in subsistence-related activities.

Sexual Dimorphism in Living Groups

A great deal of research has been published regarding sexual dimorphism using living populations, both past and present. Much of this work has focused on the adaptive response of males and females to varying degrees of nutritional stress (Bielicki and Charzewski, 1977; Dreizen et al., 1967; Eveleth, 1975; Frisancho et al., 1973; Gaulin and Boster, 1992; Greulich, 1951; Hall, 1978; Stini, 1969, 1972), and disease-related stress (Scrimshaw and Behar, 1965; Scrimshaw et al., 1968). Other studies have concentrated specifically on sex-related size differences in teeth (Black, 1978b; Garn et al., 1966, 1967a, 1971, 1979; Henderson and Corruccini, 1976; Lewis and Grainger, 1967; Moorress, 1959; Moss and Moss-Salentijn, 1977), and on the effects of social behavior on modern non-human primate species (Clutton-Brock and Harvey, 1977; Crook, 1972; DeVore and Washburn, 1963). Related work in cultural anthropology also exists studying the effects of preferential treatment of one sex over the other in some societies (Bennett, 1983; Choe, 1987; Cronk, 1989; D'Souze and Chen, 1980).

The effects of stress on the growth rate and size of children has been analyzed for several groups. For example, Bielicki and Charzewski (1977) compared the statural gains of children over parents for families in which parents had a higher education than grandparents, and for families whose educational level remained stationary. They found that while there was an increase in stature for both groups, the better-educated (hence higher socioeconomic class) group was significantly taller than the other group. The authors also found that males increased in stature more so than did females.

It has been well-documented in the literature that males are more affected by changes in stress levels than are females (Ashcroft et al., 1966; Dreizen et al., 1953; Dreizen et al., 1967; Frisancho et al., 1973; Greulich, 1951, 1957; Greulich et al., 1953; Stini, 1972; Tanner, 1962). Also, for groups under stress both male and female children experience a delayed prepuberal growth spurt. While this delayed rate of growth causes such children to continue growing to a later age, they are not able to fully catch up, and thus their adult size ends up being smaller than children from well-nourished groups.

A good example of these phenomena has been reported by Greulich (1951), who compared the growth rates of Guamanian children just after World War II with a sample of upper-class American children from Cleveland, Ohio. The author found that the Guamanian girls did not begin their prepuberal growth spurt until age 12, while the American girls began at between ages 10 and 11. The height of Cleveland boys began to exceed that of Cleveland girls between 13 and 14 years, while for Guamanian boys this did not occur until between 15 and 16 years. Also, while the height of Guamanian boys increased for a year or more after the Cleveland boys, their average stature was still 17.3 cm shorter at age 17. The Guamanian girls' stature was also shorter than that of the Cleveland girls at age 17, however the difference (14.5 cm) was not as great (Greulich, 1951). Guamanian boys were therefore affected more so by nutritional stress than were the girls, decreasing the degree of sexual dimorphism for this group over the American group.

A decrease in the degree of sexual dimorphism for groups under stress can be an adaptive rather than a pathological response to environmental pressure. Stini (1969) has shown this to be the case with populations from highland Peru. Although the overall size of individuals from this group was decreased as compared to healthy groups (again, males more so than females), Stini states this does not necessarily correspond to a decreased work capacity, since smaller body size requires less caloric intake.

Eveleth (1975) compared the adult height of European Caucasoids, Negroids, and Amerindians. The author found that Amerindians had the most sexual dimorphism, followed by European Caucasoids, and finally Negroids. Since the European Caucasoid group was the better nourished of the three groups, it was expected that they would have the greater dimorphism. The author states that the results may reflect genetic factors, or could possibly reflect preferential treatment of males in Amerindian groups. Several factors exist that can influence the size difference of males and females, as evidenced by this study.

The idea that some societies show preferential treatment toward children of one sex over another has become a topic of much research by cultural anthropologists utilizing a sociobiological paradigm (Bennett, 1983; Choe, 1987; Cronk, 1989; D'Souze and Chen, 1980). These studies show that when one sex is given preferential treatment in a society, the other sex often exhibits more nutritional stress and higher than normal childhood mortality rates. It can be inferred then that members of the neglected sex surviving past childhood will be of smaller than average size, thus increasing or decreasing the degree of sexual dimorphism depending on which gender is affected.

Sex-related tooth size differences have been studied in great detail, predominantly in the 1960s and 70s. It has been found (Garn et al., 1966, 1971; Goose, 1963; Moorrees, 1959; Moss and Moss-Salentijn, 1977) that both permanent and deciduous canines show the greatest degree of sexual dimorphism for size among human groups. Some researchers (Garn et al., 1967a, 1968) believe these differences to be genetically-related (Garn et al., 1967b have even found some evidence to suggest tooth size and body size are correlated), while others feel they are environmentally controlled (Goose, 1967; Goose and Lee, 1973). Moss et al. (1977) state that whatever factor is involved, the most likely process causing this dimorphism to occur is prolonged deposition of enamel during amelogenesis for males.

Research in sexual dimorphism using non-human primate models has tended to focus on size being related to intra-sexual competition (Clutton-Brock and Harvey, 1977; Crook, 1972; Crook and Gartlan, 1966; DeVore and Washburn, 1963; Harvey et al., 1978; Struhsaker, 1969). Although some authors (Cheverud et al., 1986; Leutenegger, 1982) have recently stated that the degree of dimorphism for size is a result of allometry, others (Godfrey et al., 1993; Kay et al., 1988) write that this concept is not a good explanation for dimorphism and therefore should not be used.

In summary, research in sexual dimorphism in physical anthropology has spanned several decades and covered several different areas. These include human evolution, skeletal biology, as well as primate studies. Accuracy of gender determination, age, and preservation of bone are all factors shown to affect sexual dimorphism.

Chapter 2

SUBSISTENCE STRATEGY CHANGES IN THE SOUTHEAST FROM THE ARCHAIC TO MISSISSIPPIAN PERIODS

Much research has been conducted on subsistence patterns during the Archaic through Mississippian Periods in the Southeast (CridleBaugh, 1985; King, 1987; Meighan, 1969; Nassaney, 1987; Parmalee, 1965; Robbins, 1986; Robison, 1982; Smith, 1987; Yarnell, 1974). During this time (roughly 6000 B.C. to 1550 A.D.), Amerindian groups shifted from a lifeway based on hunting and gathering to one predominantly composed of intensive maize agriculture. Along with this shift in subsistence strategy came a rapid increase in population density, as well as incidence of infectious disease (Cassidy, 1984; Cook, 1984; Eisenberg, 1991). Changes in diet and disease occurrence may have had a differential effect on the growth rate of males and females in prehistoric groups. In order to interpret changes in the sexual dimorphism of long bone size over these time periods, it is important to first know how prehistoric subsistence and subsistence-related activities evolved in the Southeastern United States.

Subsistence and Related Activities from the Archaic to Middle Woodland Periods

During the Archaic and into the Early/Middle Woodland Periods, prehistoric inhabitants of the Southeast utilized a hunter/gatherer form of subsistence adaptation. Groups in the Archaic appear to have been small and highly mobile, subsisting on meat and plant foods obtained by foraging (Steponaitis, 1986). Early to Middle Woodland populations became larger and more sedentary, utilizing a wider variety of food sources which included an abundance of native cultigens and, to a lesser extent, certain domesticates (Buikstra et al., 1987).

Evidence from Archaic Period sites included in this study indicate that these groups probably utilized a subsistence/settlement pattern that consisted of making seasonal rounds to certain areas in order to exploit the local resources (Bowen, 1977). For example, groups may have moved to upland areas in the fall to harvest nuts, and hunt and trap animals, and at other times of the year have moved down to major water systems to exploit freshwater mussels, fish, etc. Floral and faunal evidence from Early and Middle Woodland Period sites in East Tennessee and northeast Alabama suggests that many of these later groups may have utilized similar seasonal rounds (Butler, 1977; Faulkner, 1977; Steponaitis, 1986).

The majority of the faunal assemblages at most sites from these time periods are composed of the remains of white-tailed deer (Odocoileus virginianus), although elk (Cervus canadensis), bear (Ursus americanus), and smaller animals such as eastern cottontail rabbit (Sylvilagus floridanus), opossum (Didelphis marsupialis), raccoon (Procyon lotor), striped skunk (Mephitis mephitis), and turkey (Meleagris gallopavo) are often present as well (Dowd, 1989; Hofman, 1984; Parmalee, 1965). Since most of these sites are located in riverine environments, the remains of numerous species of turtle, fish, and shellfish are also commonly found. In fact, many of these sites are associated with shell middens indicating a seasonal harvesting of freshwater mussels, and to a lesser extent, gastropods. Of the sites utilized in this study, several from the Archaic (Anderson, Eva, Ledbetter Landing, Kays Landing, and Big Sandy) and Woodland Periods (Saltpeter Cave and Widows Creek) are associated with shell middens.

It has long been debated as to whether or not prehistoric groups utilized mussels as a primary source of food on a seasonal basis (Cook, 1946; Meighan, 1969; White, 1953), however it now appears more likely that mussels would have provided a dietary supplement when combined with other available foods (Parmalee and Klippel, 1974). While gastropods possess little in the way of protein, fat, or carbohydrates, they do provide an important source of minerals such as iron, calcium and to a lesser extent phosphorus, sodium and potassium. Thus, gastropods may have been used as a dietary supplement, especially for children and women of childbearing years (Klippel and Morey, 1986).

The remains of numerous species of nuts and seeds have often been found at Archaic and Woodland Period sites in both the Midsouth and Southeast and were no doubt an important source of nutrition to prehistoric groups (Asch et al., 1972; Shea, 1978; Watson, 1974; Yarnell and Black, 1985). Nuts such as hazelnut (Corylus sp.), hickory and pecan (Carya sp.), and walnut (Juglans nigra) are high in both protein and fat, and are easily storable. Acorns (Quercus sp.) are high in carbohydrates, but lower in both protein and fat. Since the nutritional value of nuts (excluding acorns) is similar to that found in the meat of mammals, it has been suggested (Asch et al., 1972) that nuts may have been used as a supplement for groups whose diet consisted mainly of fish.

At many of the Archaic and Woodland Period sites in the Southeast (such as Ledbetter Landing and Banks V), the remains of hickory nuts are the most abundant plant food recovered, further suggesting their dietary importance (Bowen, 1979; Shea, 1978). It should be noted, however, that the density of hickory shells may be because they were burned as fuel, which caused the remains to carbonize. This may have resulted in this nut species being overrepresented in the archaeological record (Crites, 1978; Faulkner et al., 1976; Shea, 1978).

Seeds are another type of food that are easily stored and could be used to provide nurishment during times of food scarcity. Although utilized during the Archaic, seeds appear to have been more important during the Woodland (especially Middle Woodland) Period (Buikstra, 1984). Seeds that are considered oily, such as marsh elder (Iva annua) and sunflower seeds (Helianthus annuus), contain a high percentage of fat as well as vitamins and minerals, and provide relatively high concentrations of calories (Asch and Asch, 1978). Maygrass (Phalaris caroliniana), goosefoot (Chenopidium bushianum), and knotweed (Polygonum erectum) are starchy seeds high in carbohydrates that were also gathered and cultivated by Archaic and Woodland peoples (Asch and Asch, 1978; Bradbury et al., 1992; Buikstra, 1984; Chapman and Shea, 1981; Crites, 1978; Shea, 1978).

Evidence exists for the use of squash (Cucurbita pepo) and bottle gourd (Lagenaria siceraria) as far back as the Middle Archaic Period in the Midsouth (Buikstra, 1984; Chomko and Crawford, 1978; Smith, 1987). Both squash and bottle gourd are domesticates that originated in Mesoamerica and were later introduced into eastern North America. In the Southeast, squash remains have been found as early as the Late Archaic Period (Yarnell, 1988).

In addition to large and small game, nuts, seeds, fish and mussels, other sources of food were exploited by Archaic and Woodland peoples. These other food sources include numerous species of berries and fruits, such as blackberry (Rubus sp.) and grape (Vitis sp.), as well as various types of tubers, etc.

As stated above, the size of groups during the Archaic appears to have been relatively small, with Woodland populations growing in numbers with increased reliance on storable cultigens (Dragoo, 1976). Skeletal analysis has shown that the rate of disease was rather low among hunter/gatherer groups in this region, with many of the pathologies present being traumatic in origin (Joerschke, 1983). Evidence for degenerative joint disease appears to be slightly higher in these pre-agricultural groups (Cassidy, 1984; Larsen, 1982, 1984), however Bridges (1991) believes this may be due to differences in the age structures of the samples being compared. As the size of groups increased during the Woodland Period, the disease rate began to climb. The increased incidence of linear enamel hypoplasias (LEH) and radiopaque transverse (or Harris) lines gives some indication that Middle and Late Woodland Period groups in certain areas were beginning to experience periods of stress associated with poor diet and disease (Goodman, 1993; Goodman et al., 1984; Perzigian et al., 1984).

Subsistence and Related Activities from the Late Woodland to Mississippian Periods

The heavy reliance on meat and cultigens shifted after the Middle Woodland Period, with a new focus being placed on maize agriculture. Although evidence does exist for limited use of domesticates in the Archaic Period, the use of domesticates on a wide scale did not begin until the Middle Woodland Period, with the expanded use of squash, bottle gourd, and the introduction of maize (Zea mays). By the Late Woodland/Terminal Late Woodland Periods, many groups in the Midsouth and Southeast were utilizing agricultural products as a major portion of their diets (Caddell, 1982; Goodman et al., 1984; Yarnell and Black, 1985).

It has been suggested that the shift from a diet composed of meat, nuts, and cultivated plants to one primarily consisting of maize was detrimental to the health of prehistoric groups, causing a high occurrence of pathologies (Angel, 1966, 1967; El-Najjar et al., 1975, 1976; Rose et al., 1984; Steinbock, 1976). Others propose that this dietary shift should be viewed as beneficial, because it helped decrease the incidence of seasonal stress, thus allowing for an increase in population (Cook, 1984). However, this increase in population density may itself also be regarded as a source of stress.

Nutritionally speaking, a diet consisting of maize alone is unhealthy, because the phytic acid it contains interferes with the absorption of iron and as such can cause anemia to develop (Steinbock, 1976). Chronic iron deficiency anemia can lead to the development of cribra orbitalia and porotic hyperostosis in the cranium. Evidence for increased occurrence of these pathologies, together with increased linear enamel hypoplasias, and caries rates, exists in the Late Woodland/Terminal Late Woodland Periods when groups first began intensive maize agriculture (Goodman et al., 1984).

At sites such as Averbuch, a Late Mississippian village/cemetery in Middle Tennessee, skeletal evidence suggests that a large percentage of individuals within the group suffered from iron deficiency anemia (Eisenberg, 1991). While it is possible that the high occurrence of this disease was related to maize consumption, it may also have been brought on by other causes, such as the presence of intestinal parasites which are often prevelant in areas of high population density lacking proper sanitation (El-Najjar, 1976). Since Late Mississippian groups in the Southeast often supplemented their diet with the same food types used in the Archaic and Woodland Periods (Kline and Crites, 1979), it is very possible that population density was a leading factor in causing stress at Averbuch and other large sites dating to this time period.

Research Objectives

Subsistence practices utilized by Amerindian populations in the Midsouth and Southeast changed between the Archaic and Mississippian Periods as groups relied to a greater extent on food types that were both reliable and storable. Throughout the Archaic and earlier Woodland Periods, groups hunted, fished, and collected nuts, seeds, fruits, berries, and mussels. Late Woodland and Mississippian groups also utilized many of these food sources, though to a lesser extent, as the planting of domesticated crops was a more stable means of subsistence. The increased stability of food sources allowed for larger population sizes among agricultural groups. Poor nutritional value of maize, expanded workload associated with agriculture, and sanitary problems related to high population density all led to nutritional and disease-related stress for these later populations.

This study examines skeletal populations from 17 different sites spanning approximately 7000 years in order to observe size and shape differences between males and females in groups utilizing different nutritional strategies. Since it is believed by many (Smith, 1990) that the Mississippian emergence in the Southeast was an in-situ development, all of the groups compared in this study are believed to have come from the same geographical region. It is hypothesized that there will be a significant decrease in the degree of size-related sexual dimorphism for Archaic, Woodland, and Mississippian Period populations in this study, due to increased nutritional and disease-related stress. It is further hypothesized that there will be a significant increase in the degree of shape-related sexual dimorphism for these groups, caused by increased workloads associated with maize agriculture and a continued reliance on hunting and horticulture.

Chapter 3

MATERIALS AND METHODS

Measurements Taken

Measurements were taken on the skeletal remains of adult individuals from 17 archaeological sites, all of which are located within the Southeastern United States (Tennessee, and Alabama) (Appendices A and B). These sites range in age from the Middle Archaic Period (5500 B.C.) to the Late Mississippian Period (1470 A.D.). The gender for all skeletal remains included in this study was assigned on the basis of morphological characteristics of the pelvis. Individuals whose pelves were not recovered or were too fragmentary for proper analysis were not included in the sample. Gender assignment was based on Phenice's (1969) criteria, along with the presence of a groove of parturition (Houghton, 1974), and the presence or absence of a postauricular sulcus (Iscan and Derrick, 1984).

Measurements were taken only on postcranial elements, specifically the humerus, femur, and tibia. The following measurements were used to analyze the degree of sexual dimorphism: Maximum length of the femur; maximum length of the tibia; maximum vertical diameter of the head of the humerus; maximum diameter of the head of the femur; and antero-posterior and medio-lateral dimensions of the femur at midshaft and of the tibia at the nutrient foramen (see Appendix C for measurement definitions).

As previously mentioned, age can affect the degree of sexual dimorphism present in a population. The samples taken in this study were thus restricted to individuals between the ages of 20 and 50 years. Age determination was based on numerous criteria, including epiphyseal closure (Ubelaker, 1989; Webb and Suchey, 1985), eruption of third molars (Dahlberg and Menegaz-Bock, 1958; Ubelaker, 1989), degree of dental attrition (Lovejoy, 1985), and morphology of both the pubic symphysis (Gilbert and McKern, 1973; Katz and Suchey, 1986; McKern and Stewart, 1957), and auricular surface (Lovejoy et al., 1985).

