ONTOGENETIC VARIATION IN THREE NATIVE NORTH AMERICAN POPULATIONS: ECO-GEOGRAPHIC EFFECTS ON HUMAN GROWTH AND DEVELOPMENT

By

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ONTOGENETIC VARIATION IN THREE NATIVE NORTH AMERICAN POPULATIONS: ECO-GEOGRAPHIC EFFECTS ON HUMAN GROWTH AND DEVELOPMENT

By

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My study represents an analysis of postcranial growth and development among three Native North American populations: Native Alaskan groups, South Dakota Arikara, and New Mexico Puebloan populations. These eco-geographically distinct populations were chosen to investigate (1) whether groups vary in postcranial limb measurements as adults and if these patterns correlate to eco-geographic condition and (2) how and when do these patterns of variation arise during the juvenile period.

Analyses of the adult component of each population demonstrate statistically significant deviation of the group means for postcranial elements with significant variation manifest in the distal segments of both the upper and lower limbs. Similarly, this morphological size variation shows strong evidence for patterning along geographic boundaries and climatic conditions. These morphological differences conform to Bergmann's and Allen's biological "rules" for homeothermic animals; individuals inhabiting colder climates exhibit shorter extremities while those occupying warmer clines display longer limbs.

Patterns of growth among the juvenile components of each population were appreciable different that those seen in the adult sample. However, the adolescent period served as the transitional period linking juvenile and adult patterns of variation. The null hypothesis of

isometry was rejected favoring an alternative hypothesis of ontogenetic scaling and divergent growth trajectories dependent upon the individual skeletal element and population compared. Unique growth origins were found for the ulnae, radii, femur and fibulae but not for the humeri and tibiae when the Native Alaskan sample was compared to both the South Dakota Arikara and New Mexico Puebloan groups. This discrepancy cannot be fully accounted for at this time, but has been reported in prior analyses of human skeletal growth.

While Native North American populations share a common evolutionary history, they do conform to previously examined morphological patterns of human variation and are distinguished by certain components of their local environment.

CHAPTER 1
INTRODUCTION

It is through a comprehensive understanding of the history, origins, and biological change within human populations of the past that we come to appreciate the morphological variation expressed within modern human groups. This project looks to secure a greater appreciation and understanding of the subtle and dramatic variations of human growth and development through an eco-geographic analysis of skeletal biology in three Native North American populations. Ontogeny refers to the growth of an individual throughout their life history through embryonic and/or post-natal development (e.g., Gould, 1977; McKinney and McNamara, 1991). A broad, comparative and quantitative analysis of the rate, timing and trajectory of human skeletal maturation and ontogeny has not been accounted for in the literature. This study will allow human biologists a greater understanding of the fundamental questions relating to the morphological variation observed in the skeletal record.

Studies on pre- and post-contact Native North American human remains have been hindered by the incomplete nature of juvenile specimens in most archaeological assemblages. The lack of empirical evidence on growth and developmental plasticity of comparative populations has allowed for only theoretical discussions of ontogenetic human variation. The introduction of developmental biology, population genetics and overall integrative approaches to biological questions have greatly facilitated biologists' understanding of the tenuous nature of early development and how the internal timing of developmental events and environmental cues affect developmental processes on a population level. This discipline has enormous promise for the field of skeletal biology. This study will take a more comprehensive and quantitative approach than previously applied in the anthropological literature to better understand the origins of variation and timing of growth events between three eco-geographically distinct populations:

the Arikara of South Dakota, Ancestral Puebloan populations of New Mexico and Native Alaskan groups.

These populations were specifically chosen given their eco-geographic distinction, temporal proximity and relatively conserved evolutionary history in order to investigate whether these conditions affect final adult morphology and *how* climatic and geographic variation is manifest in the growing, juvenile skeleton. This author is unaware of alternate skeletal populations that share the degree of temporal and evolutionary relatedness exhibited in these three groups.

On an evolutionary scale, variation in skeletal morphology in many species has been attributed to variations in eco-geographic condition; therefore this variable will be the primary focus of this investigation. Concepts derived from skeletal biology, evolution, genetics and ecology will be integrated in order to more fully appreciate, from a broad perspective, how eco-geographic differences affect human skeletal development.

This project will address the following questions:

- Do significant differences exist between the adults of these three populations? If so, does this variation correlate with eco-geographic conditions?
- Given the genetic and evolutionary history of Native Americans, are members of these three populations the same physical size at birth? By identifying whether these populations begin postnatal growth at the same stage, I will discern whether differences in adult form can be attributed to heterochronic differences in the growth process and/or how these changes correlate with eco-geographic factors.
- Do these geographically distinct populations share the same developmental rates? Do they have isometric, parallel or divergent allometric growth trajectories? Do overall shorter groups merely begin development at a small size, grow more slowly throughout development or stop growing earlier? By defining critical periods of growth and variation in growth trajectory of postcranial elements, I will further define the potential influences that might critically impact overall population growth patterns.

A greater understanding of growth in Native American juvenile remains obtained in the late 19th and early 20th centuries has been hindered by the forceful treatment and handling of

Native American peoples. The harsh introduction of contact groups with Native North Americans has greatly shaped the relations between Native Americans and present-day Americans (Prince, 1998; Zimmerman, 1998). Many of the skeletal populations housed at academic institutions, including all groups in the present analysis, are in the process of repatriation in an attempt to ameliorate this history. Although these wrongs may never be suitably righted, further investigation into the biological development of the unique features that distinguish these native groups may provide the keys to an understanding of their origins, dispersal and modern day association and may add a novel and unique understanding to the repatriation effort.

Archaeological Juvenile Skeletal Remains

Numerous critics have disagreed with the analysis of juvenile, archaeological skeletal remains due the inherent limitations of these samples. This author joins many others (Kronfeld, 1935; Jantz and Owsley, 1984b; Johnston, 1968; Steyn and Henneberg, 1996; Sundick, 1978; Y'Edynak, 1976) in confronting both the strengths and weaknesses of this type of data sample.

The Critics

Francis Johnston (1962, 1968) has been one of the more vocal critics of employing juvenile skeletal samples in the analysis of growth and development, despite his use of juvenile skeletal assemblages throughout his own research. Johnston (1968) draws attention to the inability to definitively determine accurate chronological age (similarly noted by Steyn and Henneberg, 1996; Sundick, 1978) and the cross-sectional nature of the juvenile samples determined solely by the mortality distribution of archaeological populations:

> No matter how impressive any skeletal information pertaining to immature individuals may appear, and particularly when incremental growth is the frame of reference, some degree of error is introduced by the very fact that the sample is skeletal. It does not represent the normal, healthy, population from which it was drawn. The fact that a person died young presupposed illness, injury, or other deficiency which prevented his reaching

> adulthood. These factors, limiting as they are, are present in all studies of non-living material, and, if such material is to be of use at all, they must be borne graciously and realized analytically (Johnston 1962: 249).

The most frequently illustrated argument is that juvenile skeletal samples represent the portion of the population that did not survive to adulthood. Thus this population of juveniles could be representing potentially retarded or pathologically altered growth patterns (Jantz and Owsley, 1984b; Johnston, 1968; Steyn and Henneberg, 1996; Sundick, 1978; Y'Edynak, 1976). McKern (1970) and Sundick (1978) highlight that when dealing with remains of unknown chronological age there is no way for investigators to determine which individuals followed "normal" growth patterns for that population and which may have been subject to outside influences affecting skeletal maturation.

Beyond aging criteria, juvenile archaeological samples are plagued by other potential roadblocks. Studies of juvenile skeletal growth are generally hindered by small sample size (Steyn and Henneberg, 1996; Walker, 1969; Y'Edynak, 1976). Many authors (Steyn and Henneberg, 1996; Walker, 1969; Y'Edynak, 1976) also note the difficultly in sex assessment among juvenile skeletal remains, forcing analysts to pool both male and females together despite their variation in growth and development, particularly toward puberty. In addition Sundick (1978) highlights the frequent incompleteness of juvenile skeletons, scarcity of individuals from the adolescent period and the effect of secular trends that may affect maturation stages making comparisons between different time periods inappropriate.

The Proponents

Many authors and academics cite juvenile skeletal remains as an important and necessary tool in appreciating variation among past populations. Lovejoy et al. (1990) comment that children are more likely, particularly among archaeological assemblages, to die of acute disease leaving little or no skeletal evidence. As far as physical size is concerned, Sundick (1978)

concludes that children frequently ill are comparable in overall growth to those less prone to illness. More importantly, Kronfeld (1935) highlights what could be lost to the literature if analyses of archaeological skeletal remains were not conducted. If juvenile human remains are not "suitable" for scientific analysis, the fields of human embryology, histology and anatomy would never produce the understanding that these fundamental disciplines have offered to science thus far. If growth analyses were to be conducted solely on animal instead of human remains the results, "for obvious reasons, [these studies would] never be applicable to man" (Kronfeld, 1935: 1139).

A Deeper Appreciation for Human Variation

Despite the limitations of analyzing juvenile skeletal remains for growth research, it has been noted by many authors (e.g. Hunt, 1958; Jantz and Jantz, 1999) that younger individuals, undergoing rapid growth and development, are most susceptible to ecological change which manifest in population variation. It is through such analyses that a deeper understanding of the mystery behind this variation can be appreciated. Johnston (1969: 335) finds:

> . . . The major component of variation among adults is due to variations in the growth process. In other words, the first step in understanding differences among groups, whether at the level of genus or of population, lies in the understanding of the processes of growth of each.

The evolving and exploding discipline developmental biology has revealed that through a developmental focus a greater degree of information can be assembled concerning evolution and the relationship between ancestral groups. "By viewing evolution as a branching tree of adults or genes, theorists have omitted what selection really acts upon: ontogeny. Ontogenies evolve, not genes or adults" (McKinney and Gittleman, 1995: 21). This project analyzes the ontogenies of three Native North American populations to further appreciate the variation that exists among these groups.

CHAPTER 2

RELEVANT BACKGROUND LITERATURE

Study Limitations

> Naturally, the very existence of skeletons implies death from one cause or another, including pathological states. This means that in any collection of skeletons, some are included because as living individuals they succumbed to illness.
>
> -- Stewart, *The Effects of Pathology on Skeletal Populations.*

Numerous authors have highlighted the inherent difficulty of analyzing archaeological juvenile human remains given their unknown causes of death. McKern (1970) and Sundick (1978) note that when dealing with remains of unknown chronological age there is no way for investigators to determine which individuals followed "normal" growth patterns for that population and which may have been subject to outside influences affecting skeletal maturation. The most frequently highlighted argument is the undeniable fact that juvenile skeletal samples represent the portion of the population that did not survive to adulthood. When the elderly pass away, it is unfortunate yet anticipated; when a child dies it is always premature. Because of this, juveniles represented in archaeological populations could be indicative of those adversely affected by illness hindering skeletal growth (Jantz and Owsley, 1984b; Johnston, 1962, 1968; Steyn and Henneberg, 1996; Sundick, 1978; Y'Edynak, 1976).

A population may be defined as a group of interbreeding individuals sharing a similar environment, culture and often an evolutionary history. Goodman and Armelagos (1989) note that environment is the predominant force responsible for the stressors adversely affecting past human populations. In this case, environment includes pathogens, culture and nutrition. Lampl and Johnston (1996: 346) highlight the shared environmental condition of a population as a potential "systematic error" in the analysis of skeletal juvenile remains with the result of being "relatively similarly delayed or advanced by reference to a standard of known chronological

age." However, in terms of the comparative purposes of the present investigation, New Mexico, Alaska and South Dakota are considered distinct "populations" sharing common nutritional, environmental, and pathological influences.

Goodman and Armelagos (1989) highlight that there are many pathogens, such as viruses, that leave no appreciable physical manifestation on the human skeleton. Such pathogens harm soft tissue only and generally work so "quickly" that bone and teeth do not have ample time to manifest a substantial, lasting response. Given the fragile immune system of very young children in particular, who may have died of a virus related infection, the disease may not have "had time" to leave its markings on the skeleton. Lovejoy and co-workers (1990) have similarly found that in most anthropological populations juvenile deaths are the result of acute conditions that did not affect dental or osteological maturation.

Diet and nutrition are known to be influential variables in skeletal development. However, while the potential for nutritional and dietary variation between these populations is probable, the ability to accurately account for that in prehistoric, archaeological populations of skeletal remains is difficult. The advent of isotopic analysis could lead to a more accurate assessment of dietary variation between these groups, however given the repatriation guidelines affecting all populations in the present investigation, destructive analysis is prohibited.

Despite any negatives on the analysis of archaeological juvenile skeletal remains, it has been noted by many authors (e.g. Hunt, 1958; Jantz and Jantz, 1999) that younger individuals, undergoing rapid growth and development, are most susceptible to ecological change manifest in human variation. It is through such analyses that greater appreciation of the mystery of this variation can be best appreciated. Despite the inherent difficulties posed by an analysis of

archaeological juvenile remains, the potential of a more robust understanding of the origin of variation in past and present human populations outweighs the difficulties of the sample.

> Skeletal growth is a complex phenomenon and is sensitive to a wide variety of influences. Endocrine titers, nutrition, genome, and disease are among factors directly bearing on the rate and pattern of growth. Final adult stature is a result of all these factors, and there exists no method by which they can easily be partitioned into their relative contribution to its achievement (Lovejoy et al., 1990: 534).

Understanding the patterns of growth across archaeological populations through analysis of juvenile skeletal remains is an important component of understanding the variation seen in human populations today. While it is an ideal scientific and statistical scenario to analyze growth patterning of a population of known age, such studies are not conducive to archaeological assemblages. All scientific investigations have some degree of inherent limitation. What is important is the author's ability to clear highlight and define these limitations and how they may influence the results and conclusions drawn from their data.

Dental Development

Studies of physical growth have historically centered on long bone and dental development. The present investigation upholds this tradition. Historically, investigators of growth and development have used either dental or skeletal estimated age as the proxy for true chronological age. However, it has become clear that dental age provides a more accurate and less variable representation of chronological age when the individual is of an archaeological context, forensic nature, or circumstance where exact birth dates are unknown (Albert and Greene, 1999; Anderson et al., 1975, 1976; Dahlberg and Menegaz-Boch, 1958; Delgado et al., 1975; Garn et al., 1965; Gustafson and Koch, 1985; Haavikko, 1974; Hagg and Matsson, 1985; Hedge and Sood, 2002; Hummert and Van Gerven, 1983; Johnston, 1961; Lampl and Johnston, 1996; Liversidge et al., 1998; McGregor et al., 1968; McKenna et al., 2002; Merchant and Ubelaker, 1977; Moorrees et al., 1963a, b; Nolla, 1960; Robinow et al., 1942; Smith, 1991;

Sundick, 1977, 1978; Walker, 1969). These studies have demonstrated that, as compared to skeletal development, dental calcification and eruption is less effected by local environment, nutritional modification and is highly genetically conserved.

Determination of dental age is the estimate of the "age best associated with a developmental stage in a normal reference population" (Smith, 1991: 160). Estimated dental aging has many advantages as compared with other biological indices. Garn et al. (1965) examined tooth formation and eruption throughout the growth of participants in the Fels Longitudinal Growth Study. It was concluded that dental development is less affected by nutritional or hormonal variations than were other developing systems such as osseous development (Garn et al., 1965; Smith, 1991). Lewis and Garn (1960) similarly highlight that dental development is more highly correlated to chronological age than skeletal development.

Methodological Concerns

In the absence of definitive birth or medical records dental age assessment has been shown to be the best available method of chronological age estimation (Demirjian et al., 1973; Demirjian and Goldstein, 1976; Gustafson and Koch, 1985; Hunt and Gleiser, 1955; Moorrees et al., 1963a, b, 1965; Schour and Massler, 1941). Dental age estimates are varied however and may be hindered by the many methods created and employed as well as the method-sample application (Liversidge, 1994; Merchant and Ubelaker, 1977; Smith, 1991; Sundick, 1978).

Maturity scales, providing a broad developmental scheme, best approximate chronological age in archaeological assemblages (Moorrees et al., 1963a, b; Schour and Massler, 1941; Smith, 1991; Ubelaker, 1978). Schour and Massler's (1941) atlas, while one of the best known, appears to also be most highly and severely criticized (Merchant and Ubelaker, 1977; Smith, 1991; Sundick, 1978) given the small sample size employed, unknown samples per age group, lack of differential sex standards or population affiliation. Schour and Massler's (1941) atlas also has

been cited as overestimating chronological age as compared to the Moorrees et al. (1963a, b) standards (Merchant and Ubelaker, 1977; Smith, 1991).

Moorrees et al. (1963a: 205) note that while an estimate of dental age can be assessed with precision for a given tooth in a particular population, variability still exists and averaging assessments for numerous teeth "increases the reliability of the determination." Moorrees et al. (1963a) highlight that in developing dental standards, chronological age as well as sex are integral factors for the most precise age estimation. Finally, and most importantly, it is noted that: "in applying these normative data, sampling variations must be taken into consideration, inasmuch as other populations may differ in the rate of their dental development" (Moorrees et al., 1963a: 212).

Merchant and Ubelaker (1977) highlight Moorrees et al. (1963a, b) as the most suitable methodological dental standard for estimating age of proto-historic Arikara from South Dakota. The large, longitudinal sample, objectively defined dental stage, and the variability presented in their sex-specific standards are cited as factors making Moorrees et al.'s (1963a, b) more appropriate (Merchant and Ubelaker, 1977; Sundick, 1978) than alternative studies.

Dental Calcification

Dental development has two primary stages: (1) calcification and formation of crowns and roots, and (2) eruption. Dental calcification has the distinct advantage of being able to be perceived, radiographically, from a child's jaw at any age and monitored throughout life and after death (Hunt and Gleiser, 1955; Moorrees et al., 1963a, b; Saunders, 1992). Through the numerous studies of formation versus eruption, tooth formation proves to be a more reliable correlate to chronological age (Albert and Greene, 1999; Anderson et al., 1976; Hunt and Gleiser, 1955; McKenna et al., 2002; Moorrees et al., 1963a, b; Smith, 1991; Sundick, 1977; Thompson et al., 1975).

Dental formation begins prenatally. The first stages of calcification begin in the second semester of pregnancy as early as 12-16 weeks (Smith, 1991). The calcification process takes approximately 2-3 years from initial calcification to root completion and is a standard used by many investigators to highlight variability in sex, population and dental development (Christensen and Kraus, 1965; Garn and Lewis, 1956, 1957; Garn et al., 1959, 1965; Gilster et al., 1964; Gleiser and Hunt, 1955; Haavikko, 1974; Hagg and Matsson, 1985; Kronfeld, 1935; Lunt and Law, 1974; Nystrom and Ranta, 2003; Smith, 1991).

"The calcification of a tooth may be a more meaningful indication of somatic maturation than is its clinical emergence" (Gleiser and Hunt, 1955: 269) Tooth formation is a process that can be observed for a confined period of time and is less affected by nutritional, hormonal or environmental extremes than other somatic systems (Garn et al., 1965; Haavikko, 1974; Liversidge et al., 1998; Sundick, 1978). Demirjian (1978), Gron (1962), and Saunders' (1992) assessment of calcification confirms Gleiser and Hunt's (1955) statement describing eruption or emergence as a "fleeting event" while calcification is a "continuous process" that can be more readily documented in both longitudinal and cross-sectional studies.

Christensen and Kraus (1965) examined 73 human fetuses to determine the time and location of the calcification of the human permanent first molar. The first stages of calcification were noted in all permanent first molars prior to birth occurring as early as 28-32 fetal weeks. It was concluded that, overall, initial calcification of the permanent first molars and deciduous molars are strikingly consistent with little to no inter-individual variation (Christensen and Kraus, 1965; Hunt and Gleiser, 1955). Nystrom and Ranta (2003) sought to test the consistency of dental formation among a group of 29 Finns as seen through panoramic tomograms taken at autopsy. In 14 tooth pairs, 5.5% displayed differences in calcification stage; among 30 tooth

pairs of permanent first molars, differences in calcification were noted in only 3 or 10%. Nystrom and Ranta's (2003) results highlight the consistency seen in the earliest stages of dental formation and calcification. These studies highlight the highly conserved nature of human dental calcification and support the use of calcification standards for chronological age estimation.

Dental Eruption

The use of the term "eruption," as an indicator of physical maturity, was first seen in England's Factory Act of 1833, which dictated the age at which children could work regular or extended hours in the factories. A medical, gross examination was required for "true" age assessment (Saunders, 1837 cited in Demirjian, 1978). Since then, eruption has been noted as one of the many possible indicators of chronological age assessment.

Dental eruption or gingival emergence (Demirjian et al., 1973), as defined by numerous authors (Bailey, 1964; Bambach et al., 1973; Billewicz et al., 1973; Brown, 1978; Demirjian, 1978; Eleveth, 1960; Gustafson and Koch, 1985; Helm, 1969; Meredith, 1946; Nanda, 1960; Saunders, 1992; Ulijaszek, 1996), is penetration of the surface of the gum by the dental enamel. Liversidge et al. (1998) and Demirjian et al. (1973) define eruption as two distinct stages: (1) alveolar eruption, when the tooth emerges from the alveolar bones, and (2) clinical, or gingival emergence, when the tooth penetrates the gingiva. Other authors, as cited above, combine these processes into a single event.

Tooth eruption patterns and sequence vary among individuals and populations (Holman and Yamaguchi, 2005; Lee et al., 1965; Nanda, 1960; Steggerda and Hill, 1942; Watts, 1985; Y'Edynak, 1976). Falkner (1957) identifies the most active period of dental eruption as taking place between 9-18 months of age. Robinow et al. (1942) examined eruption of the deciduous dentition among 64 white children and noted significant difference in the eruption time of central and lateral incisors between the maxilla and mandible (Meredith, 1946). It was also concluded

that boys were less variable in eruption time and were advanced in eruption of all deciduous teeth (Robinow et al., 1942). Malcolm and Bue (1970: 307) highlight eruption as "one of the few developmental indices which are relatively unaffected by factors which delay the development of other physical growth characteristics." Gron (1962) concluded that tooth emergence was dictated more by stage of root formation than chronological, somatic or skeletal age.

Sequence of Calcification and Eruption

Knowledge of the sequence of dental calcification and eruption is generally variable yet influential in age assessment of individuals of different ancestry and sex (Garn et al., 1956, 1959; Garn and Lewis, 1957; Gilster et al., 1964; Gleiser and Hunt, 1955; McGregor et al., 1968; Meredith, 1946; Steggerda and Hill, 1942; Sundick, 1978). Garn et al. (1956) investigated the sequence of calcification in mandibular molars and premolars among 359 American children. It was concluded that mandibular M1, P1, and M3 showed first, second and last evidence of calcification respectively; M2 and P2 varied in timing of calcification, if not occurring at the same time. Siblings tended to display more consistently identical calcification sequences than would be expected by chance, thus it was concluded that developmental calcification sequences were likely genetically determined (Garn et al., 1956).

Sex has also been sited as an influential factor in the sequence of dental calcification (Garn et al., 1956; Gilster et al., 1964; Gleiser and Hunt, 1955; Steggerda and Hill, 1942). Gilster et al. (1964) concluded that development and calcification of the mandibular second deciduous molars were advanced in females over males. Gleiser and Hunt (1955) noted a "slight precocity" in the onset of dental calcification of the mandibular first permanent molar in girls. Children of African descent appear to be slightly advanced in formation and calcification over Caucasian children (Gilster et al., 1964). Garn et al. (1956) found that in females, P2 tended to calcify before M2 and in boys, the (P2 M2) sequence, or coincidental calcification, was more apparent. Overall,

Garn et al. (1956) concluded that 40.3% of the children examined display M1 P1 P2 M2 M3 sequence, 37.7% displayed M1 P1 (P2 M2) M3 sequence, and finally 21.9% displayed M1 P1 M2 P2 M3 sequence.

These analyses highlight that dentition that calcifies and/or erupts earlier in the dental sequence is more deeply canalized than later calcifying/erupting teeth.