Archaeological Site Description

This section describes the archaeological sites used in this study, and evaluates the health of the skeletal samples. A total of 17 sites was analyzed, 6 Middle/Late Archaic, 8 Early/Middle Woodland, and 3 Late Mississippian. Where possible, the taxa of foods recovered from sites are listed, however, since some of the material was collected by amateurs, this data was not always collected or available for analysis. Several of the sites were excavated before implimentation of the Smithsonian site designation system. For these sites both designations are given, since the skeletal material is stored under the original site number.

Anderson

The Anderson site (40WM9) is a Middle Archaic shell midden with an associated cemetery located along the Harpeth River in Middle Tennessee (Fig. 1). This site was excavated in 1980 and 1981 by members of the Middle Cumberland Archaeological Society. Two charcoal samples taken from lower levels of the site yielded radiocarbon dates of 6720 ± 220 B.P. (4770 B.C.) and 6495 ± 205 B.P. (4545 B.C.), while a sample of burned deer bone also from a lower level provided a date of 5680 B.P. (3730 B.C.) (Joerschke, 1983).

Aside from an abundance of shellfish, faunal remains at the Anderson site include: White-tailed deer *(Odocoileus virginianus);* striped skunk *(Mephitis mephitis);* racoon *(Procyon lotor);* beaver *(Castor canadensis);* fox and eastern gray squirrel *(Sciurus niger, Sciurus carolinensis);* turkey *(Meleagris gallopavo);* and various species of duck, turtle, and fish (Dowd, 1989; Joerschke, 1983). Although an analysis of botanical remains recovered from Anderson was not available, Dowd (1989) does provide a table listing the pollen taxa identified. This includes: Goosefoot *(Chenopodium bushianum);* ragweed *(Ambrosia* sp.); sunflower *(Helianthus annuus);* and mulberry *(Morus alba).* In addition, Joerschke (1983) states that the charred remains of nuts were also recovered from this site.

Human remains excavated at the Anderson site consist of 73 individuals, 12 of which were used within this study. The bone preservation for these burials is exceptionally good, due to their association within the shell midden. The incidence of infectious

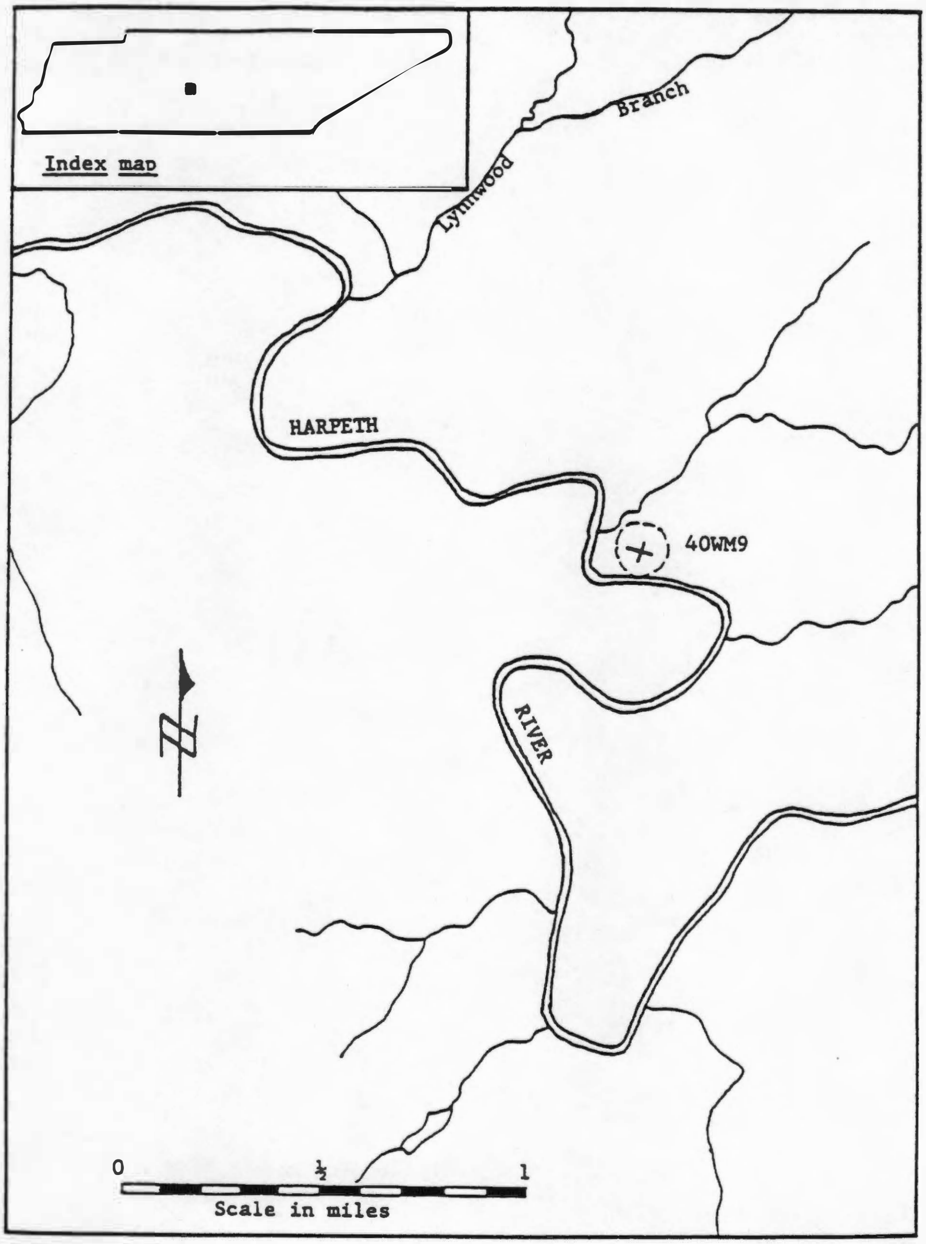

Fig. 1 The Anderson Site (40WM09), located along the Harpeth River in Middle Tennessee (U.S.G.S. topographical map, survey 1949, in Joerschke, 1983).

disease is quite low, with no occurrence of rickets, osteomalacia, cribra orbitalia, or porotic hyperostosis (evidence does exist for mild osteomyelitis in four individuals). The presence of traumatic injuries is higher, and includes periostitis, fractures, and collapsed vertebrae. Overall, the Anderson population appears to have been relatively healthy (Joerschke, 1983).

Eva

The Eva site (40BN12 [6BN12]) is situated in West Tennessee on a broad floodplain of the Tennessee River approximately 12 miles above its convergence with the Duck River (Fig. 2) (Lewis and Kneberg, 1961). As with Anderson, the Eva site is a stratified shell midden that dates to the Middle Archaic Period, although a Late Archaic horizon was also encountered. One radiocarbon date was obtained from the Eva I component of the site, producing a date of 5200 ± 500 B.C. A total of 17 individuals were recovered from this component. Another 161 individuals were recovered from the Eva II component, which is also believed to be Middle Archaic in age (Lewis and Kneberg, 1961; Smith, 1982). Twenty-seven individuals from Eva I and II were used in this study.

Eva, like Anderson, was probably utilized as a seasonal habitation site that allowed for the exploitation of freshwater mussels and fish. Other than shellfish, faunal remains recovered include (among others): White-tailed deer (Odocoileus virginianus); bear (Ursus americanus); racoon (Procyon lotor); opossum (Didelphius marsupialis); turkey (Meleagris gallopavo); and various species of turtle, and fish (primarily freshwater drum Aplodinotus grunnieus).

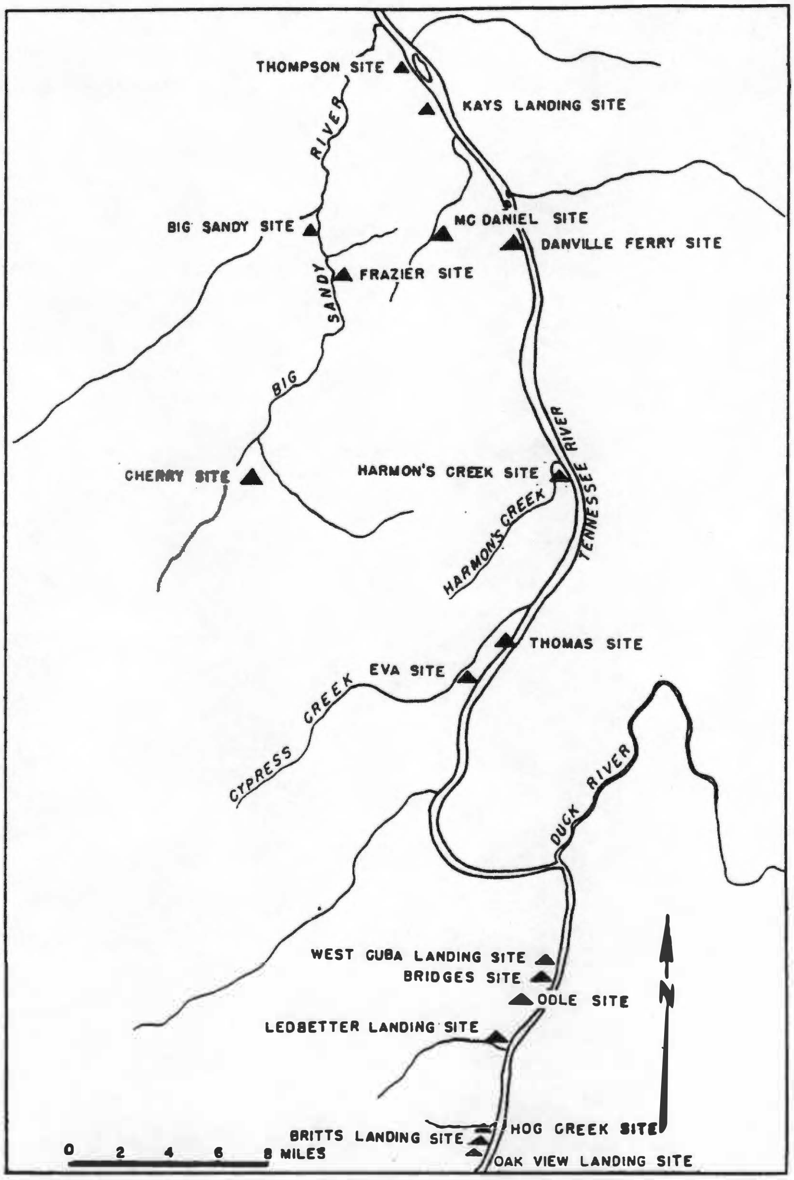

Fig. 2 Map of the Western Valley of the Tennessee River showing the location of numerous Archaic Period sites, including Eva, Ledbetter Landing, Kays Landing, Big Sandy, and Cherry (Lewis and Kneberg, 1947).

According to Lewis and Kneberg (1961) floral remains were not preserved at this site.

Lewis and Kneberg (1961) feel that the shift from a warmer climate during the Hypsithermal Interval to a cooler and moister climate in the Medithermal Interval may have been responsible for a change in subsistence strategies from the Middle to Late Archaic Periods in West Tennessee. The Middle Archaic Eva components produced a large percentage of shellfish remains as compared to white-tailed deer. This was likely due to arid conditions causing shallower water levels which are favorable for mussels. The cooler, moister climate of the Late Archaic was less favorable for shellfish, as is noted by the lack of mussel shells in the Eva III component (Lewis and Kneberg, 1961).

Information on the nutritional status of the skeletal series from Eva is scanty. Lewis and Kneberg (1961) discuss only the relative degree of dental attrition, along with the presence of absesses and caries (the latter of which appears to be minimal). Smith (1982) has utilized the Eva skeletal series along with other Archaic and Mississippian groups to analyze patterns of oral health with regard to subsistence. She has found, as have others (Goodman et al., 1984; Larsen, 1982, 1984; Perzigian et al., 1984) that hunter/gatherer groups such as the population from Eva tend to have a high degree of attrition with low caries rates, in contrast to high caries rates for agricultural groups.

Ledbetter Landing

The Ledbetter Landing site (40BN25 [9BN25]) is located along the Tennessee River, approximately $^1/_4$ mile north of the confluence with Morgan Creek, in West Tennessee (Fig. 2, p. 31) (Bowen, 1977). This is a Late Archaic stratified shell midden and associated cemetery, with 177 individuals, 9 of which are cremations (Lewis and Kneberg, 1947). Ten of individuals from Ledbetter Landing were included in the study sample. The site was first examined by C.B. Moore in 1914 (Moore, 1915). In 1940 George Lidberg excavated Ledbetter Landing as part of the Tennessee Valley Authority project for building the Kentucky Dam. There has unfortunately been no report written for Ledbetter Landing, although information from this site has been utilized by two researchers: Bowen (1975, 1977) used Ledbetter and other Archaic sites in the area to reanalyze subsistence and settlement patterns in the western Tennessee valley, while Higgins (1982) has discussed the mortuary patterning of the site.

Kays Landing

The Kays Landing site (40HY13 [15HY13]) is situated on the Tennessee River a few miles south of the Big Sandy River, in West Tennessee (Fig. 2, p. 31) This site is composed of a shell midden and associated village area (Lewis and Kneberg, 1947). Eighty-three burials were recovered within the two lower components of this site, both of which are Late Archaic in age (Kays I being dated at 2800B.C. ±500, and Kays II at 2100 B.C. ±300). Of these, 5 were measured and used for this study.

Big Sandy

The Big Sandy site (40HY18 [25HY18]) is located on the Big Sandy River at the mouth of the West Sandy Branch, in West Tennessee (Fig. 2, p. 31). This site has two components: Big Sandy I, which consists of a shell midden, and Big Sandy II, in which no mussel shells are associated. Sixty-two human burials were recovered from both components of this site (Lewis and Kneberg, 1947), 3 of which were included in the sample. According to Lewis and Kneberg (1959), Big Sandy I was contemporaneous with Eva I, thus dating to between 5200 and 3500 B.C. (i.e., Middle Archaic), while Big Sandy II is considered to be Late Archaic, and is thought to be contemporary with both Eva III and Cherry.

Cherry

The Cherry site (40BN74 [84BN74]) is located on a small rise of land between two tributary streams of the Big Sandy River, roughly 22 miles above the confluence of the Big Sandy River with the Tennessee River in West Tennessee (Fig. 2, p. 31) (Magennis, 1977). Although a site report has never been written for Cherry, it has been discussed to some extent by Magennis (1977), Lewis and Kneberg (1947, 1959), and Bowen (1975).

No radiocarbon dates are available for the Cherry site. The projectile points recovered from this site indicate that it dates to the Late Archaic Period. The Cherry site, then, was probably contemporaneous with the Eva III component from the Eva site, dating roughly from 2500-1000/500 B.C. (Magennis, 1977). Bowen

(1975) in fact proposes that the two sites (together with the Ledbetter site) are related to the same Ledbetter Phase population, with Eva and Ledbetter having been occupied in the summer months for fishing, mussel gathering, and hunting, while Cherry (which is in a more remote location) was occupied in the winter months for hunting, plant gathering, and trapping.

Sixty-nine burials were recovered from the Cherry site, however they have not been adequately analyzed. Magennis (1977) states that she scored pathologies on individuals from the Cherry and Eva sites according to generalized categories discussed by Neumann (1967). The author fails, however, to mention the overall health of these individuals, or list the pathologies present. Of the 69 individuals recovered, 9 were included in this study.

Bible Farm

Bible Farm (40CK11) is situated in Greene County on the Nolichucky River, in East Tennessee. This site, which was excavated in 1966, appears to be Early Woodland in age. Twenty-nine burials were recovered from the Bible Farm site. Of these, 6 were measured for this study. No other information exists on this site, as it was excavated by amateurs from the Tennessee Archaeological Society.

Ebenezer

The Ebenezer site (40GN6) was excavated a year later, also by amateurs. This site is located in Greene County along the left bank of the Nolichucky River. Of the 44 Early Woodland Period burials excavated at Ebenezer, 5 were used in the present study. No other information is available on either the excavation, or the burials.

Del Rio

The Del Rio site (40CK7 [6CK7]) is an Early Woodland Period site located along the French Broad River at the confluence of Big Creek, in East Tennessee. Three individuals were recovered from this site, one of which was utilized for this study. No other information is available for this site, as it was excavated by amateurs.

Candy Creek

The Candy Creek site (40BY14 [17BY14]) is situated at the confluence of Candy Creek with the Hiwassee River, in East Tennessee (Fig. 3). This site dates to the Early Woodland Period (Lewis and Kneberg, 1941).

Lewis and Kneberg (1941) suggest that the main subsistence economy of this group appears to have been fishing, since notched stone pebble sinkers were found while no appreciable amount of animal bone or mussel shell was recovered. Many large kettle-shaped pits were excavated, some of which were filled with fire-cracked rock (FCR). These were likely used for food preparation. Those pits without FCR may well have been used for food storage.