Canalization of Dentition

While variation in the timing and sequence of dental formation and eruption has been documented, the process has come to be considered highly genetically canalized and less influenced by environmental condition (Albert and Greene, 1999; Brown, 1978; Butler, 1967a; Dahlberg and Menegaz-Bock, 1958; Delgado et al., 1975; Demirjian, 1978; Garn et al., 1965; Gleiser and Hunt, 1955; Gustafson and Koch, 1985; Harris and McKee, 1990; Holman and Yamaguchi, 2005; Lewis and Garn, 1960; Liversidge et al., 1998; Mays, 1995; McKay and Martin, 1952; Moorrees, 1965; Nystrom and Ranta, 2003; Robinow et al., 1942; Smith, 1991; Sundick, 1977; Tanner, 1962; Thompson et al., 1975; Turner, 1963; Walker, 1969). Garn et al. (1965: 228) comment: "Since the most advanced eruption appears to exist in least-favored groups, the genetic hypothesis perhaps reasonably stands."

Garn, Lewis and associates, in 1959, studied overall variability in tooth formation in an analysis of 255 white, Ohio-born, middle-class children. It was concluded that variability increases steadily as age progresses and later formed teeth showed more variability than earlier forming ones (Garn et al., 1959; Gleiser and Hunt, 1955). Liversidge et al. (1998: 421) similarly note that while genetic foundations guide early development, environmental influences increase with age "so that eventually only few percent of the variation of time at death is controlled biologically." These results are expected as formation of earlier developing teeth are more

"rooted" in genetic predetermination, while later forming teeth are subject to nutritional variation, disease, population variability, sex, etc.

Population Variation

Investigators of population discrepancies in dental eruption have found that some groups are more precocious, while others display consistent emergence patterns (Bambach et al., 1973; Banerjee and Mukherjee, 1967; Brown, 1978; Chagula, 1960; Dahlberg and Menegaz-Bock, 1958; Friedlaender and Bailit, 1969; Garn et al., 1965; Harris and McKee, 1990; Holman and Yamaguchi, 2005; Johnston, 1961; Malcolm and Bue, 1970; Meredith, 1946; McGregor et al., 1968; McKay and Martin, 1952; McKenna et al., 2002; Moorrees et al., 1963a, b; Nanda, 1960; Owsley and Jantz, 1983; Saunders, 1992; Steggerda and Hill, 1942; Sundick, 1977, 1978; Ulijaszek, 1996; Y'Edynak, 1976). Of particular importance when employing dental standards in the archaeological context, Owsley and Jantz (1983) highlight the problems of applying White standards to Native American groups, particularly archaeological Arikara of South Dakota. Similarly, Y'Edynak (1976) found that Eskimo and Aleut populations were one year advanced when compared with White standards (Hurme, 1948; Robinow et al., 1942) for dental eruption.

Garn et al. (1973) concluded that population differences exceeded variation based on nutrition or socio-economic status by a factor of two or more. Bambach et al. (1973) found that, that up to 18 months of age, European and American children were dentally precocious as compared to the Tunisian children examined. Banerjee and Mukherjee (1967) found that among 588 Bengalee children, the initiation of dental eruption was considerably later when compared with Japanese, Koreans, European Whites and Americans. Bengalee children exhibited an average eruption time of 10-13 months for their first tooth compared to 6-8 months for Whites and 7-9 months seen in Japanese and Korean samples (Banerjee and Mukherjee, 1967).

Friedlaender and Bailit (1969) examined a "technologically primitive group" of Melanesians juveniles living in New Guinea. It was concluded that both males and females examined in this analysis displayed permanent dental eruption precocious to Europeans and Asiatic populations but later than Africans. Due to the lack of modern medical care and a lower nutrition level than surrounding areas, these results further the notion that the differences in dental eruption are of genetic origin rather than nutritional or environmental (Friedlaender and Bailit, 1969). Friedlaender and Bailit (1969) do not deny environmental effects on development, only posit that they may be less operative than genetic canalization.

Influence of Sex

Studies have shown a significant difference between the sexes in terms of dental calcification (Anderson et al., 1975, 1976; Demirjian, 1978; Eleveth, 1960; Gustafson and Koch, 1985; Hagg and Matsson, 1985; Harris and McKee, 1990; Helm, 1969; Hunt and Gleiser, 1955; Lewis and Garn, 1960; Maj et al., 1964; Malcolm and Bue, 1970; McKenna et al., 2002; Moorrees et al., 1963a, b; Moorrees, 1965; Owsley and Jantz, 1983; Schour and Massler, 1941; Sundick, 1977; Thompson et al., 1975). This difference increases with age and successive dental stages of calcification (Anderson et al., 1976; Thompson et al., 1975). Anderson et al.'s (1975, 1976, 1977; Thompson et al., 1975) studies of children of the Burlington Growth Centre found that molars displayed the greatest sex difference as compared to skeletal maturity and canines displayed the greatest sex variation in calcification. Thompson et al. (1975) found that male calcification of the canine lagged behind females by almost 20%. These results are confirmed by Brown (1978) where the mandibular canines of girls erupted over 10 months earlier than in boys. Mandibular central incisors and M1 displayed the least variation in Anderson et al.'s (1976) analysis. Moorrees (1965) noted that while variation in dental formation and development is a complex issue, sexual dimorphism among dentition has been shown to be less variable in

females over males, leading researches to posit that variability may be an X-chromosome linked feature.

Research has also commented on the effects of sex on dental eruption (Brook and Barker, 1972; Brown, 1978; Gleiser and Hunt, 1955; Hurme, 1949; Lewis and Garn, 1960; McKay and Martin, 1952; Meredith, 1946; Moorrees et al., 1963a, b; Nanda, 1960; Steggerda and Hill, 1942). Brook and Barker (1972) similarly found that among 4873 eastern New Guinean children little difference was seen in the eruption of deciduous dentition. Brown's (1978) analysis of Australian Aborigines concluded that for most teeth, girls displayed precocious eruption of 6 months with maxillary I1 and mandibular I2 emerging earlier in boys. These results are consistent with Gleiser and Hunt (1955) and Hurme (1949) results on sex differences in dental eruption (Lewis and Garn, 1960).

However, among permanent teeth, females display a given developmental stage earlier than males (Brook and Barker, 1972; Demirjian, 1978; Steggerda and Hill, 1942; Thompson et al., 1975). Lewis and Garn (1960) examined three stages of tooth formation (calcification of the crown, crown completion, and apical closure) and two stages of dental movement (alveolar eruption and attainment of occlusal level). Their analysis found that female children were advanced over males by and average of 0.32 years and as high as 0.92 years in the permanent dentition.

While numerous authors have sited sex as a significant discriminator between male and female dental eruption and calcification, other investigators found evidence to the contrary (Anderson and Popovich, 1981; Bailey, 1964; Bambach et al., 1973; Billewicz et al., 1973; Brook and Barker, 1972; Falkner, 1957; Friedlander and Bailit, 1969; Gron, 1962; Hurme, 1948, 1949; Lee et al., 1965; McGregor et al., 1968; Nanda, 1960; Nolla, 1960; Scott and Ferguson,

1956). As compared to dental formation, Anderson et al. (1981) found that emergence sequences were not significantly different between male and female children of the Burlington Growth Centre. Bailey's (1964) study of New Guinean infants found no significant difference between male and female dental patterning.

Effects of Varied Nutrition

The effect of malnutrition on dental development is an important consideration as the eruption of the deciduous and permanent dentition is often used for chronological age estimation. While malnutrition may be expected to adversely affect dental maturation, several comparative studies have not been able to produce definitive results as to the effects of moderate protein deficiencies on dental development (Anderson et al., 1975, 1976; Bailey, 1964; Delgado et al., 1975; Holman and Yamaguchi, 2005; Tisdall, 1937).

There is debate as to the consistency of dental emergence as compared to calcification. Anderson et al. (1975, 1976) found that malnutrition affects skeletal maturation significantly more than dental development. In Bailey's (1964) analysis, as discussed above, the similarity of dental eruption rates in healthy Chimbu infants as compared to malnutrition apparent in other New Guinean groups studied indicated that protein deficiencies do not greatly affect dental eruption rates. Holman and Yamaguchi (2005) found conflicting evidence of the effects of severe malnutrition on dental eruption; much of this variation was attributed to the study design employed. However, they conclude that nutritional status may be a significant factor leading to variation in dental eruption among varied human populations (Holman and Yamaguchi, 2005).

Skeletal Development

> Growth is an easily measured and well-defined characteristic that has the potential to tell us a great deal about the past and present of our species.
>
> -- Tanner, *Human Growth and Development*.

While dental formation and eruption timing has been shown to be less variable, long bone growth variation is an important source of information concerning not only development and regional variation but nutrition, health and environmental influence (e.g. Armelagos et al., 1972; Blanco et al., 1974; Deutsch et al., 1981; Hewitt et al., 1955; Hummert and Van Gerven, 1983; Humphrey, 1998; Jantz and Owsley 1984b; Owsley and Jantz, 1985). Johnston and Snow (1961) highlight that the entire skeleton, both dentition and postcranial long bones, are a better judge of age and maturation at death than any single element. Recent studies have attempted to promote an understanding of the relationship between dental and postcranial age assessment and broaden our appreciation for the study of juvenile development and what it may provide our knowledge of geographically and temporally distinct populations (Jantz and Owsley, 1984a). However, further examination of multiple comparative populations is necessary to expand our understanding of how growth in the past may influence our understanding of the present.

Studies of long bone growth and maturation cited one of its earliest experiments in 1747 by Stephen Hales (Bisgard and Bisgard, 1935). Hales drilled two holes in the tibial shaft of a growing chicken and found that when the animal was examined two months later, while the long bone had grown 1 inch in length, the distance between the two holes remained the same. Hale concluded that increase in long bone length occurred at the proximal and distal extremities and growth was not equally distributed between these two ends (Bisgard and Bisgard, 1935).

As rudimentary as this growth experiment may seem, some of its central conclusions hold true today. Longitudinal growth of long bones takes place at the ends through deposition of new

bone between the diaphysis and epiphyseal cartilage. Similarly, bone growth does not occur proportionally over time (Bisgard and Bisgard, 1935). Through further analysis of long bone growth and development an even deeper understanding of its intricacies can be exposed.

Investigations of growth on skeletal remains provide advantages not seen in growth studies on living children. Jantz and Owsley (1984a) have noted that direct measurement on juvenile skeletal remains provides easier and more direct methods of data on proportional change. Skeletal samples similarly extended the temporal, geographic and ecological range of conditions in which human populations have been found (Jantz and Owsley, 1984a).

Methodological Concerns

Methodological concerns in estimating chronological age are of utmost importance in dealing with juvenile, archaeological skeletal remains (Johnston, 1969; Lampl and Johnston, 1996; Lovejoy et al., 1990; Merchant and Ubelaker, 1977). Numerous authors (e.g. Johnston, 1969; Lampl and Johnston, 1996; Lovejoy et al., 1990) have looked to alternate theories of estimating juvenile chronological age through the postcranial remains. Lampl and Johnston (1996) highlight two primary sources of error in aging skeletal remains: human variability, not knowing the consistency of maturation rates in a given society and the use of reference standards to age remains when such standards may not be population appropriate.

Growth Velocity

Growth has been defined by Needham (1933) as an increase in spatial dimensions, not necessarily taking place in all dimensions equally. Growth velocity is term that this author takes to connote span of time within which significant periods of size increase and/or maturation occur. Timing and intensity of growth and development are of particular importance when studying variation and particularly when comparing distinct human groups (Armelagos et al., 1972; Hummert and Van Gerven, 1983; Lovejoy et al., 1990; Roberts, 1960; Schultz, 1960;

Smith and Buschang, 2004; Sundick, 1978; Tanner, 1960; Todd, 1931; Y'Edynak, 1976). Armelagos et al. (1972) highlight this problem in the analysis of growth velocities among archaeological populations; sufficient sample size of individuals of all developmental stages may not be guaranteed. Despite its limitations, the postnatal period is characterized by "rapid growth increments in all dimensions" and thus deserves careful consideration in order to understand how populations come to vary as adults (Cameron and Demerath, 2002).