The only information available about the 62 individuals recovered from this site is that they were interred in pits and were placed in tightly flexed positions on either the back or side (Lewis and Kneberg, 1941). Of the 62 Early Woodland individuals recovered

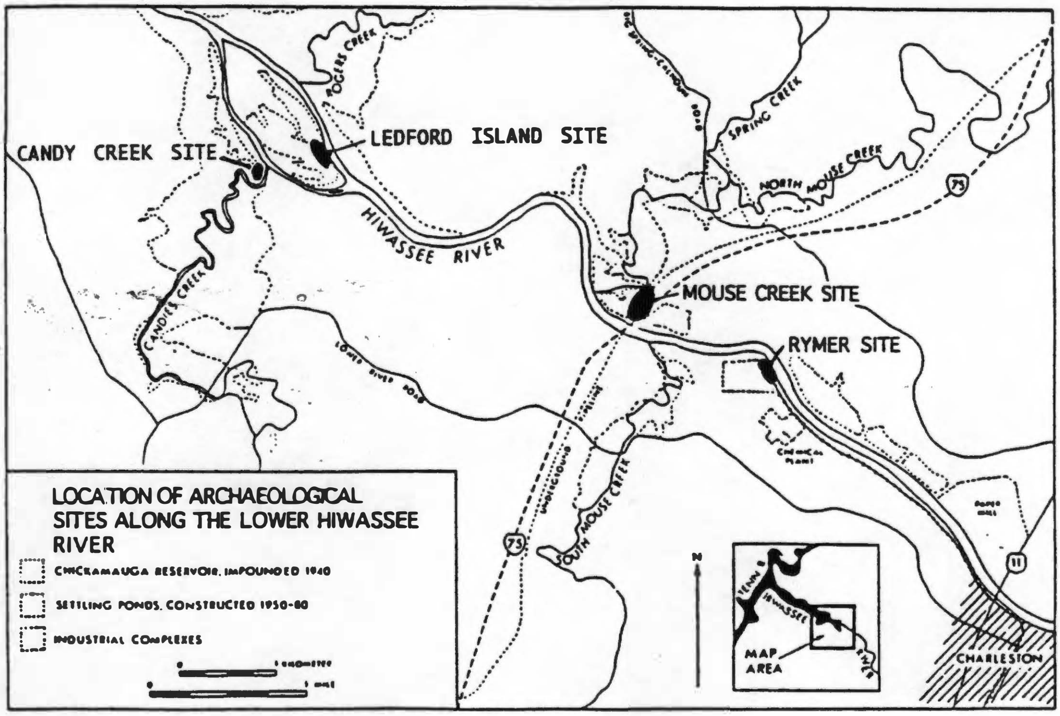

Fig. 3 Map of the Lower Hiwassee River in East Tennessee showing the location of the Candy Creek site, the Ledford Island site, the Rymer site, as well as the Mouse Creek site (adapted from Boyd and Boyd, 1984).

from Candy Creek, 3 were complete enough for measurements to be taken for use in this study.

Saltpeter Cave

Saltpeter Cave (40CP3 [3CP3]) was excavated in 1934 by T.M.N. Lewis. This site, which is considered to be Early Woodland in age, is located in Campbell County, Tennessee, two miles west of the Powell River and approximately five miles upstream. Thirteen burials were recovered from Saltpeter Cave, one of which was cremated. Two of the non-cremated individuals were used in this study. The burials from this site were found associated with a shell midden, which also contained a large quantity of animal bone (Webb, 1938).

Rankin

The Rankin site (40CK6) is located along the French Broad River across and just up from the mouth of the Nolichucky River, in East Tennessee. This Early Woodland Period site was discovered in 1960 and excavated by members of the University of Tennessee Anthropology Department. One hundred and sixty-four burials were recovered from Rankin, with a small number more (estimated at less than 10) being lost to looters (Smith and Hodges, 1968). Of these, 3 were included in the present study.

No detailed analysis is available for either the Rankin skeletal series or for the floral and faunal remains recovered at the site. Smith and Hodges (1968) write that burials were recovered from all levels of the site, many of which were in flexed positions and associated with pit features. Smith and Hodges (1968) also state that there were a few cremations, as well as several dismembered burials.

Widows Creek

Widows Creek consists of two Middle Woodland Period sites located along the Tennessee River in northeast Alabama (Fig. 4). These sites were excavated in 1973 by Dr. F. A. Calabrese and members of the University of Tennessee at Chattanooga (Calabrese, 1974).

The two sites that comprise Widows Creek are the Spur site (1JA305), and the Williams Landing site (1JA306). The Spur site is a shell midden, while the Williams Landing site consists of both a shell midden and a burial mound. Spatially these sites are located one mile from each other, with the Spur site being situated at the mouth of Widows Creek (west bank), and the Williams Landing site one mile down the Tennessee River. Twenty-nine individuals were recovered from the Spur site, and 42 from Williams Landing. Of these, a total of 18 individuals were used in this study from both sites combined.

Analysis of the vertebrate faunal remains from Widows Creek is currently being conducted at the University of Tennessee. The remains recovered are identical to those from the Archaic Period sites used in this study and include white-tailed deer (Odocoileus virginianus), racoon (Procyon lotor), squirrel (Sciurus sp.), turkey (Meleagris gallopavo), along with numerous species of fish and turtle (Dr. Darcey Morey, personal communication 1993). As stated

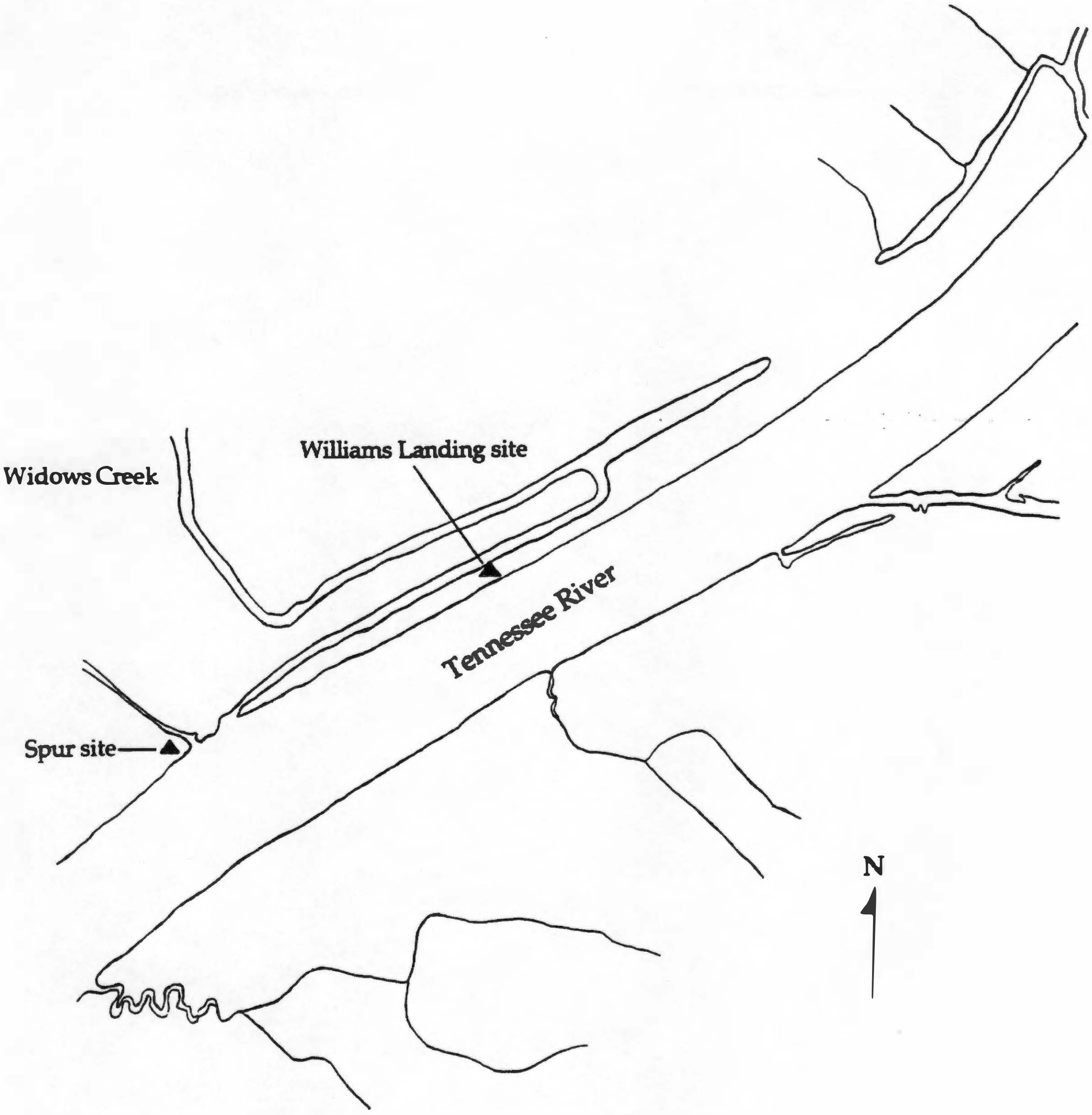

Fig. 4 Map showing the location of the Widows Creek sites (Spur and Williams Landing), situated along the Tennessee River in Northeast Alabama (U.S.G.S. topographical map, survey 1974).

previously, both sites are associated with shell middens indicating that shellfish were probably exploited on a seasonal basis. Floral remains have been recovered from Widows Creek and include hickory nut (Carya sp.), acorn (Quercus sp.), walnut (Juglans nigra), pecan (Carya illinoensis), butternut (Juglans cinerea), hazelnut (Corylus sp.), and grape (Vitis sp.) (Calabrese, 1974). Unfortunately, analysis of these remains has yet to be undertaken.

According to Calabrese (1974), all but three of the interments from the Williams Landing site appear to be Copena-like, thus dating to the Middle Woodland Period (1-500 A.D.). Two skeletons from this site may represent intrusive Mississippian burials (as suggested by the inclusion of shell-tempered vessels within their burial pits, while another skeleton is likely Late Woodland, since the burial contained a Hamilton Phase projectile point.

The presence of pathologies for the Widows Creek series was noted by the author during analysis of skeletal remains for an earlier work on sex ratios (Grant, 1993). The percentage of infectious pathologies for individuals from these two sites (excluding the 3 later burials) is much greater than for the Archaic populations analyzed in this study. Of the 71 individuals from both sites, 4 (5.63%) exhibited treponemal infection ("saber tibia"), 1 (1.41%) suffered from rickets, 3 (4.23%) showed evidence of porotic hyperostosis, and 3 (4.23%) were found to have periostitis. The occurrence of dental pathologies was higher: 13 individuals (18.3%) had linear enamel hypoplasias, 10 (14.09%) had caries, and 8 (11.27%) suffered from absesses. Only 2 individuals (2.82%) showed signs of healed fractures.

Averbuch

Averbuch (40DV60) consists of three Late Mississippian Period cemeteries and an associated habitation site located in Middle Tennessee, which date from 1275 to 1400 A.D. (Fig. 5) (Berryman, 1981; Eisenberg, 1991). Eight hundred and eighty-seven individuals were recovered from Averbuch, although an estimated 409 others could not be excavated due to cultivation practices, construction, and lack of available excavation time (Berryman, 1981). The large number of burials and good preservation at Averbuch allowed for a sample size of 59 individuals to be used in this study.

Much of the floral remains recovered from Averbuch came from several burned structures, although samples were also obtained from other features. Plant remains recovered include (among others): Maize (Zea mays); hickory nut (Carya sp.); black walnut (Juglans nigra); persimmon (Diospyros virginiana); and bean (Phaseolus vulgaris) (Crites, 1984). The list of faunal remains recovered from Averbuch are similar to the taxa found at temporally earlier sites. Some these include: Elk (Cervus canadensis); white-tailed deer (Odocoileus virginianus); black bear (Ursus americanus); beaver (Castor canadensis); and eastern cottontail (Sylvilagus floridanus). In addition, the metatarsal from a cougar (Felis concolor) was also recovered (Romanoski, 1984).

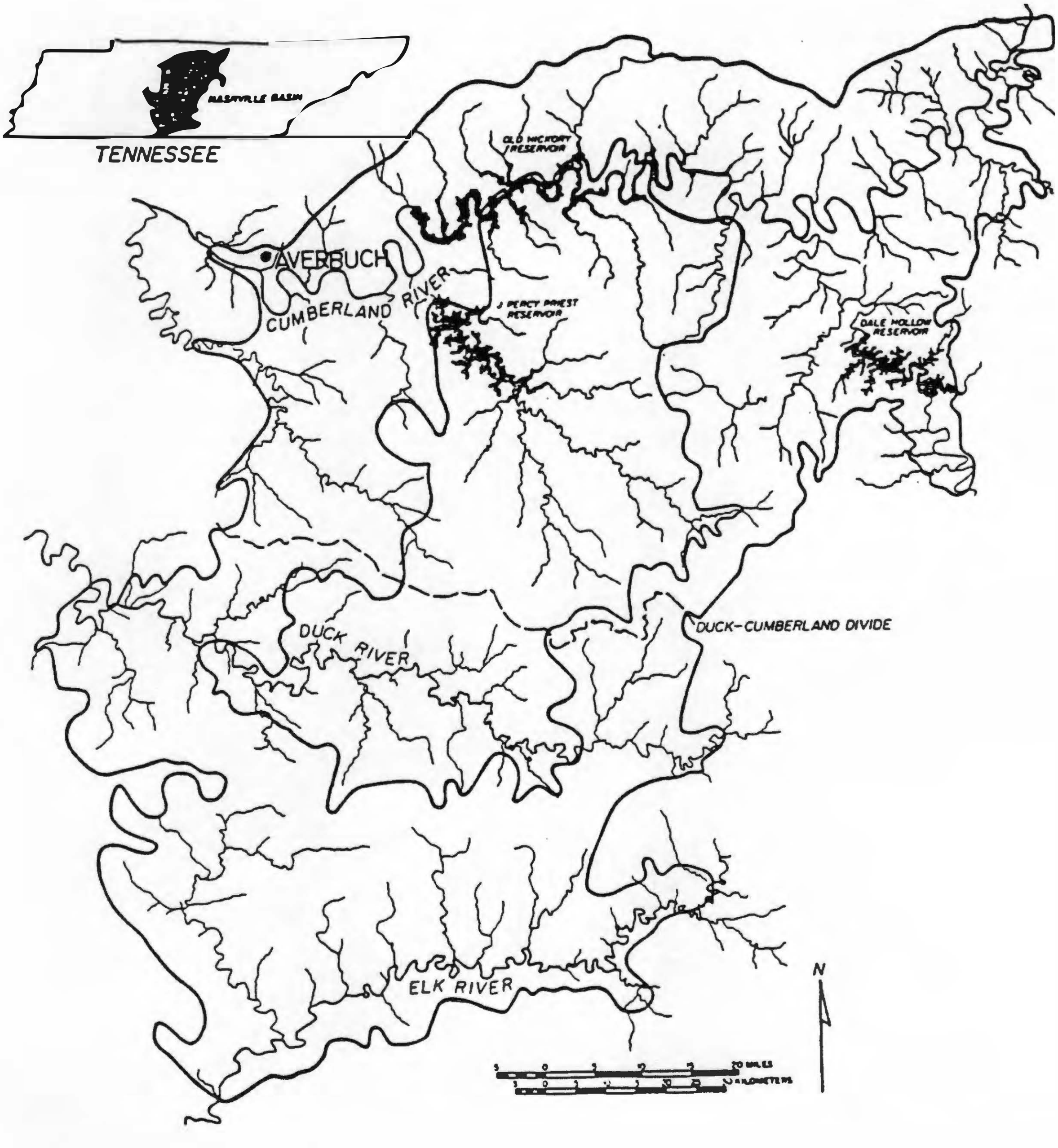

Fig. 5 Map of the Averbuch site, located within the Nashville Basin (Berryman, 1981).

Skeletal evidence indicates that this Middle Cumberland culture experienced a great deal of environmental and nutritional stress. For example, cribra orbitalia was found in nearly 20% of the population from Averbuch, while 39.07% showed signs of porotic hyperostosis (Eisenberg, 1991). Both of these pathologies are associated with iron deficiency anemia and have been linked to a diet consisting of intensive maize consumption (El-Najjar et al., 1975, 1976; Rose et al., 1984; Steinbock, 1976). According to Eisenberg (1991), of the porotic lesions found on adult individuals from Averbuch, 18.74% were active at the time of death, indicating that anemia was a problem for adults as well as children.

Ledford Island

The Ledford Island site (40BY13 [16BY13]) is a Late Mississippian Mouse Creek Phase village site located on an island in the Hiwassee River approximately $1^1/_2$ miles down from the confluence with North Mouse Creek, in East Tennessee (Fig. 3, p. 37) (Boyd, 1984). The site has been dated at between 1420 and 1470 A.D.

The 462 burials associated with this site were found in groups both in and around house structures, as well as clustered in an area east of the village, near the bank of the river (Fairbanks and Lidberg, 1938). Of the 462 burials recovered from this site, 16 were used within this study.

The incidence of pathologies for the skeletal series from Ledford Island suggests that this population was somewhat healthier than Averbuch. For example, 11.66% of the population exhibited caries and/or absesses, 8.97% had periostitis, 7.18% suffered from an unidentified bone deformity, and 15.7% of the population were found to have porotic hyperostosis and/or cribra orbitalia (Boyd, 1984).

Rymer

Rymer (40BY11 [15BY11]) is another Mouse Creek Phase site situated along the Hiwassee River, a mile above the mouth of South Mouse Creek, in East Tennessee (Fig. 3, p. 37). The Late Mississippian component of this site consists of a village with 168 associated burials, 8 of which were analyzed for the present study. Boyd (1984) writes that the location of these burials appears to have been associated with the remains of house structures, many of which had been burned.

According to Boyd (1984) individuals from Rymer showed a relatively higher incidence of disease than did those from Ledford Island. Although the incidence of several pathologies was lower for Rymer (4.3% absess/caries, and 13.98% porotic hyperostosis/cribra orbitalia), 23.66% of the individuals suffered from periostitis, and a like number from an unidentified bone deformity, an increase of 14.69% and 16.48% respectively.

Statistical Methods

Researchers conducting both inter- and intragroup comparisons of the degree of sexual dimorphism have relied on numerous statistical techniques to quantify their results. For example, Brace (1973) compared mean tooth cross-section areas for robust and gracile australopithecines, as well as several modern non-human primates. Larsen (1982, 1984) analyzed percent sexual dimorphism (+[1-$\overline{X}_f/\overline{X}_m$][100]) in his comparison of preagricultural and agricultural groups from the Georgia coast. Hamilton (1975, 1982) also used percent sexual dimorphism in her examination of samples from the Midsouth and Mexico, however, she calculated it as follows:

$$\frac{\overline{X}_1-\overline{X}_2}{\overline{X}_1}$$

In addition to percent sexual dimorphism, Hamilton utilized a dX score, a Mahalanobis D^2, as well as several analyses of variance (ANOVAs), to compare the differences in measurements within populations by sex, and the degree of sexual dimorphism between populations.

Relethford and Hodges (1985), and Greene (1989) both utilized modified *t* -tests for determining sexual dimorphism between two populations. While both of these methods can be run with only summary statistics, Greene feels that his test is more similar to conventional *t* -tests and is thus easier to use. In a related article, Konigsberg (1991) states that the latter two tests are actually two-way unbalanced ANOVAs, which can be converted into multivariate analyses of variance (MANOVAs) for use with more than two populations. Key and Jantz (1981), also use the MANOVA test to compare temporal change in Arikara crania.

Data collected in this study were analyzed using both the SAS and SYSTAT statistical systems. As stated previously, the sample was limited to those individuals with skeletal elements complete enough for all required measurements to be taken, thus, avoiding statistically estimating values for missing data. By doing so, however, the sample size is somewhat limited.

The statistical tests applied to this data include the D^2 of Mahalanobis (1925), the MANOVA, and Burnaby's (1966) size-adjusted discriminant function. The Mahalanobis D^2, or square of the generalized distance, is used to help determine the morphological relationships between groups utilizing multiple measurements. The MANOVA procedure allows for a comparison of inter- and intragroup variation using more than two populations. In this study, the procedure will test for significance by gender, by time, and by gender*time. Finally, Burnaby's size-adjusted discriminant function is used to determine whether variation exists that is shape-related. Thus in this study, the size differences between males and females from each time period are compared, and size- and shape-related differences are discriminated.

Chapter 4

RESULTS

The data from this study were subjected to a series of multivariate statistical analyses to determine whether or not a significant difference exists in the degree of sexual dimorphism of populations from the Archaic, Woodland, and Mississippian Periods. It has been hypothesized that the shift in subsistence from hunting and gathering to agriculture would cause a decreased level of sexual dimorphism, due to increased nutritional and disease-related stress. The results of this study show that certain changes do exist in the dimensions of long bones for these three Amerindian groups, as has been previously demonstrated by Hamilton (1975, 1982), and that some of these changes are shape-related rather than size-related.

A Mahalanobis D^2 (on log data) was utilized first as a means of ascertaining the distance between samples (classified by gender and Period) (Table 1). This indicates that the Archaic males and females have the greatest distance (11.48679), followed by the Mississippian males and females (10.91249), and finally the Woodland males and females (10.71245). Since the Mahalanobis D^2 does not provide information as to exactly how the genders in each time period differ, other statistical procedures were utilized.

Three MANOVAs were run to determine the significance of measurement variation for gender from these three time periods. Significance was assessed at the $p=0.05$ level. When gender and time

TABLE 1. Mahalanobis distance matrix (log scale) for Archaic, Woodland, and Mississippian males and females.

	Arch. F.	**Wood. F.**	**Miss. F.**	**Arch. M.**	**Wood. M.**	**Miss. M.**
Arch. F.	0.00000	3.80029	2.37381	11.48679	17.27765	16.29284
Wood. F.	3.80029	0.00000	1.74167	8.78015	10.71245	13.36563
Miss. F.	2.37381	1.74167	0.00000	8.35574	10.95981	10.91249
Arch. M.	**11.48679**	8.78015	8.35574	0.00000	2.62513	2.58490
Wood. M.	17.27765	**10.71245**	10.95981	2.62513	0.00000	4.63140
Miss. M.	16.29284	13.36563	**10.91249**	2.58490	4.63140	0.00000

period are crossed, there is a significant interaction (p=0.0015) (Table 2). Out of the 8 measurements utilized in this test, only the M-L diameter of the tibia at the nutrient foramen shows significance (p=0.0252). The next closest value is that of the M-L diameter of the femur at midshaft, however it is not significant at the level determined for this study (p=0.0774). The other p-values, which are all insignificant, range from 0.1724 to 0.9027 (Table 2).

A comparison of sexual dimorphism in the Mississippian group to the pooled sexual dimorphism from Archaic and Woodland Period groups also produces a significant difference (p=0.0011) (Table 3). In this test, both the tibia M-L diameter at the nutrient foramen (p=0.0318), and the femur M-L diameter at midshaft (p=0.0272) are significant. All of the other measurements have insignificant p-values, ranging from 0.1139 to 0.9602 (Table 3).

When Woodland and Mississippian groups are pooled and compared with the Archaic group, the difference in the degree of sexual dimorphism is not significant (p=0.1302), nor are the p-values of the individual measurements (Table 4). These values range from 0.1111 to 0.9438.

Following this, a Burnaby's size-adjusted discriminant function was utilized to separate out the effects of size and shape for these measurements. The results of this procedure indicate that there is a decrease in size-related sexual dimorphism for the Mississippian group (Table 5). A plot of size coordinates from this test (Fig. 6) illustrates the decreased size dimorphism for the agriculturalists. This plot also shows that the Woodland Period males and females

TABLE 2. Analysis of Variance (ANOVA) test for individual variables, and Multivariate Analysis of Variance (MANOVA) test for sex by time interaction.

Univariate F Tests

Variable	SS	DF	MS	F	P
Femur length	882.1733	2	441.0867	1.4364	0.2405
ERROR	55582.7639	181	307.0871		
Tibia length	152.9078	2	76.4539	0.3539	0.7024
ERROR	39100.0725	181	216.0225		
Humerus head	1.0000	2	0.5000	0.1024	0.9027
ERROR	884.0636	181	4.8843		
Femur head	13.9474	2	6.9737	1.7749	0.1724
ERROR	711.1806	181	3.9292		
Femur A-P	14.5077	2	7.2539	1.3755	0.2554
ERROR	954.5541	181	5.2738		
Femur M-L	15.3099	2	7.6549	2.5951	0.0774
ERROR	533.9004	181	2.9497		
Tibia A-P	9.0269	2	4.5134	0.6740	0.5109
ERROR	1212.0963	181	6.6967		
Tibia M-L	33.1037	2	16.5519	3.7559	0.0252
ERROR	797.6401	181	4.4069		

Multivariate Test Statistics

Wilks' Lambda = 0.8072
F-Statistic = 2.4590
DF = 16, 348
Probability = 0.0015

TABLE 3. Analysis of Variance (ANOVA) test for individual variables, and Multivariate Analysis of Variance (MANOVA) test for significance comparing Mississippian group with pooled Archaic/Woodland groups.

Univariate F Tests

Variable	SS	DF	MS	F	P
Femur length	774.9018	1	774.9018	2.5234	0.1139
ERROR	55582.7639	181	307.0871		
Tibia length	151.5276	1	151.5276	0.7014	0.4034
ERROR	39100.0725	181	216.0225		
Humerus head	0.0122	1	0.0122	0.0025	0.9602
ERROR	884.0636	181	4.8843		
Femur head	8.1429	1	8.1429	2.0724	0.1517
ERROR	711.1806	181	3.9292		
Femur A-P	5.0271	1	5.0271	0.9532	0.3302
ERROR	954.5541	181	5.2738		
Femur M-L	14.6292	1	14.6292	4.9595	0.0272
ERROR	522.9004	181	2.9497		
Tibia A-P	4.5395	1	4.5393	0.6779	0.4114
ERROR	1212.0963	181	6.6967		
Tibia M-L	20.6330	1	20.6330	4.6820	0.0318
ERROR	797.6401	181	4.4069		

Multivariate Test Statistics

Wilks' Lambda = 0.9318
F-Statistic = 1.5920
DF = 8, 174
Probability = 0.1302

TABLE 4. Analysis of Variance (ANOVA) test for individual variables, and Multivariate Analysis of Variance (MANOVA) test for significance comparing Archaic group with pooled Woodland/Mississippian groups.

Univariate F Tests

Variable	SS	DF	MS	F	P
Femur length	1.5320	1	1.5320	0.0050	0.9438
ERROR	55582.7639	181	307.0871		
Tibia length	24.2576	1	24.2576	0.1123	0.7379
ERROR	39100.0725	181	216.0225		
Humerus head	0.8300	1	0.8300	0.1699	0.6807
ERROR	884.0636	181	4.8843		
Femur head	10.0733	1	10.0733	2.5637	0.1111
ERROR	711.1806	181	3.9292		
Femur A-P	13.1162	1	13.1162	2.4871	0.1165
ERROR	954.5541	181	5.2738		
Femur M-L	3.8721	1	3.8721	1.3127	0.2534
ERROR	533.9004	181	2.9497		
Tibia A-P	7.1478	1	7.1478	1.0674	0.3029
ERROR	1212.0963	181	6.6967		
Tibia M-L	3.8142	1	3.8142	0.8655	0.3534
ERROR	797.6401	181	4.4069		

Multivariate Test Statistics

Wilks' Lambda = 0.8634
F-Statistic = 3.4406
DF = 8, 174
Probability = 0.0011

TABLE 5. Burnaby's distance matrix (log scale) separating out size for Archaic, Woodland, and Mississippian males and females.

	Arch. F.	**Wood. F.**	**Miss. F.**	**Arch. M.**	**Wood. M.**	**Miss. M.**
Arch. F.	0.00000	0.73006	1.54606	6.72783	12.16058	11.81161
Wood. F.	0.73006	0.00000	0.15130	3.02541	6.93146	6.66862
Miss. F.	1.54606	0.15130	0.00000	1.82358	5.03461	4.81098
Arch. M.	**6.72783**	3.02541	1.82358	0.00000	0.79816	0.71064
Wood. M.	12.16058	**6.93146**	5.03461	0.79816	0.00000	0.00254
Miss. M.	11.81161	6.66862	**4.81098**	0.71064	0.00254	0.00000

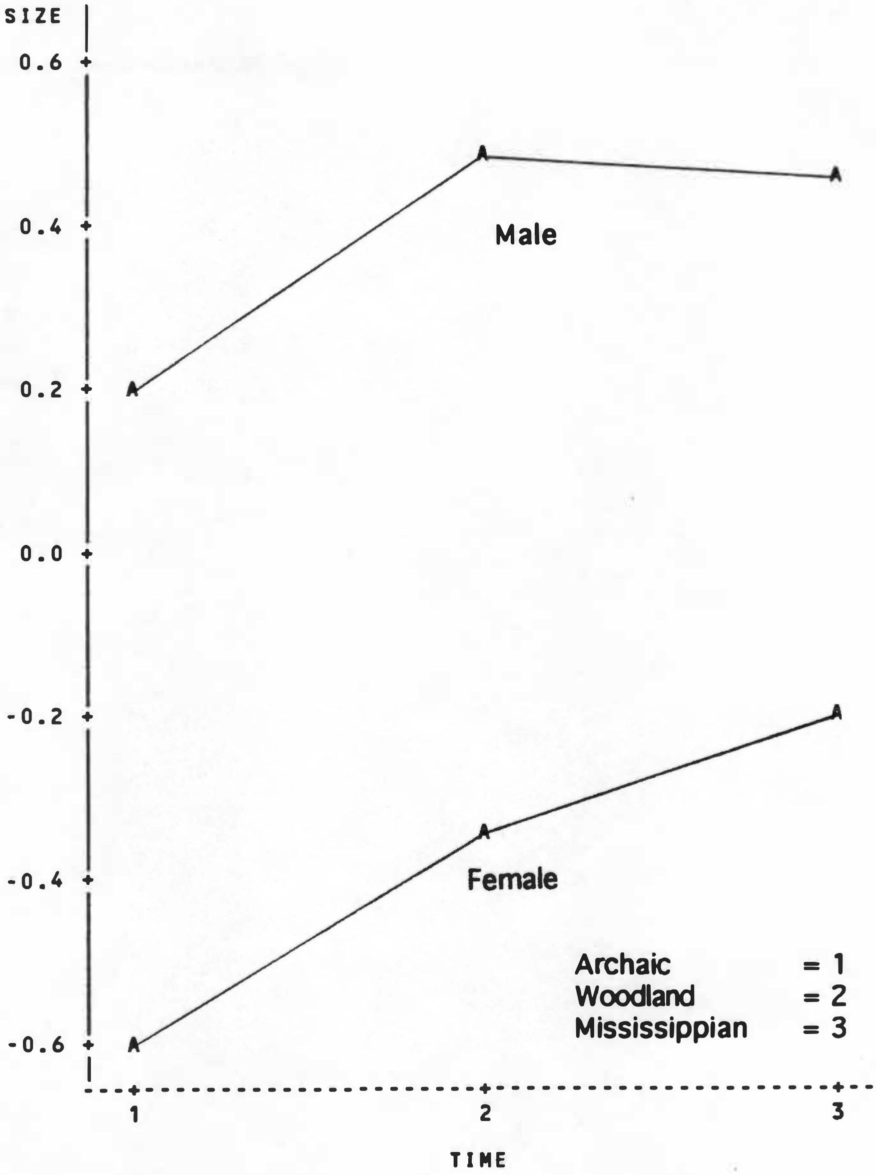

Fig. 6 Plot of Burnaby's size coordinates showing decreased size dimorphism for Mississippian males and females and increased size dimorphism for Woodland males and females.

have the greatest degree of size dimorphism of the three groups. This could indicate that there was an improvement of overall health during this time. It is possible, however, that the results may be caused by a small sample size.

The Burnaby's size-adjusted discriminant function also indicates that there is an increase in the degree of sexual dimorphism for shape (Table 6). A plot of shape coordinates (Fig. 7) shows a similar pattern for Archaic and Woodland groups, with Mississipian groups exhibiting marked change from the former two. One area exhibiting a great deal of shape change over time is the diaphysis of the tibia. A plot of tibia A-P and M-L measurements (Fig. 8) illustrates that for females, the tibial diaphysis gets relatively broader A-P and narrower M-L over time, while for males, the diaphysis gets relatively narrower A-P and broader M-L over time. These changing dimensions correspond to an increase in shape-related sexual dimorphism over time.

The least square means of each measurement were plotted to help show the size differences between males and females from each time period. These plots do not assess significance, but give an indication of overall trends. There is decreased dimorphism for femur length (Fig. 9), tibia length (Fig. 10), femur A-P (Fig. 11), tibia A-P (Fig. 12), and tibia M-L (Fig. 13) for the Mississippian group. Increases in sexual dimorphism exist for femoral head (Fig. 14), and femur M-L (Fig. 15) for the Mississippian group. The Woodland Period group shows increased sexual dimorphism for humeral head (Fig. 16), femur length (Fig. 9), and tibia M-L (Fig. 13).

TABLE 6. Burnaby's distance matrix (log scale) separating out shape for Archaic, Woodland, and Mississippian males and females.

	Arch. F.	**Wood. F.**	**Miss. F.**	**Arch. M.**	**Wood. M.**	**Miss. M.**
Arch. F.	0.00000	3.07023	0.82774	4.75895	5.11707	4.48123
Wood. F.	3.07023	0.00000	1.59037	5.75473	3.78099	6.69701
Miss. F.	0.82774	1.59037	0.00000	6.53216	5.92520	6.10151
Arch. M.	**4.75895**	5.75473	6.53216	0.00000	1.82698	1.87426
Wood. M.	5.11707	**3.78099**	5.92520	1.82698	0.00000	4.62886
Miss. M.	4.48123	6.69701	**6.10151**	1.87426	4.62886	0.00000

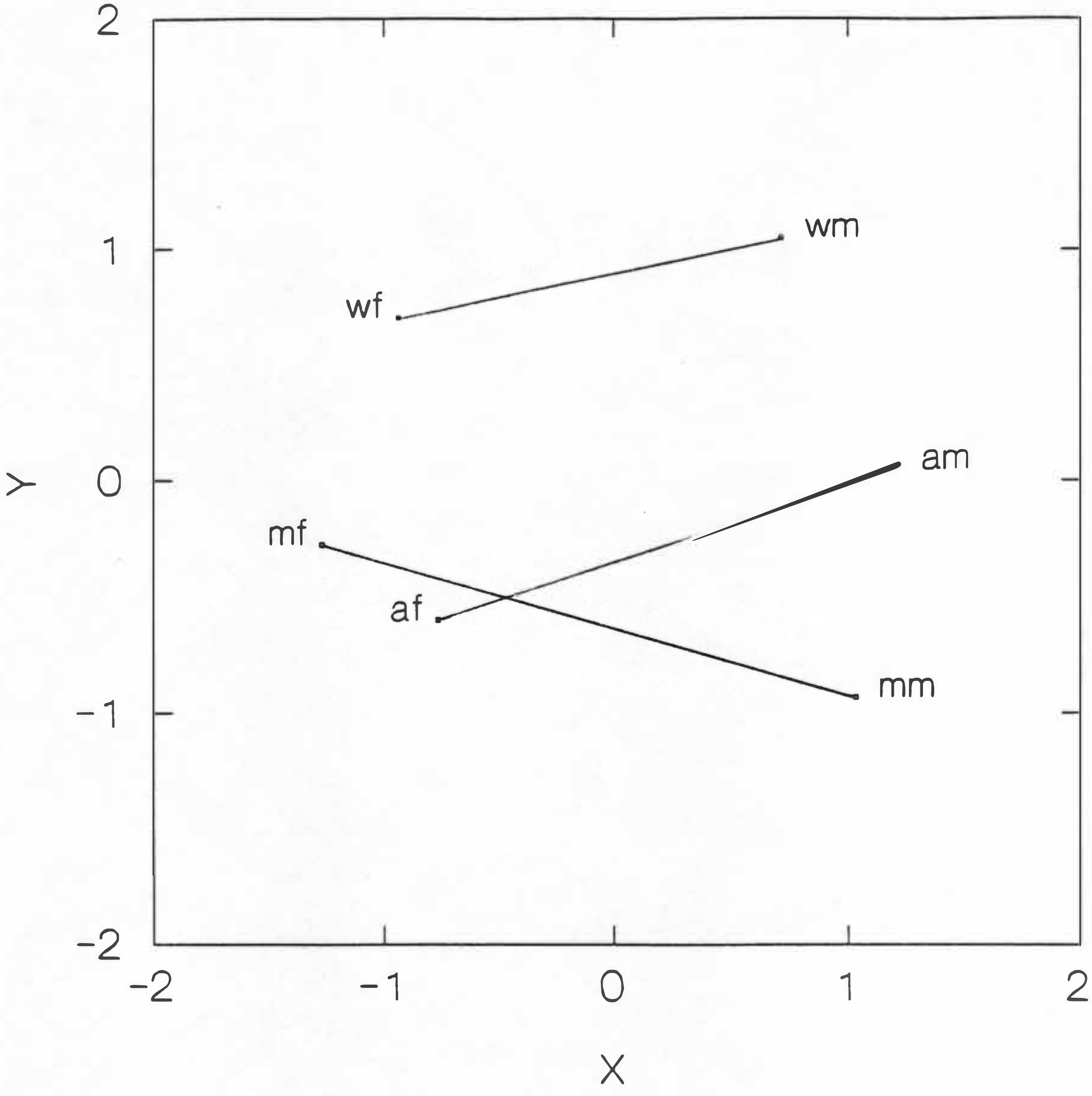

Fig. 7 Plot of Burnaby's shape coordinates showing dissimilarity of Mississippian group to other groups.