Armelagos et al. (1972) concluded that growth velocity in their prehistoric Sudanese Nubian sample was more irregular, yet similar to that of the growth velocity seen in the longitudinal study of American boys. Lovejoy et al. (1990; Maresh, 1955) compared the growth velocity of juveniles of the Libben population with healthy Euroamerican children from Maresh's 1955 study in Denver, Colorado. It was concluded that growth patterns were quite comparable between these two populations with a significant lag observed in the Libben population's growth velocity during the first three years of life (Lovejoy et al., 1990). In Y'Edynak's (1976) analysis of Western Eskimo and Aleutian juvenile skeletal remains, it was found that while White children's femora and tibiae tend to grow in relatively comparable growth velocities, among Alaskan populations the tibia appears to "grow shorter," as compared to the femur, with increasing age.

Smith and Buschang (2004) analyze growth velocity among children 3 to 10 years of age noting a consistent decelerating pattern of growth over the juvenile period. Growth velocities also were found to display a proximal-distal gradient with proximal elements (e.g. humeri, femora) displaying a greater growth velocity than distal elements (e.g. radii, fibulae). Similarly, the lower limb was shown to have a greater growth velocity than the upper limb (Smith and Buschang, 2004).

Population Variation

Numerous studies of human post-cranial remains were carried out in the pursuit of population specific standards or in the appreciation of human variation (Armelagos et al., 1972; Blanco et al., 1974; Jantz and Owsley, 1984b; Johnston, 1962; Lovejoy et al., 1990; Nyati et al., 2006; Roberts, 1976; Saunders, 1992; Steyn and Henneberg, 1996; Todd, 1931; Toselli et al., 2005; Ubelaker, 1989; Y'Edynak, 1976). Blanco et al. (1974) found that the skeletal development of rural Guatemalan children lagged behind that of both British and American children. Steyn and Henneberg's (1996) analysis of Iron Age children at site K2, South Africa, discovered that these children had greater diaphyseal long bone lengths than those of Libben, Altenerding, Eskimo and Native American sample groups. The description of these patterns of growth velocity, symmetry and overall variation impart important morphological characteristics used to better understand prehistoric populations (Armelagos et al., 1972; Garn, 1957; Lovejoy et al., 1990).

Studies of variation among the growth trajectories of closely related groups have also been pursued in nonhuman models. Falsetti and Cole (1992) investigated relative growth in three species of callitrichines. The models Falsetti and Cole (1992) explore in this inter-specific analysis are comparable to human population variation in adult shape and size:

- Model I, divergent growth trajectories: no shape differences apparent at birth, adult differences accumulated through divergent growth patterns through life
- Model II, parallel allometry: interspecific/interpopulation differences are present at birth and are maintained through similar allometric growth
- Model III, parallel isometry: common, isometric growth patterns produce adult shape differences
- Model IV, ontogenetic scaling: adult size and shape discrepancies are produced through different and changing rates or duration of growth along similar allometric trajectories (Falsetti and Cole, 1992).

While human variation is encompassed within a single species and is not directly comparable to trends of inter-specific analysis, the models discussed above open discussion as to what factors may influence the variation seen among adults.

Proportionality in Growth

Growth symmetry and proportionality are an integral component of the analysis of human variation across the globe and the span of human evolution (Armelagos et al., 1972; Buschang, 1982; Holliday and Falsetti, 1995, 1999; Holliday and Ruff, 2001; Humphrey, 1998; Jantz and Owsley, 1984a; Jungers et al., 1988; Moss et al., 1955; Roberts, 1978; Tanner et al., 1982; Y'Edynak, 1976). Mammalian limb proportions are used to investigate allometric constraints, functional morphology, and the relationship of climatic factors (Holliday and Ruff, 2001). Population axial indices have also been found to have a large genetic component being less affected by nutritional insult (Holliday and Ruff, 2001; Meadows and Jantz, 1995).

Body proportions change with growth over an individual's lifetime to arrive at their final adult form. These proportional differences over time also reflect population and ancestral variations (Hiernaux, 1968; Jantz and Owsley, 1984a). Different regions of the body have their own rate/velocity of growth that is constantly changing with age and maturity (Schultz, 1960). Y'Edynak (1976) shows that the comparatively short forearms of Aleuts and Eskimos are established early in childhood; this is also reflected in Aleutian and Eskimo growth velocity. These early patterns presuppose adult Eskimo and Aleutian adult body proportions, which conform to ecogeographic rules of proportionality. Such sensitive variations detected in growth can provide insight to the patterns of intermembral (and intramembral) and physical variation noted across populations today.

Buschang's (1982) study of differential long bone growth of a longitudinal sample of upper-middle class white children showed that through age 11, diaphyseal long bone lengths

sustain positive allometric growth with stature. It is also noted that allometric growth within each extremity is consistently similar and intralimb variation is small, the humerus maintaining greater allometric growth in the upper limb and tibia displaying greater relative growth over the femur (Buschang, 1982). Jantz and Owsley (1984a) note that within both the upper and lower limbs, proximal elements increase more rapidly than distal elements.

Influence of Sex

Many authors have noted the discrepancy between skeletal growth of males and females over their lifetime (Acheson, 1954; Buschang, 1982; Gasser et al., 2000, 2001a, b; Gindhart, 1973; Hewitt et al., 1955; Humphrey, 1998; Johnston, 1961; Liliequist and Lundberg, 1971; Lovejoy et al., 1990; Maresh, 1955; Nyati et al., 2006; Roche, 1978; Sheehy et al., 2000; Smith and Buschang, 2004; Todd, 1931; Watts, 1985). Humphrey (1998) refers to differential male/female growth as "sexual bimaturism"; the duration and velocity of growth varying by sex. Roche (1978) and Gasser et al. (2000) find that typically, girls achieve adult stages of skeletal development at earlier chronological ages than their male counterparts. Watts (1985) notes that this trend of female advanced development over males is evident across not only humans, but similarly among chimp and macaque development. Humphrey (1998) highlights that sexual dimorphism in the human skeleton is not a "uniform phenomenon." Considerable diversity arises from the differential rate and duration of growth during different periods of development between males and females, particularly around the time of puberty (Gasser et al., 2000, 2001a, b; Lovejoy et al., 1990; Maresh, 1955).

Buschang's (1982) work concluded that although allometric sex differences are small, males are consistently favored over females. Gasser and co-workers (2000) find that males tend to exhibit greater height than females based upon a variety of variables active during juvenile development (i.e. early increase in testosterone in prepubescent boys, beginning as early as

infancy) that do not manifest in greater physical size until puberty. Gindhart (1973) observed that male and female white North American children have comparably sized tibiae until age 13 with the males being slightly, yet not significantly, ahead of females. While males and females tend to remain comparable in size through the juvenile period, boys tend to have a later onset of puberty by approximately 1.5 years accounting for the substantial gain in physical size, relative to females (Gasser et al., 2000).

Nutritional Considerations

Nutritional considerations are always discussed when considering the somatic and skeletal growth of juveniles (Acheson, 1960; Blanco et al., 1974; Hewitt et al., 1955; Holliday and Ruff, 2001; Humphrey, 1998; Jantz and Owsley, 1984a, b; Lovejoy et al., 1990; Martorell et al., 1979; Owsley and Jantz, 1985; Roberts, 1978; Ruff, 1993; Sellen, 1999; Toselli et al., 2005). Childhood growth has often been seen as a marker of health and nutrition in society (Lampl and Johnston, 1996). Humphrey (1998) highlights that significant nutritional resources are required to support the energetic constraints imposed particularly during adolescent growth.

Historically, the most noted nutritional effect manifest in the juvenile skeleton are lines of arrested growth, called Harris lines. Harris lines are dense calcium deposits, visible in radiography, laid down in the metaphysis when grow recommences after a period of growth cessation. Harris lines have been attributed to illness, acute infection, inoculation or any somatic insult such as malnutrition (Acheson, 1960; Blanco et al., 1974; Clarke, 1982; Gindhart, 1969; Hewitt et al., 1955; Mays, 1995). Hewitt et al.'s (1955) analysis through the Oxford Child Health Survey attributed the incidence of Harris lines to acute, abrupt illness such as measles. These researchers similarly note that apparent severe, long term illness left no trace on the bone radiographically and conversely some films displayed prominent Harris lines when no illness was recorded (Hewitt et al., 1955).

While evidence of Harris lines have been associated with illness and malnutrition, these periods of arrested growth do not appear to affect overall skeletal development. Mays (1995) found no significant relationship between long bone growth and the appearance of Harris lines. Gindhart's (1969) analysis of the frequency of Harris lines concluded that although most individuals display evidence of Harris lines at some point in time, these arrested periods of development do not appear to affect final adult stature.

Similarly, discussions on the affects of nutritional insults during childhood are often accompanied by what is referred to as "catch-up growth" (Cameron and Demerath, 2002; Eckhardt et al., 2005; Martorell et al., 1979; Sellen, 1999). This term refers to a confined period of exceptionally rapid growth following an identified episode of constraint. Cameron and Demerath's (2002: 166) study concluded that following a period of stress, growth rate accelerates which "brings the child's growth pattern back towards the normal centiles."

Catch-up growth has even been found to account for resolving constrained growth throughout the developmental period in developed and developing countries. Martorell et al. (1979) concluded that among four rural Guatemalan villages chronic malnutrition affected overall body size to a significantly greater extent than skeletal maturation. Eckhardt et al. (2005) note that extending growth beyond the adolescent state may be an adaptive response to growth insults affecting early maturation. It was concluded that those individuals with the greatest "growth potential" (i.e. tall parents) were least effected by nutritional or illness-related developmental constraints throughout childhood (Eckhardt et al., 2005).

Nutritional factors, though significant in individual development, are considered "unlikely" to affect patterns of variation between geographically distributed populations (Ruff 1993:55; Schreider, 1964). Ruff (1993) finds that although secular trends and improved nutrition may

account for increases in height, evolutionary trends in limb proportionality are not affected. Conserved population proportionality in the postcrania makes "good evolutionary sense" as nutritional variations tend to be short-lived relative to eco-geographic variation (Ruff 1993:56).

Dental Development vs. Skeletal Maturation

There is much debate in the literature as to the relationship between dental and skeletal maturation and their comparability (Anderson et al., 1975; Billewicz et al., 1973; Demirjian and Goldstein, 1976; Demirjian, 1978; Demisch and Wartmann, 1956; Falkner, 1957; Malcolm and Bue, 1970; McGregor et al., 1968; McKay and Martin, 1952; Todd, 1931). Anderson et al. (1975) found that dental calcification was significantly related to skeletal maturation. However, other researchers have indicated that the skeletal system, as well as other maturation factors such as puberty, remains fundamentally independent of dental development (Demirjian, 1978; Falkner, 1957; McGregor et al., 1968).

Demirjian (1978) cites the distinct developmental origins of skeletal versus dental development. Bone is derived from mesoderm and teeth are, in part, epithelial (Falkner, 1957). In Billewicz et al.'s (1973) analysis of 542 Chinese children from birth to 3 years found no significant association between dental and skeletal maturity at any given age or developmental stage. Demisch and Wartmann (1956) found the mean difference between skeletal age and chronological age among 151 American white children from Boston was 0 months. While, as discussed above, nutritional, environmental, population and sex difference may affect the dentition as well as the postcrania, dental maturation appears to be more resistant to such extrinsic perturbations.

Malcolm and Bue (1970) noted a trend toward later eruption times in individuals with slower overall physiological growth. Such findings link dental and postcranial growth based upon the extrinsic factors influential in their acceleration or retardation. McGregor et al. (1968)

concluded that among young children in the rural villages of Gambia, children taller or heavier for their age displayed precocious dental eruption. While they noted no evidence to the contrary (slow growth related to a prolonged period of eruption), it was highlighted that children smaller for their age may be assessed as chronological younger than they truly are as compared to the larger precocious children. In contrast to McGregor et al.'s (1968) analysis, McKay and Martin (1952) found that among Zulu and Bantu, who displayed precocious dental development of 1 year as compared to Americans, exhibited carpal ossification which was delayed 18 months to 2 years as compared to these same Americans. McKay and Martin (1952) attribute this discrepancy to the genetically predetermination of tooth bud formation and eruption, while later physical development is more subject to harsh environmental influences.

Evolutionary-Genetic Relatedness of Populations

Relethford (2004) described global patterns of human genetic and morphological diversity by the isolation-by-distance model citing geographic distance as a significant predictor of genetic variation. This model posits that the genetic distinction between populations will increase as the physical, geographic distance between groups increase. Many studies have been conducted, employing a wide range of genetic, morphological, linguistic and dental evidence, to determine the origin of and relationship between Native American groups (Crawford, 1998; Greenberg et al., 1986; Kolman et al., 1995, 1996; Malhi et al., 2003; Mulligan et al., 2004; Relethford, 2004; Schillaci and Stojanowski, 2003; Torroni et al., 1992, 1994; Zlojutro et al., 2006).

One of the longest lived and widespread explanations for the distribution of Native Americans throughout the Americas has been Greenberg et al.'s (1986) three wave hypothesis. The three wave model is represented by the three main linguistic families of New World populations: Na-Dene, Aleut-Eskimo and Amerind. Amerind, representing those individuals from North and South American being the oldest, based upon its rate and range of geographic

dispersion, placing these individuals' entrance to the New World at approximately 11,000 B.P. Na-Dene, individuals residing on the Pacific Northwest, central Alaska and northwest Canada, represent a second migration with deep internal linguistic divisions among speakers, dates to approximately 9,000 B.P. Greenberg et al. (1986: 470) note that Aleut-Eskimo speakers are most recent; the internal divisions are "less deep" than the Na-Dene and correlate to an entrance into the New World between 2,900 and 5,600 B.P.

Support for the three wave hypothesis has also been drawn from preliminary analyses of mitochondrial DNA (mtDNA) (Torroni et al., 1992, 1994). However, further analysis finds little support for the separation of these three main New World groups based on mtDNA (Kolman et al., 1995). Kolman and colleagues (1995) compared mitochondrial DNA sequences between three Amerind populations representing the geographic extremes of Amerind settlements and one Na-Dene group from the Pacific Northwest. It was concluded that the average genetic distance among the mtDNA haplotypes between the major groups is equivalent between Amerind and Na-Dene populations compared. The reduced genetic diversity displayed between these groups "blurs the clear genetic distinction" previously drawn between Na-Dene and Amerind groups (Kolman et al., 1995: 281). Kolman et al. (1995) conclude that the diversity presented here could have been accumulated after entry into the New World.

While initial genetic investigations lent support to all or part of Greenberg et al.'s (1986) model, recent analyses point toward a single migration, approximately 17,000 years ago, with Mongoloid origin (Mulligan et al., 2004). With the advent of comparative analyses on indigenous genetic data, investigations became directed toward Native American origins based on the distribution of New World haplotypes in Asia. Native American mtDNA has been attributed to one of four main haplotypes labeled A, B, C and D. These haplotypes populations

are nonrandomly distributed throughout Native North Americans (Kolman et al., 1996; Malhi et al., 2003; Mulligan et al., 2004). Kolman et al. (1996) note general clines of the four haplogroup distributions throughout the Americas; a north-to-south decrease in A haplotypes and an increase in haplogroups B, C and D. Haplogroup A is predominantly found in Eskimo-Aleut populations; B and C dominate in the Southwest (Mulligan et al., 2004; Zlojutro et al., 2006). It was found that the four Native American haplotypes are not frequent or widespread among Asian populations, particularly in Siberia, the once thought origin of New World populations (Kolman et al., 1996). Kolman et al. (1996) note that this disparity of haplotypes dispersion in Asia weakens Greenberg et al.'s (1986) hypothesis; the implausible probability that the same four genetic markers would be reproduced in the New World on three, distinct occasions.

Comparable to Native American diversity, Mongolian populations occupy a wide geographic range yet appear to have low levels of genetic variation (Kolman et al., 1996; Malhi et al., 2003). Lending further credence to their ancestral connection, Kolman et al. (1996) attribute this homogeneity to life history and cultural factors of Mongolian life. Malhi et al. (2003) similarly noted the high frequency of haplogroup B and overall genetic homogeneity of Ancestral Puebloan and Zuni populations of the Southwest which they similarly attributed to cultural factors of the region and shared evolutionary history.

The lower level of overall genetic diversity among Native American groups promotes a single migration of Native peoples from Asia into the New World with subsequent bottleneck effects and gene flow (Mulligan et al., 2004). Mulligan et al. (2004: 307) caution that "no single genetic element, analysis or study should be considered definitive". However, the variation appreciated in Native American populations today is most probably a product of their shared

genetic and evolutionary history influenced by eco-geographic destinations, cultural development and life history factors.

Given the three populations of Native North American populations compared in the present analysis, an appreciation of their potential evolutionary relatedness and/or genetic distinction is important in evaluating the conclusions drawn from their comparison. Numerous authors (e.g. Eveleth and Tanner, 1990; Holliday and Ruff, 2001) have made similar comparisons to those proposed here on human populations that span the farthest extremes of the world. This project explores population variation on three human populations that display a more highly conserved evolutionary history.

Ecological Considerations

> It is clear that genes per se were not 'drivers' of evolution. The genetic tool kit represents possibility – realization of its potential is ecologically driven.
>
> -- Carroll, *Endless Forms Most Beautiful*.

Numerous authors have identified eco-geographic influences on the morphology of human populations (Abouheif, 2004; Blackburn et al., 1999; Blanco et al., 1974; Carroll, 2005; Corruccini, 1974; Franciscus and Long, 1991; Freitas et al., 2004; Hall, 2004; Holliday, 1997a, b; Holliday and Falsetti, 1995, 1999; Holliday and Ruff, 2001; Hunt, 1958; Jantz and Owsley, 1984a, b; Jantz and Jantz, 1999; Johnston, 1962; Larsen, 2004; Lovejoy et al., 1990; Mayr, 1956; McHenry, 1994; Moorrees et al., 1963a, b; Moorrees, 1965; Nanda, 1960; Newman, 1956; Newman and Munro, 1955; Owsley et al., 1982; Owsley and Jantz, 1985; Pearson, 2004; Ravosa et al., 1995; Reid, 2004; Roberts, 1960, 1976, 1978; Ruff, 1993; Ruff et al., 2006; Tanner, 1960, 1992; Todd, 1931; Trinkaus, 1978, 1981; Van Valen, 1962; Warren, 1997; Weaver and Ingram, 1969; West-Eberhard, 2004). Blanco et al. (1974), Freitas et al. (2004) and others note that population and individual human variation in physical development results from the interaction

between genes and the environment. “It is now widely believed that each individual has a genetically predetermined potential for the velocity at which he will grow and mature and this velocity may be modified by environmental factors” (Blanco et al., 1974: 39). Matsuda’s (1987) “pan-environmentalism” emphasizes the role of the external environment in highlighting existing genetic variability or bringing about genetic change in a population (Hall, 2004). An understanding of the evolutionary and current environmental pressures affecting population variation is critical to evaluating adult morphological variation (Ruff et al., 2006).

Many authors note that the “marked relationship” between morphology and climate align directly to Bergmann and Allen’s “rules” for homeothermic animals (Holliday, 1997a, b; Holliday and Falsetti, 1995, 1999; Newman and Munro, 1955; Roberts, 1978: 34; Ruff, 1993; Schreider, 1964; Trinkaus, 1981; Warren, 1997; Weaver and Ingram, 1969). Extremity lengths are attributed to two complementary “rules” for homeothermic animals and can be seen in human variability. Allen’s rule (1877) asserts that lower latitude populations display longer extremities while those of higher latitudes have shorter limbs. This stems from gene flow from warmer geographic regions during the transition to modern *Homo sapiens*. The complementing “rule” or hypothesis is posited by Bergmann (1847): body mass increases as a population inhabits cooler or more polar regions resulting in shorter extremities and an overall decrease in body surface area. These rules of morphological patterning to geographic variation are attributed to methods of heat dissipation. In warmer climates, linear individuals with longer extremities have a greater surface area/volume ratio than those in cooler climates with shorter limbs (Blackburn et al., 1999; Holliday and Falsetti, 1995; Holliday, 1997a, b; Schreider, 1964; Weaver and Ingram, 1969). In an analysis of modern human populations, Warren (1997) finds that these rules of human proportionality manifest early in fetal development.

Significant evidence for eco-geographic patterning of skeletal morphology and proportionality has been found among evolutionary study of hominids (Holliday 1997a, b; Holliday and Falsetti, 1995, 1999; Holliday and Ruff, 1997, 2001; McHenry, 1994; Ruff, 1993; Trinkaus, 1981). Many authors cite the strong genetic component that guides these "rules" in modern populations which stems from evolutionary climatic adaptations (Holliday and Falsetti, 1995, 1999; Holliday and Ruff, 2001; Vrba, 1996). Holliday (1997b) and Trinkaus (1981) note that Neandertal postcranial features are "hyper-polar" in morphology, similar to modern "Eskimo" populations, characterized by short proximal and shorter distal limb segments relative to skeletal trunk height and size. These characteristics are attributed to the extremely cold temperatures of glacial Europe as well as a lack of sufficient "cultural buffering against cold stress" (Holliday 1997b:245). Similarly, hominids living in warm climates were found to have extremely linear, "hyper-tropical", proportions (Ruff, 1993).

Evidence of regional variation has also been identified among mammals (e.g. Riesenfeld, 1973; Weaver and Ingram, 1969). Riesenfeld (1973), in experimental studies on the effects of extreme heat and cold on rats, found that when subject to extreme cold growth was retarded in the distal segments (radius, ulnae, tibiae) of the limbs while the proximal limb (humeri/femora) were less significantly affected. When subject to heat exposure, all limb elements were found have elongated relative to trunk length (Riesenfeld, 1973). Similar results were found by Weaver and Ingram (1969) in an experimental study of pigs. Littermates were separated and raised in two separate, temperature controlled rooms. Those raised in the cooler environment were "more stocky" exhibiting shorter extremities than those littermates raised in warmed conditions (Weaver and Ingram, 1969:710).

While a true causal explanation for the variation seen following Bergmann's and Allen's rules has not been identified, many theoretical mechanisms have been proposed (Holliday 1997a, b; Holliday and Falsetti, 1995; Trinkaus, 1981; Weaver and Ingram, 1969). One of possible mechanisms responsible for the variation resulting from Bergmann's and Allen's rules involves conservation of heat in colder regions by minimizing surface area/volume ratio. Heat loss in any animal is directly proportional to body surface area (Holliday, 1997b). An increase in body size (Bergmann's rule) and decrease in extremity length decreases overall surface area/volume ratio. Similarly, increasing extremity length (Allen's rule) augments overall body surface area which subsequently increases surface area/volume ratio making it easier for organisms in warmer climate to dissipate heat (Holliday, 1997a, b; Holliday and Falsetti, 1995).

An alternate mechanism for changing in body form resulting from eco-geographic condition involves blood flow (Trinkaus, 1981; Weaver and Ingram, 1969). Animals subject to cold stress are habitually vasoconstricted which could reduce oxygenation and nutrient supply to the extremities (Trinkaus, 1981; Weaver and Ingram, 1969). Following this hypothesis Trinkaus (1981) proposed that under cold stress distal segments would be more affected by this vasoconstriction than proximal components accounting for the pattern of shorter distal limb segments evidenced in cold stressed, homeothermic animals.

The theory and practice of eco-geographic patterning among human populations has its critics and exceptions (Geist, 1987; Mayr, 1956; McNab, 1971; Schreider, 1964; Vrba, 1996). While exceptions to these "rules" may exist, arguments cited in the literature tend to focus on variables that may not be properly associated with geographic variation. McNab (1971:852) argues that body size is determined by the food available and associated competition for resources noting Bergmann's rule as a "special case of this general phenomenon." These

conclusions are based upon correlations of head-body lengths to latitude without regard to relative extremity length to body size. Similarly, Geist (1987) criticizes Bergmann's rule, correlating body mass, calculated from skull data, to latitude among deer and wolves. While body mass was found to be correlated with latitude, Geist (1987:1037) concludes that "there is neither an empirical nor a theoretical basis for Bergmann's rule" as the positive correlation of body size with increasing latitude was not as large a magnitude as predicted. Unfortunately, craniometric data might not be the best proxy for body size and extremity length.

These numerous studies have set the stage for this analysis to confirm whether climatic patterns of variation are preserved among these three eco-geographically distinct populations.