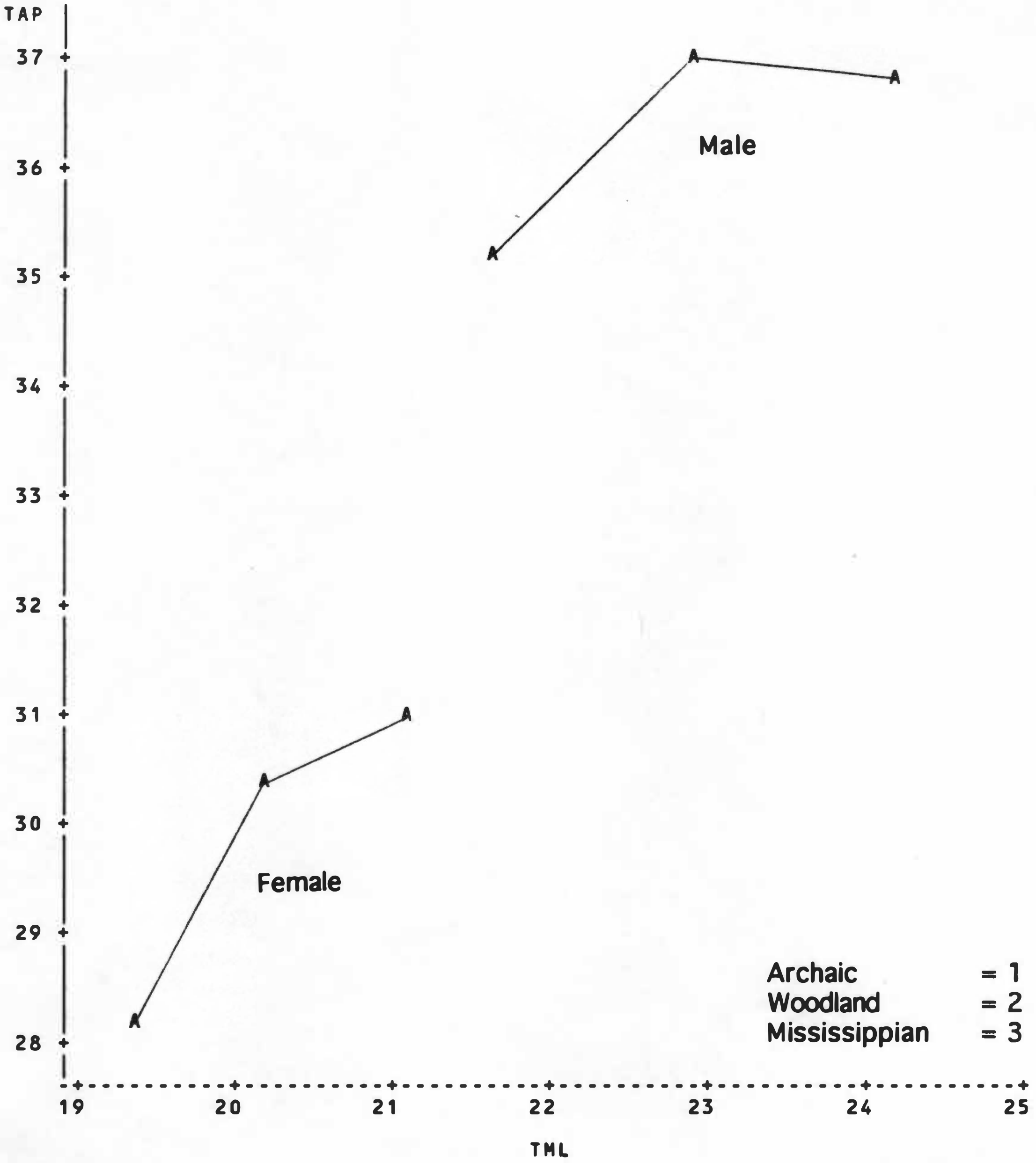

Fig. 8 Plot of tibia A-P and M-L measurements showing an increase in the degree of shape-related sexual dimorphism for Mississippian males and females.

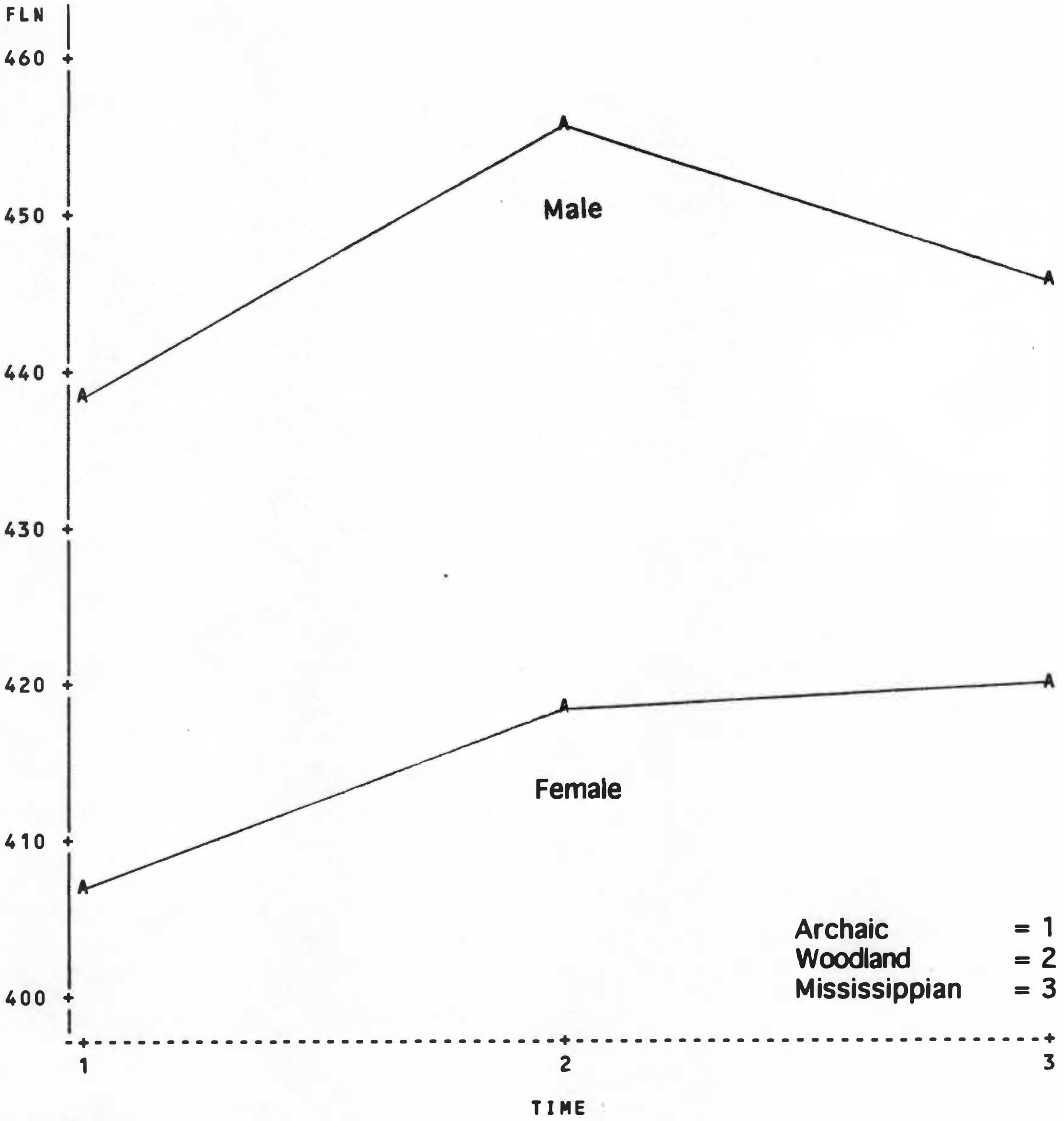

Fig. 9 Plot of femur length by time period showing a decrease in sexual dimorphism for the Mississippian Period group.

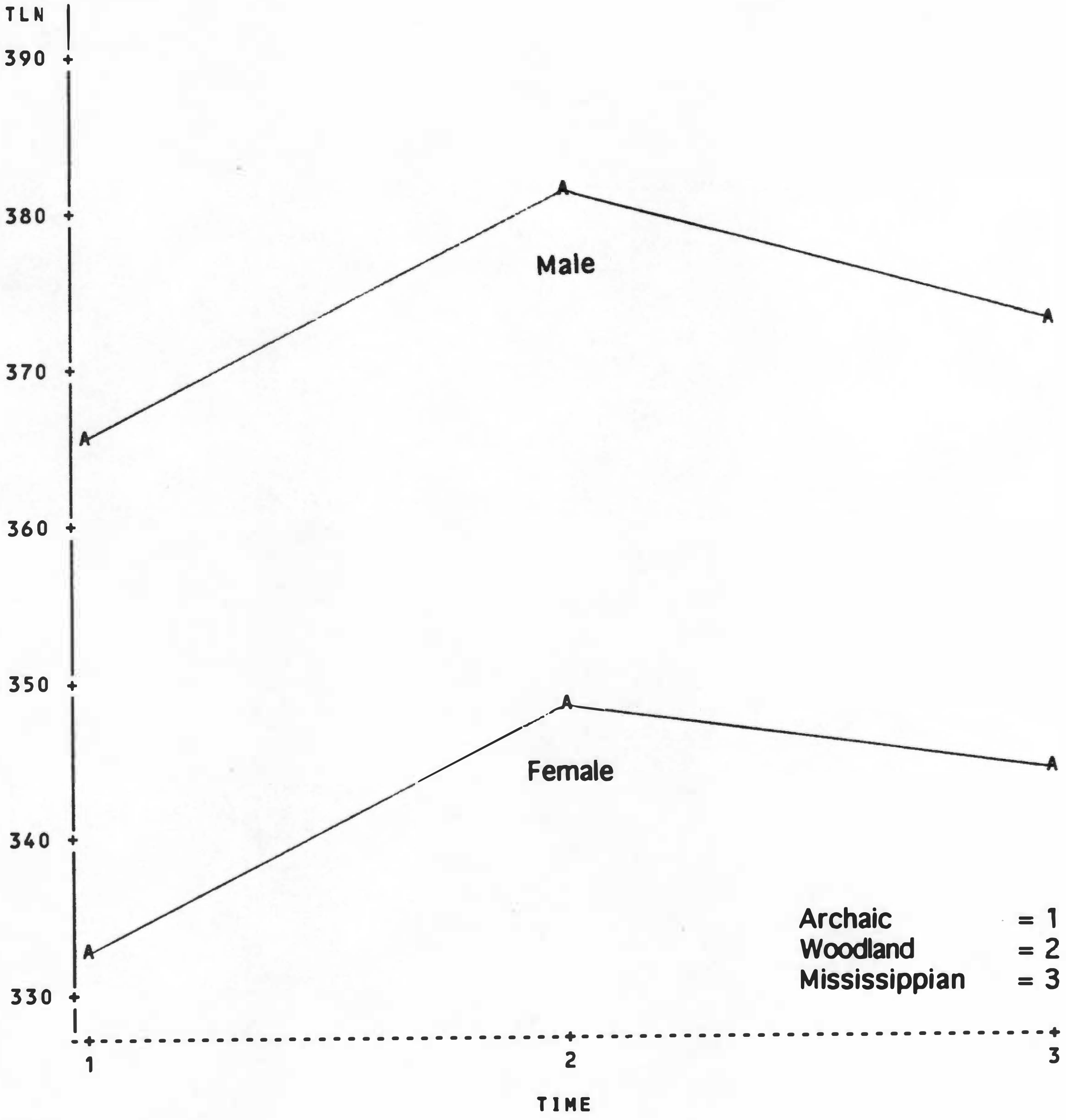

Fig. 10 Plot of tibia length by time period illustrating a slight decrease in sexual dimorphism for the Mississippian group.

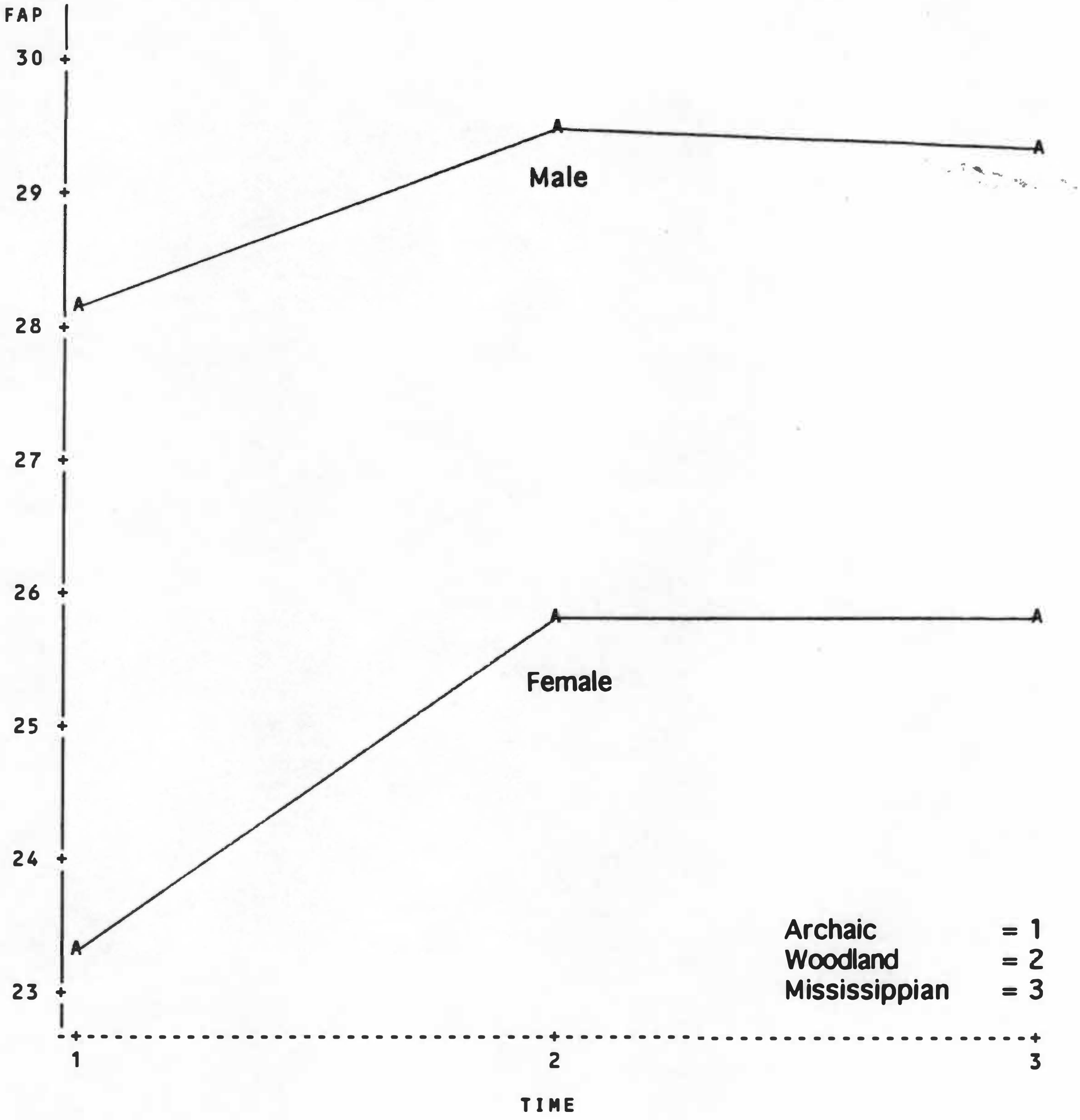

Fig. 11 Plot of femur A-P diameter by time period illustrating a decrease in sexual dimorphism for the Mississippian group.