CHAPTER 3
MATERIALS

Native Alaskan

The 242 individuals representing the Native Alaskan sample are all currently housed at the National Museum of Natural History, Smithsonian Institution. Dental and postcranial data collected on all individuals is found in Appendix A. All materials were analyzed between December 2004 and May 2005.

Spatial distribution

The Native Alaskan skeletal remains were recovered from a series of archaeological sites distributed throughout the Aleutian Islands and the north and west coast of mainland Alaska.

Table 3-6. Spatial distribution of Native Alaskan archaeological sites.

Quad/Region	Longitude	Latitude	N	Locale	n	Longitude	Latitude
Afognak	---	---	3	Hog Isl.	3	53° 54'20.38"	166° 33'42.88"
Atka	52° 12'40.36"	174° 39'40.68"	1	Atka Isl.	1	52° 12'40.36"	174° 39'40.68"
Attu	52° 26'05.55"	173° 33'48.26"	10	Agattu Isl.	10	52° 26'05.55"	173° 33'48.26"
Baird Inlet	61° 20'25.01"	149° 34'33.18"	11	Kuskogamut	11	---	---
Barrow	71° 17'24.61"	156° 47'19.61"	4	Pt. Barrow	4	71° 17'24.61"	156° 47'19.61"
Bethel	60° 47'23.05"	161° 45'31.10"	15	Akiachak	1	60° 54'20.77"	161° 25'26.57"
				Akiak	1	60° 54'35.02"	161° 13'24.46"
				Kwishluk	1	---	---
				Napaskiak	11	60° 42'18.07"	161° 45'58.85"
				Old Bethel	1	---	---
Dillingham	59° 02'24.22"	158° 27'57.75"	13	First Wood Lk.	2	---	---
				Kaskanak	5	59° 16'59.92"	156° 10'59.99 "
				Kokwak	3		
				Nushagak R.	3	59° 31'28.08"	157° 47'22.76"
Dixon Entrance	---	---	1	Dall Isl.	1	54° 57'58.33"	132° 57'19.35"
Fairbanks	64° 50'42.33"	147° 43'17.81"	1	Fairbanks	1	64° 50'42.33"	147° 43'17.81"
Goodnews	59° 07'09.85"	161° 34'53.59"	6	Mumtrak	5	---	---
				Togiak	1	59° 03'35.91"	160° 22'38.85"
Holy Cross	62° 12'06.00"	159° 46'14.32"	34	Anvik	3	62° 39'11.06"	160° 11'56.29"
				Bonasila	8		
				Ghost Creek	4	62° 12'30.68"	159° 46'45.51"
				Holochacat	3	---	---
				Holy Cross	6	---	---
				Shageluk	9	62° 39'16.94"	159° 31'28.08"

Table 3-6. Continued

Quad/Region	Longitude	Latitude	N	Locale	n	Longitude	Latitude
				Unknown	1	---	---
Hooper Bay	61° 31'54.97"	166° 05'53.16"	14	Napareyaramiut	3	---	---
				Unknown	11	---	---
Kwiguk	62° 45'23.20"	164° 30'52.39"	28	Kwiguk Pass	12	---	---
				New Fort Hamilton	10	62° 43'36.40"	164° 51'18.92"
				Old Andreivsky	2	---	---
				Old Hamilton	4	---	---
Marshall	61° 52'45.94"	162° 05'16.51"	20	Pilot Station	13	61° 56'10.31"	162° 52'53.50"
				Ingrehak	7	---	---
Naknek	58° 43'43.63"	157° 00'56.53"	10	Coffee Pt.	1	---	---
				Egegik	4	58° 13'01.33"	157° 21'18.54"
				Pawik	5	---	---
Nome	64° 29'59.73"	165° 24'20.59"	5	Cape Nome	1	64° 27'43.40"	164° 57'46.08"
				Sledge Isl.	4	64° 29'08.73"	166° 12'51.33"
Nushagak Bay	58° 56'58.76"	158° 29'10.16"	3	Kulukak Bay	3	---	---
Petersburg	56° 48'22.00"	132° 58'15.35"	2	Ft. Wrangell	1	56° 29'03.45"	132° 22'11.38"
				Prince of Wales Isl.	1	55° 31'39.88"	132° 48'20.22"
Rat Isl.	51° 48'03.69"	178° 17'36.43"	6	Amchitka Isl.	6	51° 22'44.01"	179° 15'29.88"
Russian Mission	61° 47'07.86"	161° 19'27.77"	18	Bogus Creek	2	---	---
				Okahamute	5	---	---
				Paimute	11	---	---
Samalga Isl	52° 47'08.29"	169° 12'04.52"	10	Kagamil Isl.	10	52° 59'27.12"	169° 42'41.31"
Shishmaref	66° 15'24.30"	166° 03'59.69"	1	Sarichef Isl.	1	66° 14'19.98"	166° 05'37.02"
Sleetmute	61° 42'04.44"	157° 10'09.08"	3	Old Napaimiut	3	---	---
Teller	65° 15'51.45"	166° 21'47.95"	10	Mitliktavik	4	---	---
				Wales	6	65° 36'40.58"	168° 05'51.25"
Umnak	53° 22'00.22"	167° 54'00.00"	2	Umnak Isl.	2	53° 22'00.22"	167° 54'00.00"
Unalaska	53° 37'33.97"	167° 01'57.97"	5	Amaknak Isl.	1	58° 53'49.24"	166° 31'49.40"
				Shiprock Isl.	4	---	---
Unknown			6	Yukon River	6	62° 34'55.55"	164° 28'18.18"

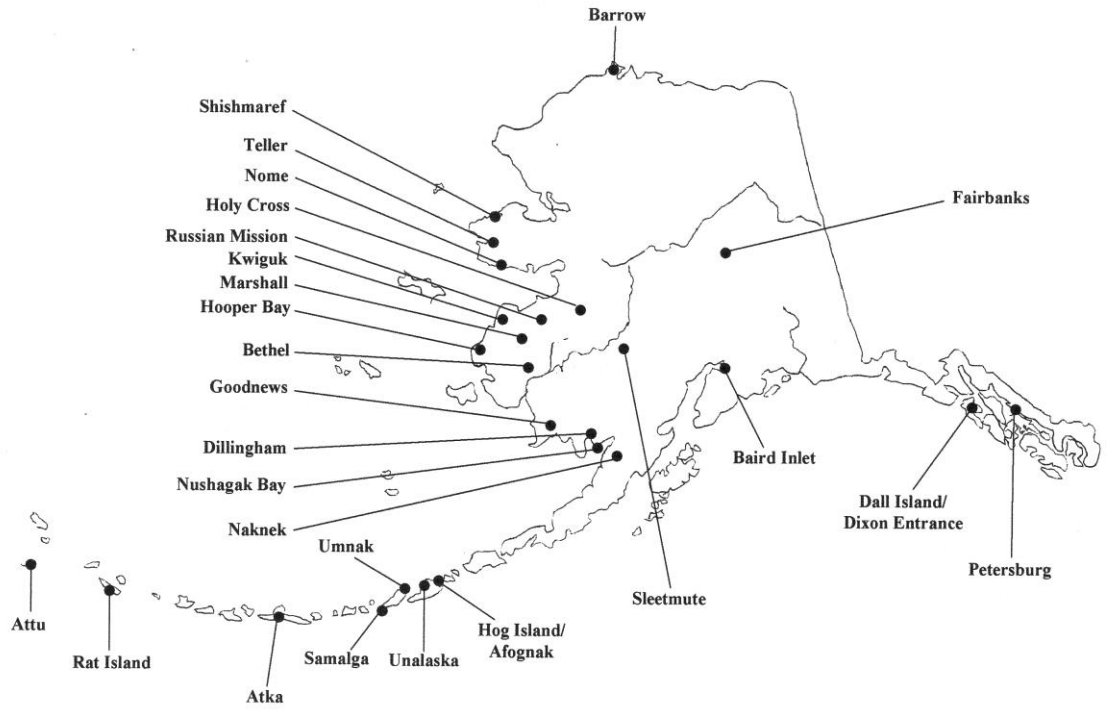


Figure 3-1. Geographic distribution of Native Alaskan sites

Temporal Distribution

Table 3-7. Temporal distribution of Native Alaskan sites.

Quad	N	Excavator	Occupation	Reference
Afognak	3	Hrdlicka	1600-1800	Dumond, 2002; Hrdlicka, 1945; Hunt 2002
Atka	1	"	"	"
Attu	10	"	"	"
Baird Inlet	11	"	"	"
Bethel	15	"	"	"
Dillingham*	13	"	"	"
Dixon Entrance*	1	"	"	"
Fairbanks	1	"	"	"
Goodnews*	6	"	"	"
Holy Cross*	34	"	"	"
Hooper Bay*	14	"	"	"
Kwiguk	28	"	"	"
Marshall*	20	"	"	"
Naknek	10	"	"	Dumond, 1981

Table 3-7. Continued

Quad	N	Excavator	Occupation	Reference
Nome	5	Hrdlicka	1600-1800	Dumond, 2002; Hrdlicka, 1945; Hunt 2002
Nushagak	3	"	"	"
Petersburg*	2	"	"	"
Rat Islands	6	"	"	"
Russian Mission*	18	"	"	"
Samalga Island*	10	"	"	"
Shishmaref*	1	"	"	"
Sleetmute*	3	"	"	"
Teller	10	"	"	"
Umnak	2	"	"	"
Unalaska	5	"	"	"
Barrow	4	Collins	1600-1750	Dumond, 2000
Unknown	6	---	---	---

* These sites were confirmed and associated with Hrdlicka's excavations during this period through personal communication with Dr. David Hunt (May 2007).

Excavation and Principal Investigators

Nearly all Native Alaskan human remains housed at the Smithsonian Institution were acquired and collected through expeditions by Ales Hrdlicka between 1926 and 1938 and one site by Henry B. Collins' expedition to Point Barrow in 1936 (Dumond, 2000, 2002; Hrdlicka, 1945; Hunt, 2002, 2007).

Life History Conditions

Some of the first explorers into the New World through the Bering Strait were Russian traders and hunters looking to expand and establish trade relations throughout Alaska in the early to mid-18th century (VanStone, 1984). Though the Alaska mainland and Aleutian Islands had a relatively "late" European arrival, given the time period that a majority of these populations occupied, European contact played a significant role in the life history of the Native Alaskan populations in this study.

European contact with native peoples in Alaska is evidenced by a relatively more amenable introduction than other regions of the New World. Russians sought out native

community leaders who were given silver medallions in recognition of their status and to encourage open trade. Communities were paid for furs, fish and work on whaling ships in items including flour, tobacco, molasses, lead, firearms and ammunition (VanStone, 1984).

Subsistence strategies in southwest Alaska and the Aleutians centered on fishing and game hunting (Dumond, 2000; VanStone, 1984). Arctic and sub-arctic populations were particularly adept in their hunting/fishing strategies as opposed to many other hunting and gathering societies at this time who derived a considerable portion of their energy sources from vegetable resources unavailable in Alaska (Freeman, 1984). Coastal and island communities subsisted primarily on fishing (predominantly salmon and cod) and hunting sea mammals, seal and walrus being the most important maritime game (Freeman, 1984; VanStone 1984). Among coastal sites the remains of cetaceans, rodents, sea invertebrates and carnivores were also found (Savinetsky, 2002). Mainland-coastal groups often ventured further inland hunting caribou and reindeer to supplement their diet (Dumond, 2000; VanStone, 1984). At Wales, Collins documented a significant quantity of bird remains found among refuse including Passerines, shore birds and gulls (Dumond, 2000; Savinetsky, 2002).

Repatriation Status

Native Alaskan skeletal remains are currently housed at the U.S National Museum of Natural History. Portions of the skeletal remains examined in the present investigation housed at the National Museum have been "offered" to the Native Americans groups of Alaska for repatriation and are unavailable for further research; other sites have already been repatriated (e.g. Kagamil Island) (personal communication with Dr. Bill Billeck, April 2007, Repatriation Department, National Museum of Natural History, Smithsonian Institution).

South Dakota Arikara

The 379 individuals representing the Arikara sample are all currently housed at the National Museum of Natural History, Smithsonian Institution. Dental and postcranial data collected on all individuals is found in Appendix A. All materials were analyzed between May 2005 and August 2005 supported by a Graduate Fellowship from the National Museum of Natural History, Smithsonian Institution.