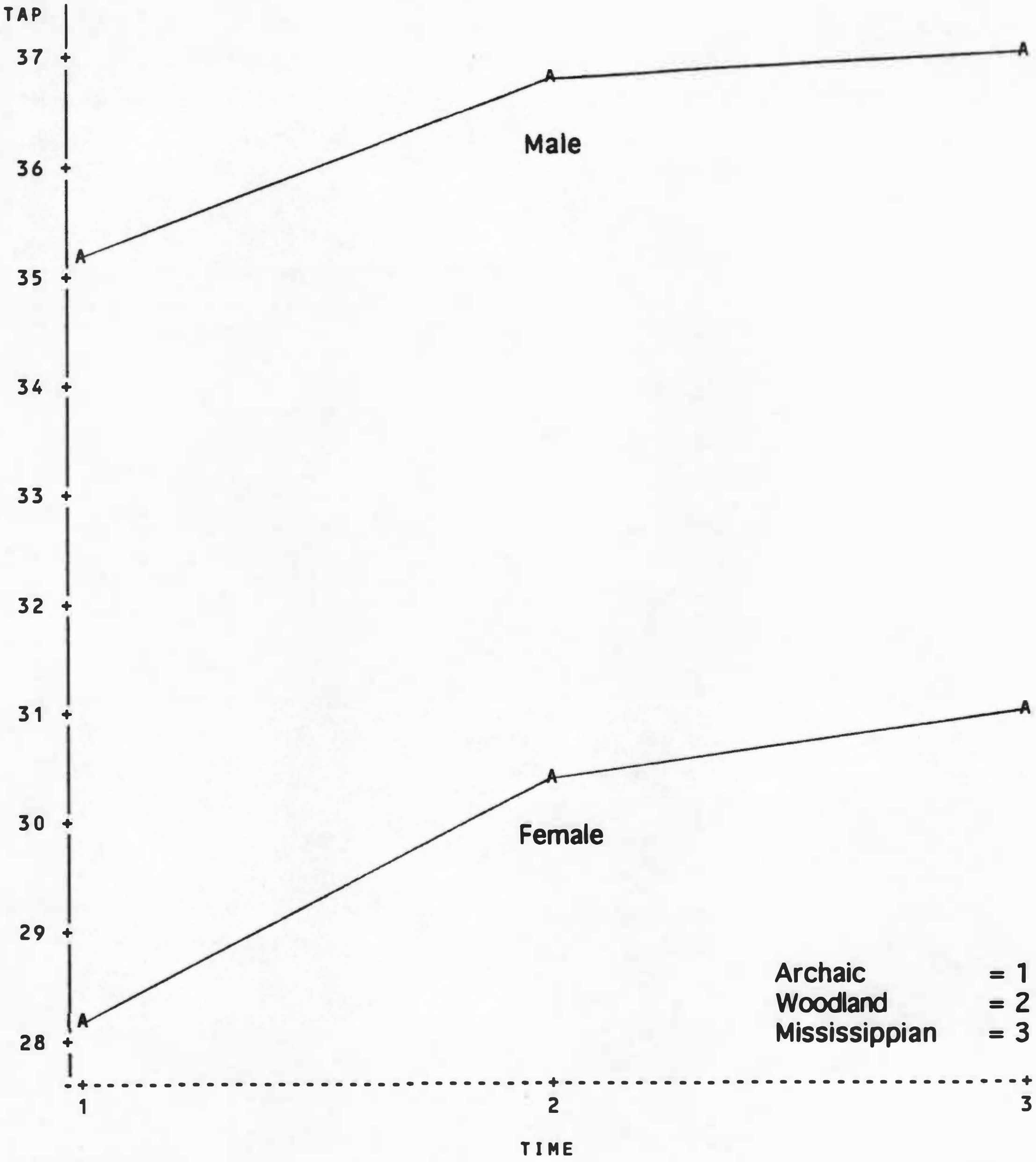

Fig. 12 Plot of tibia A-P diameter by time period showing a decrease in sexual dimorphism for the Mississippian sample.

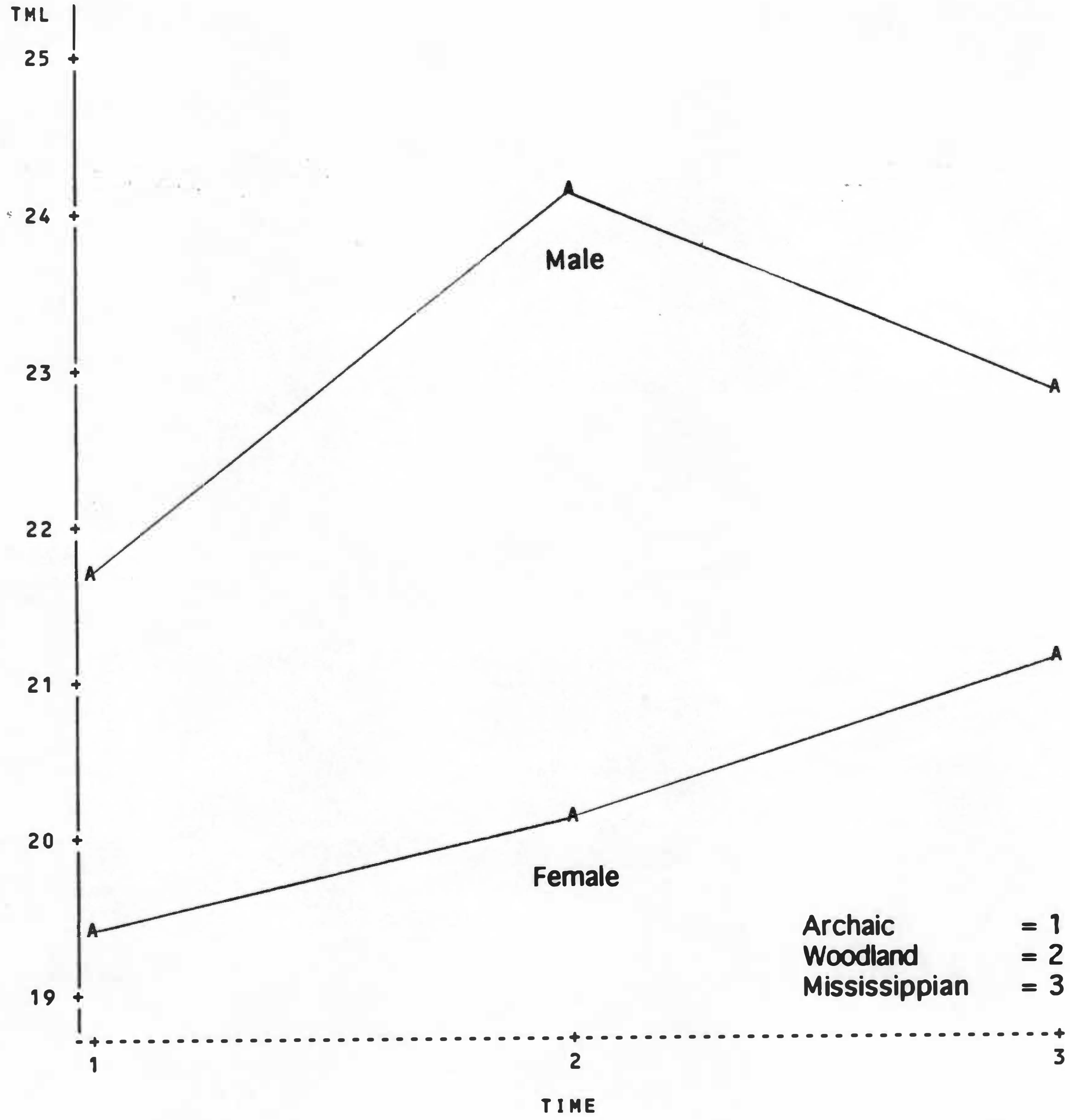

Fig. 13 Plot of tibia M-L diameter by time period showing both an increase in sexual dimorphism for the Woodland Period group, and a decrease in sexual dimorphism for the Mississippian Period group.

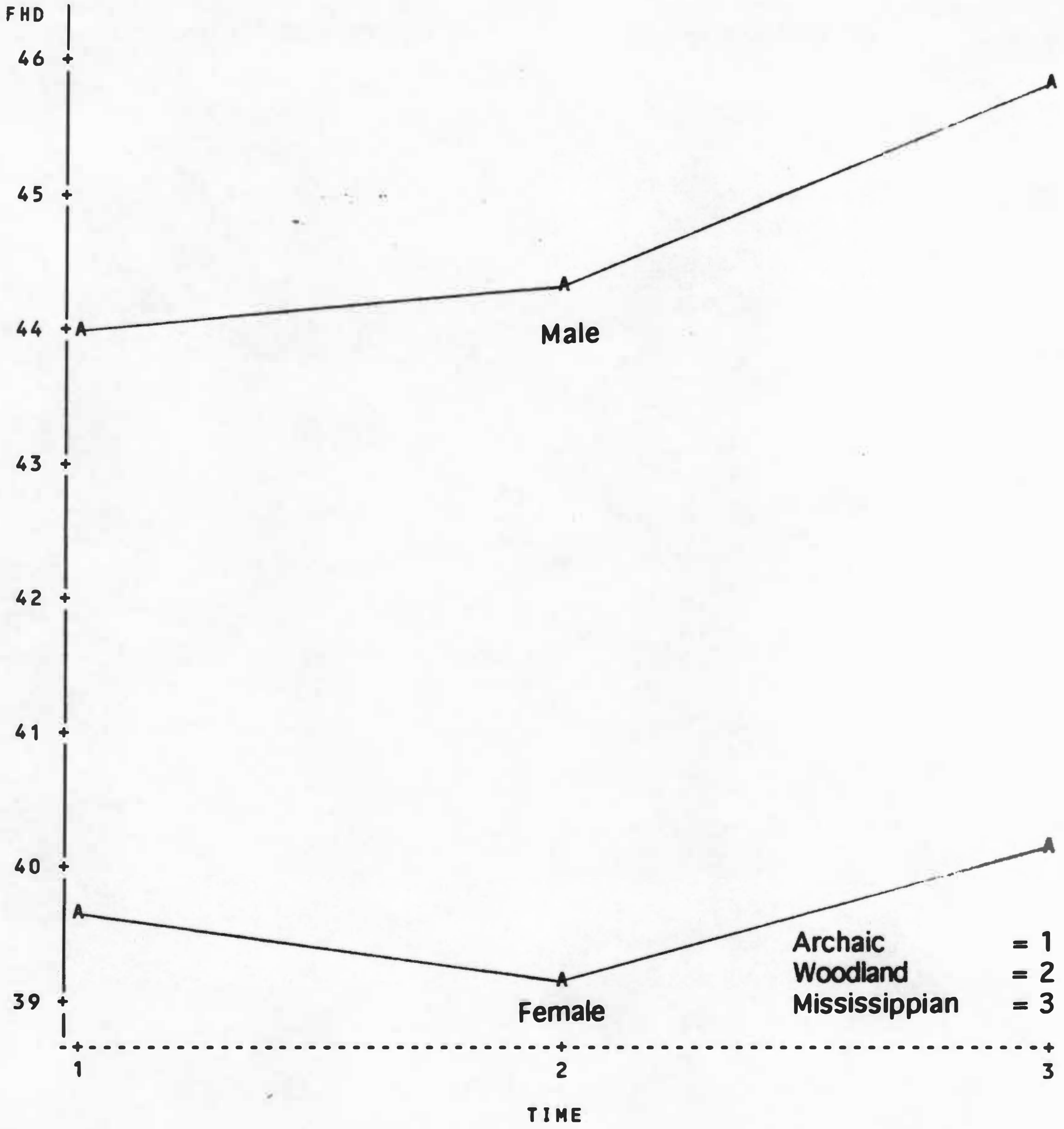

Fig. 14 Plot of maximum femoral head diameter by time period showing an increase in sexual dimorphism for the Mississippian sample.

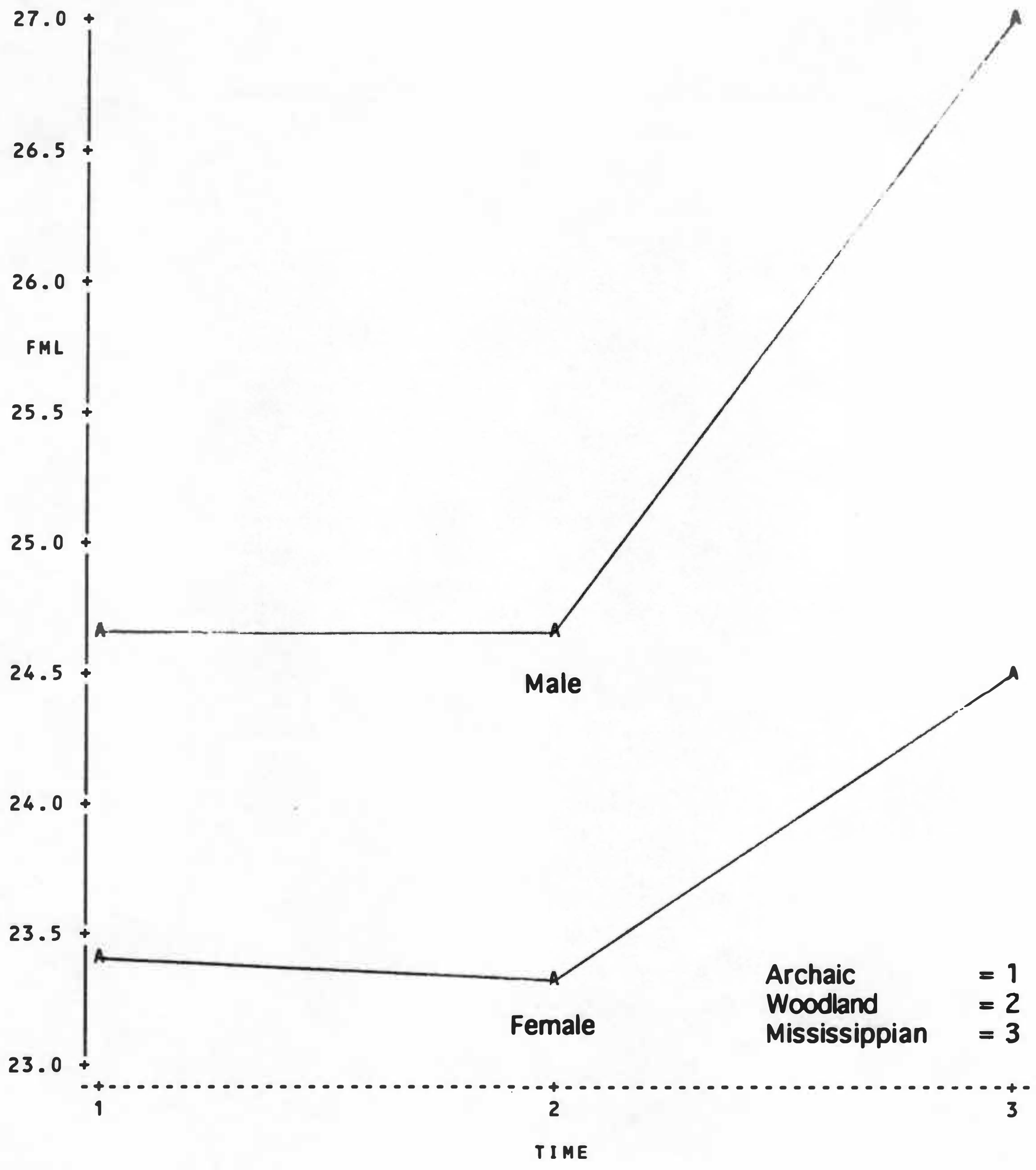

Fig. 15 Plot of femur M-L diameter by time period showing an increased degree of sexual dimorphism for Mississippian males and females.

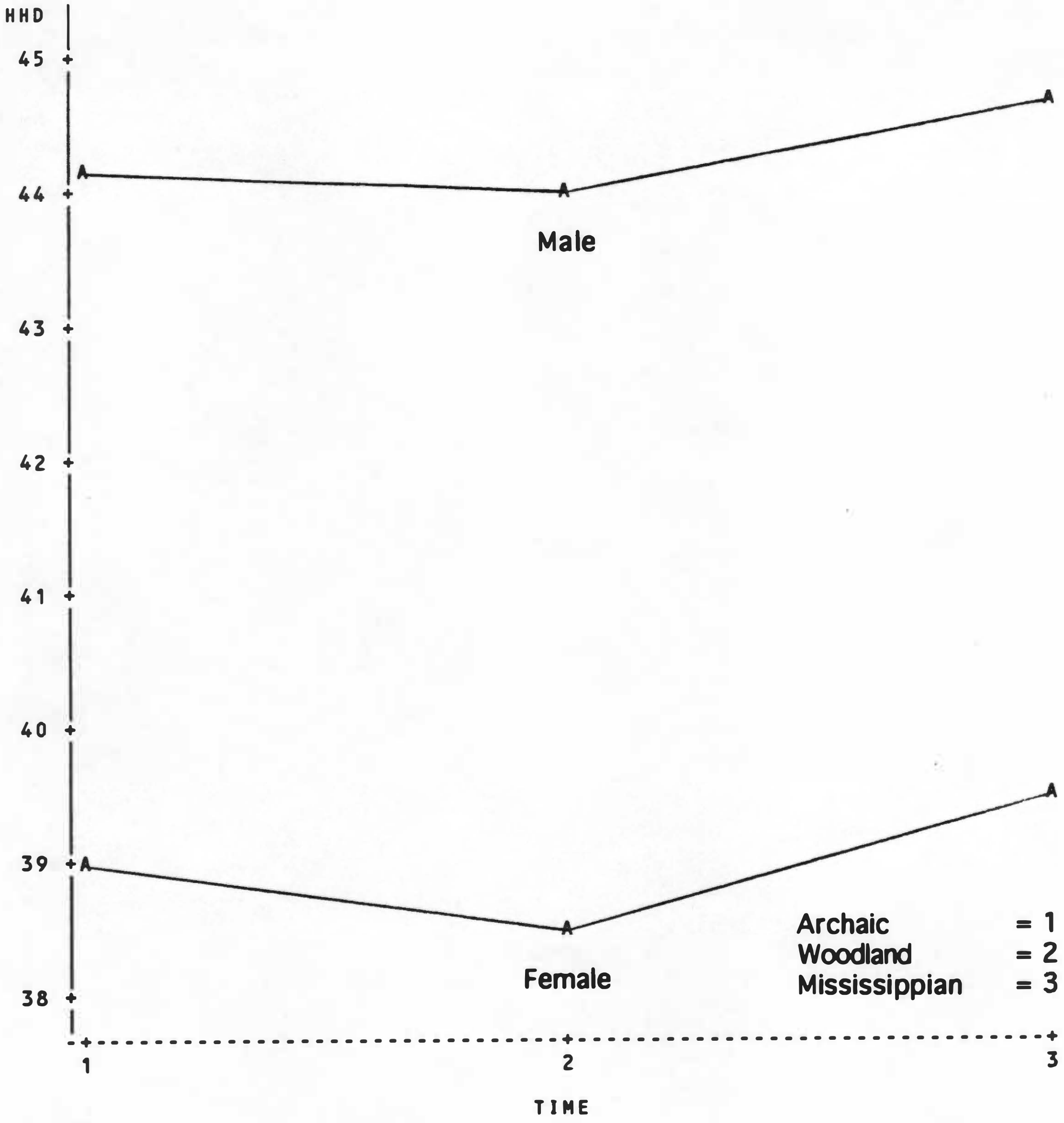

Fig. 16 Plot of maximum humeral head diameter by time period showing an increase in sexual dimorphism for the Woodland Period group.