Spatial Distribution

The South Dakota Arikara skeletal remains were recovered from a series of archaeological sites distributed throughout northern/central South Dakota.

Table 3-12. Spatial distribution of South Dakota Arikara archaeological sites

County	N	Longitude	Latitude	Site	n
Buffalo	3	43° 51'01.95"	99° 30'17.34"	39BF2A Medicine Crow	3
Campbell	11	45° 35'31.56"	99° 49'14.29"	39CA4 Rygh	11
Charles Mix	3	43° 26'30.03"	98° 42'47.23"	39CH45 Hitchell	1
				39CH7 Oldham	2
Corson	55	45° 29'29.66"	101° 35'24.86"	39CO31 Nordvold I	4
				39CO32/33 Nordvold Cemetery	32
				39CO9 Leavenworth	19
Lyman	2	43° 35'44.57"	99° 51'47.94"	39LM218 Black Partizan	2
Sully	104	44° 43'14.32 "	100° 06'23.14"	39SL29 C.B. Smith	1
				39SL38	1
				39SL4 Sully	102
Stanley	64	44° 12'56.73"	100° 30'35.84"	39ST1 Cheyenne River	43
				39ST16 Breeden	2
				39ST203 Black Widow Ridge	2
				39ST215 Leavitt	11
				39ST216 Buffalo Pasture	3
				39ST224	1
				39ST23	1
				39ST3 BLACK WIDOW	1
Walworth	134	45° 19'53.31"	99° 57'15.50"	39WW1 Mobridge	133
				39WW7 Swan Creek	1
				Unknown	3

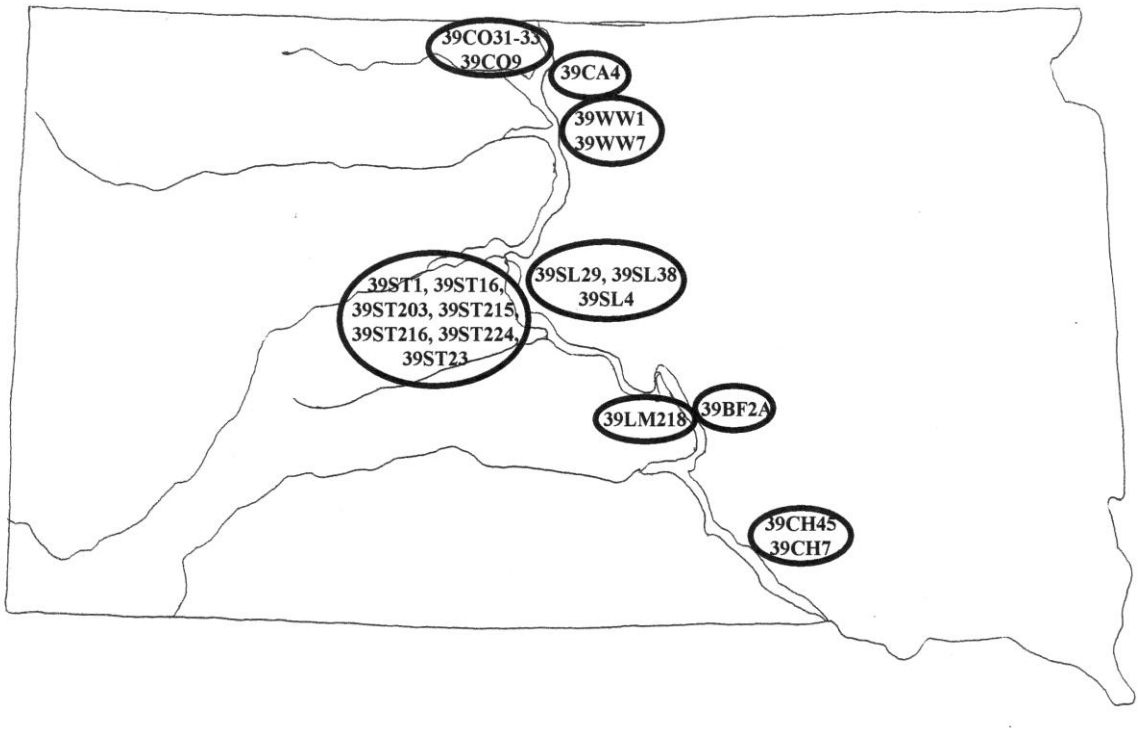


Figure 3-2. Geographic distribution of South Dakota Arikara sites

Temporal Distribution

The temporal range for the occupation of these archaeological sites was determined based on tree ring dating as well as ceramic and archaeological artifacts (Jantz and Owsley, 1984b; Owsley and Jantz, 1985).

Table 3-13. Temporal distribution of South Dakota Arikara sites.

Site	Period	Time	Reference
39BF2A Medicine Crow	Plains woodland	700-900	Ahler and Toom, 1995; Key, 1983; Lehmer, 1971
39CH7 Oldham	"	"	"
39CA4 Rygh	Extended coalescent	1550-1675	Jantz and Owsley, 1984a; Key, 1983; Lehmer, 1971; Owsley et al., 1982
39CO32/33 Nordvold Cemetery	"	"	"

Table 3-13. Continued

Site	Period	Time	Reference
39SL29 C.B. Smith	Extended-Post-contact coalescent	1550-1780	Jantz and Owsley, 1984a; Key, 1983; Lehmer, 1971
39SL38	"	"	"
39SL4 Sully	"	"	"
39CO31 Nordvold I	PC coalescent	1675-1792	Jantz and Owsley, 1984a; Key, 1983; Lehmer, 1971; Owsley et al., 1982
39ST1 Cheyenne R.	"	"	"
39ST16 Breeden	"	"	"
39ST203 Black Widow Ridge	"	"	"
39ST215 Leavitt	"	"	"
39ST216 Buffalo Pasture	"	"	"
39ST224	"	"	"
39ST23	"	"	"
39WW1 Mobridge	"	"	"
39WW7 Swan Creek	"	"	Hurt, 1957; Jantz and Owsley, 1984a; Key, 1983; Lehmer, 1971; Owsley et al., 1982
39CO9 Leavenworth	Disorganized coalescent	1780-1862	Jantz and Owsley, 1984a; Key, 1983; Lehmer, 1971; Owsley et al., 1982
39CH45 Hitchell	Unknown	Unknown	Unknown
39LM218 Black Partizan	"	"	"
39ST3 Black Widow	"	"	"

Excavation and Principal Investigators

The skeletal remains in the present analysis were excavated by multiple individuals and institutions beginning in the 1920s and continuing until the early 1970s (Bass et al., 1971; Lehmer, 1971; Owsley and Jantz, 1994; Wedel, 1961). Skeletal remains were first recovered and curated in South Dakota in the late 1920s by two notable archaeologists who were interested in uncovering the states prehistory: M.W. Stirling of the U.S. National Museum and W.H. Over of the University of South Dakota and the Over Museum later named in his honor (Ahler and Toom, 1995; Bass et al., 1971; Krause, 1971; Owsley and Jantz, 1994; Zimmerman, 1985).

Another series of skeletal remains were recovered through the Missouri Basin Project undertaken by the Smithsonian Institution, Bureau of American Ethnology and the National Park Service in conjunction with local universities and historic societies (Bass et al., 1971; Lehmer, 1971; Wedel, 1961). This endeavor sought the construction of four large reservoirs in North and South Dakota along the Missouri River. Four large cemeteries were excavated under the direction of William Bass of the University of Kansas (later University of Tennessee, Knoxville) including a majority of the present sample: Leavenworth (39CO9), Mobridge (39WW1) (the final season in 1971 under the direction of D.H. Ubelaker of the U.S. National Museum) and Sully (39SL4) (Bass et al., 1971; Owsley et al., 1982; Owsley and Jantz, 1994). Finally, W.R. Hurt partially excavated the Swan Creek (39WW7) cemetery which was added to the original Over Collection (Hurt, 1957; Owsley and Jantz, 1994). Much of the Over Museum Collection and Bass excavations of South Dakota Arikara skeletal remains were loaned to the University of Tennessee, Knoxville and the U.S. National Museum for osteological analysis. A large portion of the remaining Over Museum human skeletal collection was repatriated and re-interred in 1986 (Owsley and Jantz, 1994).

Life History Conditions

Those few individuals dated to the Late Plains Woodland period are considered pre-Arikara and characterized by a transition from hunting-gathering and small scale horticultural practices to becoming more sedentary with an increasingly intensified, full-time agricultural foundation and introduction of unique pottery styles to the region (Key, 1983; Lehmer, 1971; Wedel, 1961; Zimmerman, 1985). Paleobiotic, archaeological and zooarchaeological analyses of the Medicine Crow site, a major representative for the Plains Woodland period, revealed cultivated corn, beans, squash, sunflowers and tobacco. Native fauna predominantly exploited by the inhabitants of this period included bison, deer, and waterfowl as well as fish native to the

Missouri River including catfish and bass (Ahler and Toom, 1995; Bass et al., 1971; Lehmer, 1971; Wedel, 1961).

The Coalescent Tradition is a broad category in which the South Dakota Arikara become the group as recognized today. This period is divided into four categories of which the latter three comprise the present sample: Extended Coalescent, Post-contact Coalescent and Disorganized Coalescent (Key, 1983). Each of these phases is marked by distinctive cultural features and transitions affecting the South Dakota Arikara.

The Extended Coalescent period is marked by an explosion of fortified settlements and communities (Krause, 1971; Zimmerman, 1985). The subsequent Post-contact Coalescent period is distinguished from the Extended by the introduction of horses into the Plains from Spanish settlements in the southwest U.S. and the advent of the fur trade by European settlers moving through the central Plains (Key, 1983; Wedel, 1961). The fur trade had a significant impact on the Native American regions they encountered and this was similarly the case with the South Dakota Arikara. European contact introduced cultural artifacts, furs, trade and technology and similarly wrought disease and oppression on native groups (Key, 1983; Wedel, 1961; Zimmerman, 1985).

Finally, the Disorganized Coalescent period is the reconstitution of the South Dakota Arikara following European contact. The "remnants of the once powerful tribes" reconstructed and rebuilt themselves into banded settlements (Key, 1983: 23).

Repatriation Status

South Dakota Arikara skeletal remains are currently housed at the U.S National Museum of Natural History and the University of Tennessee, Knoxville. The skeletal material examined in the present investigation housed at the National Museum have been "offered" to the Native Americans groups of South Dakota for repatriation and are unavailable for further research in its

entirety. The Three Affiliated Tribes have not made a decision at this time and the remains are presently held by the Smithsonian (personal communication with Dr. Bill Billeck, April 2007, Repatriation Department, National Museum of Natural History, Smithsonian Institution).

Ancestral Puebloan

The 250 individuals representing the Ancestral Puebloan sample are from two collections: 197 of the individuals are currently housed at the National Museum of Natural History, Smithsonian Institution, analyzed between December 2003 and May 2005; 53 individuals are housed at the Maxwell Museum of Anthropology, University of New Mexico, analyzed during September 2006 supported, in part, by the John M. Goggin Award, University of Florida.

Spatial Distribution

The Ancestral Puebloan skeletal remains were recovered from a series of archaeological sites distributed throughout northern New Mexico.