Another test was conducted to determine whether or not there is a size increase for each gender over time, using the same methods described above. It was determined that there are significant differences in size when comparing Archaic, Woodland, and Mississippian females. The same is true for Archaic and Mississippian males, though the Woodland Period males are slightly larger than Mississippian Period males. The latter results may be due to the small size of the Woodland Period sample.

Chapter 5

DISCUSSION AND CONCLUSIONS

Discussion

This study's findings suggest that the degree of size-related sexual dimorphism in Mississippian populations is less than either Archaic or Woodland Period groups. These results are consistent with those of other researchers that have compared groups suffering from nutritional and/or disease-related stress with healthy groups (e.g., Greulich, 1951; Hamilton, 1975; Scrimshaw and Behar, 1965; Stini, 1969, 1972). There is also an increase in shape-related sexual dimorphism for the Mississippian Period group over the other two groups in this study. In addition, a trend exists for increased physical size of both males and females from earlier to later time periods.

Both long- and short-term deficiencies in dietary intake have been shown to effect growth rates in children. Although short-term periods of nutritional stress can slow the rate of growth, catch-up growth often occurs when stress is eliminated (Prader et al., 1963; Stini, 1971, 1985). Seasonal stress may well have existed in the Archaic and Woodland Periods that could have caused periods of slowed growth, as has been suggested by Cook (1984). This would probably have occurred in the late winter months, when game was scarce and stored food supplies were low.

Long-term, or chronic, nutritional stress often occurs in areas of high population density. It is therefore usually associated with an increased incidence of disease and parasites which can worsen an individual's physical condition. Chronic nutritional stress often does not allow for enough catch-up growth for individuals to attain their growth potential (Eveleth, 1975; Greulich, 1951, 1957; Scrimshaw and Behar, 1965; Scrimshaw et al., 1968; Stini, 1969, 1972). In fact, if stress is severe enough, growth may cease altogther (Young and Scrimshaw, 1971). Mississippian groups in the Southeast extensively utilized maize as a dietary resource, and often lived in villages having high population densities. Their diet, however, also included smaller amounts of meat, fish, nuts, and a variety of cultivated seeds. Therefore, although there was enough environmental stress for growth rates to have been significantly affected, the health of these people could have been much worse.

The decreased amount of sexual dimorphism for size among Mississippian groups in this study is contrary to the results of both Boyd and Boyd (1989) and Larsen (1982). Boyd and Boyd, who utilized many of the same skeletal series as the present study, state that there is no significant decrease in size-related sexual dimorphism among their agricultural group. The present results may differ in that measurements from the tibia and humerus were also included, the tibial M-L measurement of which proved to show significant difference. The present study also utilized samples from the Early and Middle Woodland Periods, neither of which were included in Boyd and Boyd's study. Finally, the statistical procedures utilized in the present study are superior to those of both Boyd and Boyd, thus allowing for more accurate results.

Larsen's (1982) study indicates that there is an increase in the degree of size-related sexual dimorphism for agricultural groups from the Georgia coast. He believes these results indicate males had more access to protein than females within the St. Catherines agricultural group, thus causing a decrease in the size of females relative to males. The decrease in sexual dimorphism found in this study is proposed to stem from increased levels of stress, which caused a decrease in the size of males relative to females. Although the samples from both studies are from the same geographical region, they are widely separated. This may explain the conflicting results.

The main objective of this study was to test for size-related dimorphism in preagricultural and agricultural groups. The statistical tests conducted have shown that shape dimorphism also needs to be taken into account. Research by Ruff (1987, 1992) and Bridges (1989, 1991) on femur and tibia cross-sections indicates that shape differences occur in Southeastern groups that are linked to subsistence-related activity patterns. Ruff believes that intensive maize agriculture limited the amount of work for males, due to a decreased reliance on hunting. Bridges states that females in prehistoric agricultural societies were subjected to an increased workload. The consequence of both interpretations is the same: A decrease in the degree of sexual dimorphism for shape.

The results of Ruff (1987, 1992) and Bridges (1989, 1991) are exactly opposite of those found in this study. The degree of shape dimorphism present in the bones analyzed in all of these studies thus appears to be dependent on the measurements being compared. In this study, the femoral head, length, and midshaft diameters were used, and the tibial length and diameters at the nutrient foramen were taken. These measurements do not determine the exact dimension of a diaphysis at a specific location on the bone, or establish cortical bone thickness, as in Bridges' (1989, 1991) and Ruff's (1987, 1992) research. They do, however, provide a good indicator of the variation in overall bone shape when a Burnaby's discriminant function is applied to the data. In summary, the conflicting results of these studies may be due to the different procedures used to anlayze shape, and the statistical tests that examine the differences in sexual dimorphism.

An increase in the overall size of Mississippian male and female skeletal elements has also been observed in this study. Similar findings have been noted by Boyd and Boyd (1989) using femora alone, although, as noted above, several of the skeletal assemblages in their sample were also utilized in the present study. Larsen (1982) determined that for agricultural groups on St. Catherines Island there is a significant size decrease in the vast majority of measurements compared with preagricultural groups. For example, male femora and tibiae from his agricultural sample show a 3.4% and 4.8% reduction (respectively) over preagricultural groups, and females are reduced 5.9% and 6.3%. Larsen attributes these findings to a decreased functional demand on the musculo-skeletal system as a result of sedentism.

The increased size of Mississippian males and females in this study is proposed to be the result of heavier workloads required with maize agriculture. Bridges (1989, 1991) and Ruff (1987, 1992) each associate the increased size of Mississippian skeletal remains in their samples with labor-intensive agricultural practices. Such tasks include clearing fields, planting, harvesting, and grinding corn, all of which require extensive physical effort. Larsen's proposal that a sedentary agricultural lifestyle is less ardurous than a hunter/gatherer lifestyle thus seems unrealistic when considering such demanding subsistence-related tasks.

Conclusion

When conducting a skeletal analysis it is always important to take into consideration the amount of sexual dimorphism that exists for that particular population. This is especially crucial when estimating the gender of individuals. Because the majority of techniques devised to establish the gender of skeletal remains do so on the basis of size, it is easy to misclassify males as females, or vice versa, depending on the reference sample initially used to develop that technique. It is therefore best to utilize a method based on shape dimorphism, such as the Phenice (1969) technique. Once a reference sample has been established for gender according to that method, it is then possible to determine the amount of sexual dimorphism present. This will, in turn, allow the researcher to use size-specific sexing methods with much greater accuracy.

This study has been concerned with determining the degree to which sexual dimorphism in skeletal populations is affected by changing subsistence strategies. Eight measurements were taken from the postcranial skeletal remains of adult males and females from 17 Southeastern archaeological sites. The skeletal sample was separated into 3 groups according to time period and subsistence strategy: Middle/Late Archaic (hunter/gatherer), Early/Middle Woodland (mixed hunter/gatherer/horticultural), and Late Mississippian (intensive agricultural). The degree of sexual dimorphism for each group was then compared using a combination of multivariate and univariate statistical analyses. These tests revealed a significant decrease in size-related sexual dimorphism, a significant increase in shape-related sexual dimorphism, and an overall significant increase in size for males and females over time.

Research conducted by numerous authors (e.g., Bridges, 1991; Greulich, 1951; Hamilton, 1982; Stini, 1985) on factors affecting sexual dimorphism reveal the complexity of this phenomenon. Both long-term genotypic selection as well as short-term phenotypic selection exists within populations. This study has been concerned with short-term phenotypic effects that are stress-related. The length and intensity of environmental (i.e., nutritional and disease-related) stress will determine whether or not growth is slowed, and whether or not enough catch-up growth will occur to allow individuals to reach their potential adult size. Changing activity patterns can also affect the degree of sexual dimorphism, for instance, when one gender does a proportionately greater amount of work than the other.

The phenotypic response to increased stress at Averbuch, Rymer, and Ledford Island is equally complex. Decreased size dimorphism in males and females at these sites is probably due to a reduction in the male growth rate, caused by increased nutritional and disease-related stress. The amount of reduction, however, does not appear to be dramatic since only two measurements show significant change. Shape dimorphism also exists, with Mississippian groups exhibiting a greater amount of sexual dimorphism for the measurements taken. These findings appear to be the result of increased work-related activities associated with maize agriculture.

Throughout the Archaic to Mississippian time periods, prehistoric groups in the Southeastern United States developed changing subsistence strategies that allowed for increased population size. This initially came as a result of groups cultivating native plants, and later developed into an intensive use of maize as a primary food source. With these changes in subsistence came changes in the skeletal structure of the groups. In general, over time, groups got increasingly larger (even though nutritional quality declined), and some changes occurred in the shapes of the limb bones. Changes in nutrition and increased rate of disease caused decreased levels of size-related sexual dimorphism for the agriculturalists. An increased level of shape-related dimorphism accompanied the change in subsistence strategies. Further research utilizing different measurements may shed light on the morphological changes noted in this study.

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APPENDICES

APPENDIX A

Appendix A: Measurement data obtained from archaeological sites

SITE	TIME	SEX	BUR	FMLN	TIBLN	HUMHD	FMHD	FAP	FML	TAP	TML
06bn12	a	male	8	417.5	343.0	45.9	44.5	25.7	24.0	33.4	20.4
06bn12	a	male	11	439.0	369.0	45.9	45.0	27.0	26.5	33.8	21.4
06bn12	a	male	44	425.5	351.5	43.6	43.3	26.5	25.6	35.1	21.9
06bn12	a	male	51	414.0	352.0	41.0	44.1	25.9	24.7	37.3	22.1
06bn12	a	male	54	430.0	375.0	45.6	46.6	25.5	23.5	36.4	19.1
06bn12	a	male	56	441.0	361.0	44.3	45.3	27.0	22.4	33.7	19.5
06bn12	a	male	57	444.5	363.0	45.1	45.9	28.8	24.1	37.6	22.1
06bn12	a	male	62	453.0	380.0	42.8	43.1	33.9	25.1	41.5	24.5
06bn12	a	male	62	453.0	380.0	42.8	43.1	33.9	25.0	41.5	24.5
06bn12	a	fem	90	435.5	349.0	38.3	40.6	22.5	25.2	28.0	20.3
06bn12	a	fem	92	423.0	334.5	39.9	40.3	25.0	23.8	30.1	22.0
06bn12	a	male	93	417.0	342.0	41.7	43.6	28.3	24.1	33.9	20.9
06bn12	a	male	103	493.0	391.0	47.8	48.1	27.1	25.4	33.7	20.7
06bn12	a	male	105	440.0	363.0	44.1	42.0	28.9	23.5	35.6	20.5
06bn12	a	fem	107	380.0	331.0	37.9	39.4	23.7	23.4	27.3	17.2
06bn12	a	fem	115	414.0	337.0	36.2	38.3	21.7	23.9	28.9	17.9
06bn12	a	fem	127	405.0	335.0	39.9	38.2	21.9	22.5	30.2	18.4
06bn12	a	male	131	446.0	385.0	41.2	39.7	24.3	25.6	31.0	21.4
06bn12	a	male	142	452.0	373.0	45.1	43.2	28.6	23.9	36.1	21.8
06bn12	a	fem	149	404.0	324.0	40.6	41.4	23.9	24.2	30.7	17.3
06bn12	a	fem	152	403.0	327.0	40.6	40.2	21.1	24.0	27.1	18.3
06bn12	a	fem	153	388.0	316.5	36.2	37.6	22.9	22.6	26.7	18.1
06bn12	a	fem	164	420.0	345.0	38.8	39.4	26.3	24.3	29.2	20.2
06bn12	a	male	166	454.0	370.5	42.3	43.9	29.4	24.3	33.5	23.5
06bn12	a	fem	175	400.5	326.0	37.4	38.9	20.2	21.5	24.4	17.1
06bn12	a	male	179	431.0	359.0	42.1	44.3	27.4	22.9	36.8	20.5
06bn12	a	fem	182	383.0	323.5	39.1	37.5	22.9	23.6	28.1	17.7
06bn12	a	fem	193	412.0	332.0	38.0	39.4	23.4	20.8	26.0	17.7
09bn25	a	male	12	458.5	378.0	46.5	45.6	28.8	24.6	38.3	24.3
09bn25	a	male	14	460.0	371.0	47.4	48.8	31.4	29.1	41.7	25.1
09bn25	a	male	34	467.0	390.0	44.7	44.8	30.7	24.2	34.9	22.7
09bn25	a	male	40	438.0	376.0	47.4	46.0	30.3	24.4	37.3	21.5
09bn25	a	male	64	446.0	373.0	45.0	45.0	26.5	23.9	36.1	22.9
09bn25	a	fem	81	401.0	343.0	40.9	42.0	26.8	24.8	37.0	25.3
09bn25	a	male	91	464.0	378.0	46.9	46.5	29.7	26.4	32.8	23.6
09bn25	a	fem	96	404.5	338.5	37.0	40.0	24.9	24.2	31.5	22.8
09bn25	a	male	116	441.0	371.0	45.8	45.2	27.7	26.6	33.3	21.6
15hy13	a	fem	22	404.5	330.0	39.0	38.5	25.0	22.5	28.5	20.0
15hy13	a	male	37	422.0	344.0	44.5	43.5	27.0	26.0	31.0	21.0
15hy13	a	male	54	422.0	360.5	43.5	41.0	29.5	22.0	33.0	22.0
15hy13	a	male	68	429.0	343.0	43.0	44.0	28.0	26.0	36.0	21.5
15hy13	a	male	70	425.0	356.0	42.5	43.0	30.0	24.5	35.5	20.5
25hy18	a	male	29	414.0	335.5	39.5	39.5	25.0	23.0	31.0	18.5
25hy18	a	male	32	444.0	371.5	49.0	44.5	29.0	25.5	38.0	19.5
25hy18	a	male	53	432.5	371.0	43.5	43.5	29.0	24.5	33.5	22.0
40wm09	a	fem	1	431.0	344.0	40.0	41.0	23.0	23.0	29.5	29.0
40wm09	a	fem	3	424.0	339.0	42.0	43.0	25.0	23.5	28.0	18.5
40wm09	a	male	18	411.0	349.0	40.5	42.0	23.5	23.0	31.0	22.5
40wm09	a	male	23	460.0	388.5	45.0	46.0	30.5	27.0	36.0	23.0
40wm09	a	fem	29	420.0	342.0	40.0	42.0	25.0	27.0	29.5	20.0

Appendix A, Cont.: measurement data

SITE	TIME	SEX	BUR	FMLN	TIBLN	HUMHD	FMHD	FAP	FML	TAP	TML
40wm09	a	fem	32	387.5	308.0	36.0	35.5	20.0	22.0	25.0	17.0
40wm09	a	male	39	425.0	350.0	46.0	48.5	28.5	25.0	38.0	24.0
40wm09	a	male	43	461.0	380.0	43.5	43.0	26.5	26.0	32.5	23.5
40wm09	a	male	52	428.0	362.0	40.5	39.0	25.0	24.5	32.0	18.0
40wm09	a	male	55	440.0	377.5	45.0	44.0	27.0	27.0	38.0	22.0
40wm09	a	fem	59	400.0	343.0	40.0	40.0	23.0	22.0	26.0	16.5
40wm09	a	fem	70	409.0	328.0	41.0	39.0	25.0	25.0	27.0	18.0
84bn74	a	male	9	430.0	365.0	43.5	44.5	29.0	23.5	35.0	20.5
84bn74	a	male	12	399.5	324.0	42.5	41.0	27.0	24.0	33.0	18.0
84bn74	a	male	13	427.0	356.0	42.0	42.0	26.0	21.0	32.0	20.0
84bn74	a	male	14	470.0	403.0	46.0	47.0	29.5	25.0	39.0	22.5
84bn74	a	male	21	442.0	367.0	46.0	44.0	31.5	26.0	38.5	25.0
84bn74	a	male	29	442.0	364.0	45.0	44.5	25.0	23.0	33.0	20.0
84bn74	a	male	33	404.0	354.0	41.5	42.5	29.0	23.5	33.5	21.0
84bn74	a	fem	48	417.0	342.0	40.0	40.5	21.5	21.0	25.0	19.0
84bn74	a	fem	73	403.0	321.0	39.5	40.0	22.0	23.5	26.0	18.0
15by11	m	fem	1	414.0	339.0	37.2	38.7	24.4	23.0	31.4	20.4
15by11	m	fem	23	456.0	375.0	39.6	39.3	27.4	24.2	34.4	24.3
15by11	m	fem	32	436.0	358.0	39.6	40.8	25.7	26.4	31.8	21.0
15by11	m	male	53	445.0	377.5	46.0	47.9	29.5	26.6	38.6	25.8
15by11	m	male	62	445.0	361.0	48.0	46.8	28.9	26.7	37.6	23.0
15by11	m	fem	73	449.5	370.5	41.1	41.2	26.6	24.9	34.0	22.7
15by11	m	fem	88	411.0	331.0	38.4	38.5	25.4	23.4	26.0	19.2
15by11	m	fem	89	429.5	353.0	40.0	40.7	30.3	25.4	32.0	24.7
16by13	m	male	44	436.0	361.0	44.5	43.5	30.5	24.5	36.0	21.5
16by13	m	male	49	428.5	367.0	41.0	43.5	29.5	27.5	37.0	22.5
16by13	m	male	112	436.0	378.0	44.0	44.0	30.0	28.0	36.5	23.0
16by13	m	fem	115	411.5	334.5	38.0	39.0	25.0	26.0	30.0	19.0
16by13	m	fem	121	415.0	341.0	42.5	42.5	24.5	23.5	29.5	21.0
16by13	m	male	130	414.0	339.0	40.5	43.0	22.0	24.0	30.0	20.0
16by13	m	fem	143	402.0	328.0	39.5	39.5	23.0	24.0	29.5	22.0
16by13	m	male	164	430.0	358.0	45.5	46.0	26.5	25.5	38.0	24.0
16by13	m	male	374	441.0	363.0	44.0	45.0	30.0	27.0	40.0	22.5
16by13	m	male	391	456.5	384.0	47.0	46.0	29.0	30.5	39.0	24.0
16by13	m	male	412	480.0	401.0	48.2	48.8	30.5	31.1	37.9	22.5
16by13	m	male	424	446.0	378.0	44.5	44.7	31.1	25.0	36.4	23.8
16by13	m	fem	430	423.5	351.0	40.9	40.9	27.7	26.7	30.1	21.3
16by13	m	fem	446	398.0	335.0	36.4	38.0	23.6	23.8	30.5	23.2
16by13	m	male	452	449.0	374.0	42.3	44.5	29.9	25.0	34.9	21.8
16by13	m	fem	456	394.0	323.0	38.3	38.1	24.8	21.9	31.5	22.2
40dv60	m	male	7	440.0	371.0	47.5	47.0	31.5	30.0	37.0	23.0
40dv60	m	fem	9	410.0	348.0	35.0	37.0	24.0	22.0	30.0	19.0
40dv60	m	fem	16	426.0	356.0	41.0	42.0	26.0	24.0	34.0	22.0
40dv60	m	fem	20	413.0	347.0	40.5	40.0	25.0	25.0	36.0	23.0
40dv60	m	male	101	462.0	378.0	47.0	48.0	32.0	28.0	37.0	26.0
40dv60	m	male	103	438.0	360.0	44.0	48.0	30.0	29.0	36.0	25.0
40dv60	m	fem	107	433.0	352.0	43.0	44.5	25.0	25.0	32.0	21.0
40dv60	m	fem	124	394.5	333.0	38.0	40.5	28.0	24.0	30.0	23.0
40dv60	m	male	137	461.0	389.0	46.0	47.0	33.0	26.0	39.0	25.0
40dv60	m	male	139	423.0	359.0	45.0	44.0	29.0	26.0	36.0	22.0

Appendix A, Cont.: measurement data

SITE	TIME	SEX	BUR	FMLN	TIBLN	HUMHD	FMHD	FAP	FML	TAP	TML
40dv60	m	male	146	434.0	354.0	45.5	46.0	33.0	27.0	39.0	23.0
40dv60	m	male	148	450.0	368.5	46.0	48.0	26.0	29.0	39.0	22.0
40dv60	m	male	157	480.0	408.0	46.0	49.0	35.0	25.0	44.0	22.0
40dv60	m	fem	164	417.5	336.5	35.5	39.0	24.0	25.0	27.0	19.0
40dv60	m	fem	170	423.5	337.0	42.0	41.0	26.0	24.5	31.0	20.0
40dv60	m	fem	194	407.0	314.0	36.0	37.0	23.0	20.5	25.0	18.0
40dv60	m	fem	202	404.5	324.0	38.0	40.0	23.0	23.0	28.0	19.0
40dv60	m	fem	288	408.5	330.0	41.5	40.0	27.0	26.0	34.0	22.0
40dv60	m	male	291	414.0	357.0	43.0	46.0	27.0	27.0	38.0	24.0
40dv60	m	male	308	430.0	364.5	44.0	44.0	31.0	25.0	38.0	24.0
40dv60	m	male	312	446.0	380.0	49.5	49.5	28.0	26.0	39.0	24.0
40dv60	m	male	332	498.0	410.0	48.0	49.0	32.0	29.0	43.0	22.0
40dv60	m	male	333	444.0	360.0	47.5	45.0	28.0	26.0	36.0	21.0
40dv60	m	male	335	446.0	386.0	46.0	48.0	29.0	27.0	37.0	22.0
40dv60	m	male	349	453.0	398.0	44.0	52.5	32.0	24.0	37.0	23.0
40dv60	m	fem	356	425.0	350.0	37.0	41.0	30.0	25.0	31.0	19.0
40dv60	m	male	374	451.0	371.0	42.5	44.5	28.0	25.5	35.0	23.0
40dv60	m	male	410	474.0	400.0	45.0	48.0	28.0	29.0	36.0	20.0
40dv60	m	fem	411	420.0	342.0	38.0	41.5	26.0	22.0	33.0	18.0
40dv60	m	fem	417	408.0	337.0	38.0	40.0	25.0	25.0	30.0	22.0
40dv60	m	fem	418	420.0	347.0	43.0	41.0	25.0	27.0	33.0	19.0
40dv60	m	fem	433	415.5	342.0	37.5	38.0	28.0	25.0	32.0	22.0
40dv60	m	male	451	433.0	358.0	42.0	42.0	26.0	27.0	35.0	20.0
40dv60	m	male	455	451.5	380.5	45.5	45.5	28.0	28.0	36.0	27.0
40dv60	m	male	471	437.0	375.0	42.0	43.0	27.0	27.0	37.0	24.0
40dv60	m	male	476	448.0	370.0	42.0	45.0	26.5	24.0	36.0	21.0
40dv60	m	fem	477	413.0	323.0	39.5	40.5	26.0	25.5	32.0	19.5
40dv60	m	male	480	469.0	394.5	48.5	48.5	38.5	29.0	35.0	25.5
40dv60	m	fem	488	412.0	329.0	39.5	41.5	26.5	25.0	31.0	21.0
40dv60	m	male	490	458.0	386.0	44.0	47.0	26.0	24.0	33.0	21.5
40dv60	m	fem	498	413.0	339.0	38.5	39.5	23.5	23.0	24.0	18.5
40dv60	m	fem	514	430.0	361.0	42.0	42.0	26.5	26.5	32.0	21.0
40dv60	m	fem	517	421.0	348.0	40.5	40.0	25.0	25.5	31.0	21.0
40dv60	m	male	521	451.0	370.0	43.0	44.0	28.0	26.0	37.0	21.0
40dv60	m	fem	524	414.5	338.5	36.5	37.0	22.0	21.0	26.0	18.0
40dv60	m	male	527	399.0	329.5	41.5	40.0	26.0	25.0	30.0	18.0
40dv60	m	male	528	428.0	353.0	43.5	47.0	27.0	33.0	35.0	27.0
40dv60	m	fem	533	412.0	342.5	40.5	38.5	28.0	25.5	34.5	24.0
40dv60	m	fem	553	435.0	350.0	40.5	42.5	25.0	28.0	28.5	21.5
40dv60	m	fem	578	424.5	344.0	38.0	38.0	25.0	24.0	29.5	21.0
40dv60	m	male	585	442.0	374.0	40.5	43.0	29.5	24.5	37.0	21.0
40dv60	m	fem	594	444.0	360.0	42.0	42.0	29.0	26.0	36.0	20.0
40dv60	m	fem	614	448.0	373.0	48.5	45.0	27.0	26.0	31.0	28.0
40dv60	m	male	616	427.0	362.0	42.5	43.0	27.0	28.0	35.0	21.0
40dv60	m	male	621	440.0	377.0	48.5	47.0	30.0	29.5	40.0	27.0
40dv60	m	fem	623	426.0	346.0	38.5	42.0	27.5	24.5	32.5	22.5
40dv60	m	fem	638	425.0	357.0	38.5	40.0	27.0	24.5	33.0	21.0
40dv60	m	male	653	472.0	379.0	44.0	44.0	32.0	24.0	36.0	23.0
40dv60	m	male	684	442.0	357.0	43.0	45.0	29.0	31.0	38.0	21.0
03cp03	w	male	4	444.0	374.0	40.6	42.5	31.8	24.8	35.9	24.8

Appendix A, Cont.: measurement data

SITE	TIME	SEX	BUR	FMLN	TIBLN	HUMHD	FMHD	FAP	FML	TAP	TML
03cp03	w	male	13	463.0	392.0	45.8	45.5	30.0	23.8	37.2	25.4
17by14	w	male	36	442.5	364.0	46.8	45.1	28.0	25.9	36.4	21.9
17by14	w	male	37	459.0	385.5	45.4	43.9	29.7	25.5	36.9	26.2
17by14	w	male	40	471.0	392.0	42.4	44.7	30.0	23.1	37.1	28.7
1ja305	w	fem	4	408.0	349.0	39.5	40.5	25.0	25.0	27.5	21.0
1ja305	w	male	12	429.0	361.5	41.5	42.5	25.5	24.5	35.0	21.0
1ja305	w	male	15	450.0	374.0	44.5	43.0	26.5	22.0	34.0	22.0
1ja305	w	fem	16	405.0	326.0	37.0	37.5	23.0	23.0	30.0	17.5
1ja305	w	fem	17	415.0	345.0	40.0	40.0	28.5	23.0	34.0	23.0
1ja305	w	male	19	446.0	379.0	43.0	43.0	25.0	25.0	36.0	25.0
1ja305	w	fem	20	433.0	361.0	37.0	39.0	25.5	24.0	32.0	21.0
1ja305	w	male	22 b	477.0	396.0	45.0	47.0	30.0	25.0	38.5	25.0
1ja305	w	fem	27	435.0	369.0	36.0	38.0	26.5	22.5	32.0	23.0
1ja305	w	fem	30	421.0	348.0	42.0	41.0	22.5	23.0	30.0	20.0
1ja305	w	male	31	438.0	367.0	44.0	45.0	28.0	23.0	33.0	25.0
1ja305	w	fem	34	408.0	347.0	36.0	37.0	22.0	21.0	27.0	20.0
1ja305	w	male	36	482.0	400.0	46.0	46.0	31.0	25.0	37.5	23.0
1ja305	w	fem	37	406.0	346.0	38.0	39.0	25.0	23.0	30.5	20.0
1ja305	w	fem	4 a	390.0	331.0	37.0	38.0	25.5	24.0	28.0	20.0
1ja305	w	male	22 a	497.0	393.0	43.0	46.0	28.0	28.0	36.0	22.0
1ja305	w	fem	24 a	396.0	326.0	36.5	38.0	24.5	21.0	30.0	20.0
1ja305	w	fem	24 a	420.0	348.0	40.0	39.5	27.5	24.0	31.5	19.0
40ck06	w	male	26	469.0	382.0	45.0	44.7	34.2	23.4	38.7	25.4
40ck06	w	fem	35	431.5	351.0	42.8	41.7	29.5	26.5	34.9	24.1
40ck06	w	fem	36	401.0	342.5	35.7	38.4	25.5	20.2	27.1	19.4
40ck07	w	fem	31	423.0	355.0	37.6	38.4	26.6	22.2	29.8	19.5
40ck11	w	fem	6	434.0	364.0	37.6	38.1	25.6	23.8	28.6	19.6
40ck11	w	fem	44	428.0	353.0	40.1	40.0	27.7	25.4	31.9	20.7
40ck11	w	fem	47	413.5	343.0	37.8	38.4	28.4	22.6	30.5	20.3
40ck11	w	fem	61	391.0	338.0	39.8	39.7	24.3	24.0	30.9	17.1
40ck11	w	male	111	447.0	383.0	44.6	43.3	32.9	25.9	37.8	23.4
40ck11	w	fem	243	456.0	381.0	39.3	41.3	24.8	25.4	30.8	20.8
40gn06	w	fem	5	446.0	355.5	42.0	40.9	25.2	24.6	31.5	19.8
40gn06	w	male	8	426.0	369.0	41.7	43.8	29.0	24.6	38.2	24.5
40gn06	w	fem	23	417.0	358.0	39.1	38.4	25.5	22.7	31.1	21.2
40gn06	w	male	49	460.0	402.0	45.8	44.2	31.2	25.5	39.5	23.9
40gn06	w	fem	61	441.0	347.0	37.9	40.1	28.4	23.0	30.5	16.8

APPENDIX B

APPENDIX B: Measurement means for Archaic Period males and females.

Archaic

Sex	N	Variable	Mean	Std. Dev.	Min.	Max.
Female	23	Femur length	407.369565	14.580667	380.0	435.5
		Tibia length	333.000000	10.242514	308.0	349.0
		Humeral head	39.055652	1.677774	36.0	42.0
		Femoral head	39.683696	1.680379	35.5	43.0
		Femur A-P	23.335652	1.896325	20.0	26.8
		Femur M-L	23.403044	1.451474	20.8	27.0
		Tibia A-P	28.235652	2.711596	24.4	37.0
		Tibia M-L	19.400435	2.965867	16.5	29.0
Male	43	Femur length	438.441861	19.234211	399.5	493.0
		Tibia length	365.500000	16.256867	324.0	403.0
		Humeral head	44.125349	2.195282	39.5	49.0
		Femoral head	44.054535	2.205527	39.0	48.8
		Femur A-P	28.105698	2.312731	23.5	33.9
		Femur M-L	24.648605	1.523206	21.0	29.1
		Tibia A-P	35.229070	2.861038	31.0	41.7
		Tibia M-L	21.661279	1.805484	18.0	25.1

APPENDIX B, Cont.: Measurement means for Woodland Period males and females.

Woodland

Sex	N	Variable	Mean	Std. Dev.	Min.	Max.
Female	22	Femur length	419.045455	17.798414	390.0	456.0
		Tibia length	349.272727	13.069163	326.0	381.0
		Humeral head	38.576364	2.033959	35.7	42.8
		Femoral head	39.223636	1.323738	37.0	41.7
		Femur A-P	25.765455	1.978910	22.0	29.5
		Femur M-L	23.357955	1.522267	20.2	26.5
		Tibia A-P	30.464091	2.006821	27.0	34.9
		Tibia M-L	20.170000	1.762212	16.8	24.1
Male	16	Femur length	456.281250	19.234211	399.5	493.0
		Tibia length	382.125000	12.985248	361.5	402.0
		Humeral head	44.063438	1.819426	40.64	46.8
		Femoral head	44.394063	1.346207	42.5	47.0
		Femur A-P	29.418125	2.534782	25.0	34.2
		Femur M-L	24.683750	1.424696	22.0	28.0
		Tibia A-P	36.728750	1.737812	33.0	39.5
		Tibia M-L	24.195938	1.948577	21.0	28.7

APPENDIX B, Cont.: Measurement means for Mississippian Period males and females.

			Mississippian			
Sex	**N**	**Variable**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Female	40	Femur length	419.600000	14.316567	394.0	456.0
		Tibia length	343.637500	13.818414	314.0	375.0
		Humeral head	39.462625	2.532850	35.0	48.5
		Femoral head	40.206500	1.862266	37.0	45.0
		Femur A-P	25.781000	1.907395	22.0	30.3
		Femur M-L	24.530000	1.629333	20.5	28.0
		Tibia A-P	30.943000	2.768382	24.0	36.0
		Tibia M-L	21.101625	2.103491	18.0	28.0
Male	43	Femur length	445.313954	18.873332	399.0	498.0
		Tibia length	372.581395	16.993672	329.5	410.0
		Humeral head	44.707558	2.355324	40.5	049.5
		Femoral head	45.842326	2.417800	40.0	52.5
		Femur A-P	29.312558	2.821722	22.0	38.5
		Femur M-L	26.975349	2.222508	24.0	33.0
		Tibia A-P	36.926047	2.571712	30.0	44.0
		Tibia M-L	22.867791	2.026489	18.0	27.0

APPENDIX C

APPENDIX C

Definitions of measurements taken on long bones (Martin, 1957 translated by Moore-Jansen and Jantz, 1989: 72-82):

Maximum Vertical Diameter of Humeral Head: The direct distance between the most superior and inferior points on the border of the articular surface.

Maximum Diameter of Femoral Head: The maximum diameter of the femur head measured on the border of the articular surface.

Maximum Femoral Length: The distance from the most superior point on the head of the femur to the most inferior point on the distal condyles.

Antero-posterior (Sagittal) Diameter of Femur at Midshaft: The anterio-posterior diameter measured approximately at the midpoint of the diaphysis, at the highest elevation of the linea aspera. This measurement is taken perpendicular to the ventral surface.

Medio-lateral (Transverse) Diameter of Femur at Midshaft: The distance between the medial and lateral margins of the femur from one another measured perpendicular to and at the same level as the sagittal diameter.

Maximum (Condylo-malleolar) Tibial Length: The distance from the superior articular surface of the lateral condyle of the tibia to the tip of the medial malleolus.

Antero-posterior (Maximum) Diameter of Tibia at Nutrient Foramen: The distance between the anterior crest and the posterior surface at the level of the nutrient foramen.

Medio-lateral (Transverse) Diameter of Tibia at Nutrient Foramen: The straight line distance of the medial margin from the interrosseous crest.

VITA

William E. Grant was born in Danbury, Connecticut on December 13, 1962. He grew up in Wiscasset, Maine, and graduated from Wiscasset High School in 1981. While a junior in high school, he joined the United States Army Reserve. After graduation he entered the Active Army, serving as an infantryman in both the 1st Cavalry Division and the 3d U. S. Infantry (The Old Guard). He left the Active Army in 1986, receiving an honorable discharge.

During the fall of 1986 the author enrolled at the University of Maine, in Orono, Maine. In May, 1990 he graduated with a Bachelor of Arts degree in Anthropology. From here he enrolled as a master's student in anthropology at the University of Tennessee, Knoxville. During this time, he has worked as a graduate assistant to Dr. William M. Bass, assisting in classes, as well as participating as a member of the Forensic Response Team.

The author is currently employed as a physical anthropologist with the U.S. Army Central Identification Laboratory in Honolulu, Hawaii.