Table 3-18. Spatial Distribution of Ancestral Puebloan archaeological sites

County	N	Longitude	Latitude	Region	Affiliation	n
Sandoval	80	35° 47'40.57"	106° 48'02.10"	Jemez	Amoxiumqua	24
					Unshagi	11
					Unknown	27
					Giusewa	18
Cibola	101	35° 13'14.18"	107° 57'33.66"	Zuni	Hawikku	101
McKinley	12	35° 48'17.89"	108° 11'47.82"		Heshatauthla	12
San Juan	25	36° 20'03.20"	108° 14'19.97"	Chaco Canyon	Pueblo Bonito	10
					Pueblo del Arroyo	4
					Unknown	11
Rio Arriba	21	36° 06'53.86"	106° 46'24.66"	Pajarito Plateau	Puye	21
Santa Fe	1	35° 30'05.14"	106° 06'44.36"		Tsankawi	1
Torrance	10	34° 44'49.95"	105° 52'47.20"	Salinas Pueblo	Quarai	10

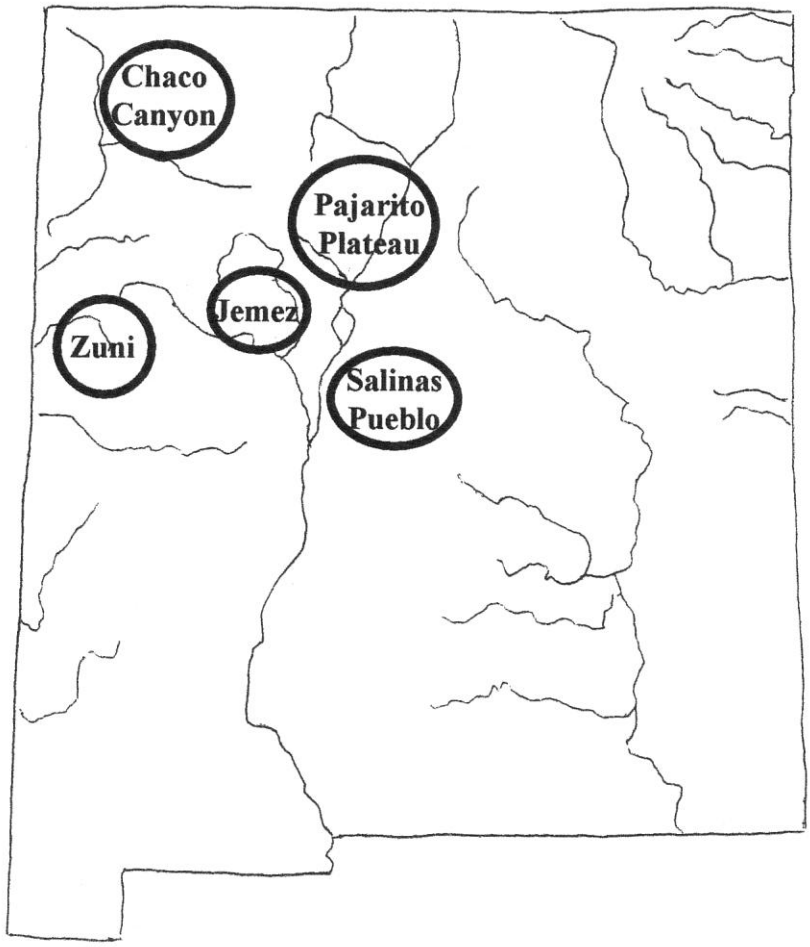


Figure 3-3. Geographic distribution of Ancestral Puebloan sites

Temporal Distribution

Table 3-19. Temporal Distribution of Ancestral Puebloan sites.

Region	Affiliation	Period	Occupation	Dating Method	Excavator	Reference
Jemez	Amoxiumqua	Pueblo V	1540-1670	archaeological remains	Hodge	Noble, 1981; Parsons, 1925; Reiter, 1938
"	Unshagi	"	"	"	"	"
"	Giusewa	"	"	"	Hewett	Reiter, 1938

Table 3-19. Continued

Region	Affiliation	Period	Occupation	Dating Method	Excavator	Reference
Zuni	Hawikku	Pueblo V	1540-1670	archaeological remains, pottery	Hodge	Corruccini, 1972; Smith et al., 1966
"	Heshatauthla	"	"	"	"	"
Chaco Canyon	Pueblo Bonito	Pueblo III	919-1130	tree-ring	Judd	Corruccini, 1972
"	Pueblo del Arroyo	"	"	"	"	"
"	Unknown	"	"	"	"	"
Salinas Pueblo	Quarai	Pueblo IV-V	1315-1677	archaeological remains, pottery	Hewett, Hurt	Hewett, 1913; Hurt, 1990
Pajarito Plateau	Puye	Pueblo IV	1507-1565	tree-ring	Hewett	Barnes, 1994; Corruccini, 1972
"	Tsankawi	"	"	"	"	"

Excavation and Principal Investigators

The Pajarito Plateau region (comprising the Puye and Tsankawi populations) was excavated and so named by Edgar L. Hewett as part of a Bureau of American Ethnology-sponsored expedition in 1909 (Barnes, 1994; Corruccini, 1972). Hewett excavated the Puye, Tsankawi and Otowi communities and sent the human skeletal remains to the Smithsonian National Museum of Natural History where they continue to be curated today (Barnes, 1994; Corruccini, 1972).

The first archaeological projects at Quarai were similarly made by E.L. Hewett in 1913 (Hurt, 1990). Expeditions to this site continued by Hewett and his team until 1936. In 1939 W.R. Hurt, sponsored by the Museum of New Mexico and the Works Project Administration, began excavation of the region that continued until 1940. Excavations made by Hewett were brought to the National Museum of Natural History, those under the direction of Hurt are housed at the Maxwell Museum, University of New Mexico (Hurt, 1990).

F.W. Hodge excavated the Zuni and Jemez regions between 1910 and 1923 with the gross majority of the human skeletal remains being sent to the Smithsonian. The Jemez site of Giusewa was also excavated in 1935 by students of the University of New Mexico Field School under the direction of E.L. Hewett (Reiter, 1938). Part of the Chaco Canyon complex (Pueblo Bonito) was excavated and human remains collected by Neil Judd in the 1920s are also housed at the National Museum (Corruccini, 1972; Schroeder, 1979; Smith et al., 1966).

Life History Conditions

The Pueblo IV Rio Grande Classic cultural stage saw enlarging communities. The Ancestral Puebloan peoples began to colonizing areas with abundant water supplies along the Rio Grande and away from the intruding Spaniards. The Zuni, during the Pueblo V period, were subject to strong influence and devastation by the Spanish expeditions (Cordell, 1984; Hewett, 1937; Hooton, 1930). Europeans were lured to the area by the promise of reported riches and gold in the region. Legions of armed horsemen came into the Zuni region and settled. Many Puebloan and Zuni populations revolted in 1680 killing hundreds of Spanish settlers and managed to stave off their return for over a decade (Cordell, 1984; Hewett, 1937).

The Pueblos of northern New Mexico were rich in volcanic soil which provided for an abundance of crops when water supplies were sufficient (Barnes, 1994; Hewett, 1913). The region is home to abundant native plants including corn, yucca fruit and seeds, prickly pear, pinon nuts, wild plumes, grapes and chokecherries (Barnes, 1994; Cordell, 1984; Hewett, 1937). Puebloan populations during this period were communally involved with agriculture employing a highly developed irrigation system (Hewett 1937). Wild game hunted in the area included mule deer, cottontail rabbits, black bears, squirrels, mountain lions, raccoons and beavers (Barnes, 1994).

Repatriation Status

The Ancestral Puebloan skeletal remains examined in the present analysis are currently housed at the U.S National Museum of Natural History and at the Maxwell Museum, University of New Mexico. The Jemez and Salinas Pueblo skeletal material housed at the National Museum have been "offered" to the Native Americans groups of New Mexico for repatriation and are unavailable for further research. The appropriate modern tribal groups have not made a decision at this time and the remains are being held by the Smithsonian (personal communication with Dr. Bill Billeck, April 2007, Repatriation Department, National Museum of Natural History, Smithsonian Institution).

Eco-Geographic Data

For each population, seven eco-geographic variables were obtained from the National Climatic and Data Center, National Oceanic and Atmospheric Administration, U.S. Department of Commerce (2004). This source compiles monthly and annual averages of climatic data from between 1931-2001. Earliest date of recorded data varies by location.

Six variables were chosen for each population that best reflect the general climatological conditions of that region. Ideally, climatic information would match the temporal period of each population, however that data was not available at this time. The period of recorded data for each population is found in Table 3-20.

Table 3-20. Period of recorded climatic data

State	Years
Alaska	1948-2001
South Dakota	1949-2001
New Mexico	1931-2001

Climatic data is represented by three variables relating to temperature and three related to precipitation. Annual mean temperature is the average temperature recorded over the period of

record for each station. Highest and lowest monthly means reflect the seasonal highs and lows. Annual mean precipitation reflects the average precipitation recorded over the period of record by recording station. Monthly high and low values reflect the seasonal extremes of precipitation (NCDC, 2004).

Table 3-21. Climatological conditions

			Temperature (°F)			Precipitation (inches)		
State	Latitude	Longitude	Annual mean	Highest month mean	Lowest month mean	Annual mean	Monthly high	Monthly low
Alaska	60° 47N	161° 50W	29.9	60.0	-13.2	16.18	5.49	0.00
South Dakota	45° 01N	99° 58W	44.0	77.7	-1.0	18.94	7.00	0.00
New Mexico	35° 03N	106° 36W	56.8	82.7	29.8	9.47	3.29	0.00

The single recording stations/climatic values for each population reflect a weighted average of the intra-population longitude and latitude weighted by the number of individuals from that location.

CHAPTER 4
ASSUMPTIONS, METHODS AND HYPOTHESES

Theoretical and Methodological Assumptions

Previous research on human skeletal remains documents variation between eco-geographically distinct groups. This project looks to more closely examine the origin and subsequent distribution of variation in growth and determine whether this early variability can be attributed to eco-geographic origin. This project presupposes the following theoretical and methodological assumptions (modeled after Schillaci and Stojanowski, 2003):

- Given the skeletal remains available for each individual, the most appropriate methods for both age and sex estimations were employed. The literature has provided systematic, experimentally tested methods for accurate age and sex determination.

- The sex of each individual in the present analysis was determined without error. This assumption is supported by the comparison of the present data sample to those analyses conducted by the Repatriation Department at the Smithsonian Institution's National Museum of Natural History. Any discrepancies were re-evaluated in conjunction with Dr. David Hunt and Ms. Erica Jones.

- The age of each individual in the present analysis was estimated to be as accurate as possible given the remains available. This assumption is supported by the comparison of the present data sample to those analyses conducted by the Repatriation Department at the Smithsonian Institution's National Museum of Natural History. Any discrepancies were re-evaluated in conjunction with Dr. David Hunt and Ms. Erica Jones.

- For the purposes of this analysis, growth for all individuals is considered to begin at birth.

- Individuals will be considered "adult" when the epiphyses have completely fused to the diaphysis.

- The individual remains recovered within the three burial areas were members of the populations that these individuals represent: individuals recovered from the specified Alaskan sites were Native Alaskans; individuals recovered from the specified sites in New Mexico were Ancestral Puebloan; individuals recovered from the specified sites in South Dakota were members of Arikara groups. It is difficult to say with certainty that individuals buried at a particular site were members of that cultural group. However, it is improbable that the deceased were brought in from unrelated groups for burial.

- These groups represent three distinct samples which are continuous within each group. Human skeletal remains are often used to account for processes that have gone on in the

past. The remains available for each eco-geographic group represent the population from each specific region and time period.

- Members of each population and their recent ancestors are assumed to have lived in that region for the entirety of their lives; sharing similar life history and cultural factors.
- The eco-geographic conditions for each area have not drastically changed over the course of the population's occupation of that region.
- While the diet and life history conditions between these groups are assumed to be varied, it will not be considered an influential factor in the present analysis.
- The cause of death for these individuals did not significantly affect their growth.
- Although "heterochrony" is historically used to discuss ancestor-descendant relationships, heterochronic perspectives will be used in the present analysis as an interpretative framework to discuss the analytical results. No ancestor-descendant relationship is strictly inferred by these associations and conclusions.
- Given these theoretical and methodological assumptions, these three groups are appropriate for comparative analysis.

Methods

This project has two analytical objectives: (1) do these three populations have significantly different postcranial long bones lengths as adults, if so does this variation correlate to eco-geographic conditions (2) how and where does this variation manifest in the juvenile skeleton. Once these two areas are explored the question of *why* they differ can be addressed. These analyses are conducted through examination of a mixed, cross-sectional sample of three archaeological populations of Native North Americans.

The methods presented here represent the most appropriate statistical tools appreciated from the literature. All statistical analyses in this investigation were conducted through the statistical program SAS Institute Inc., Version 9.1 (2004) except for the reduced major axis regression which was graphed and completed, in part, through PAST Version 1.68 (Hammer et al., 2001).

Data Collection

Dental Data Collection and Dental Age Determination

Dental age determinations are provided for each individual as a secondary variable for data analysis. Dental age estimation has been shown to be the most reliable surrogate for chronological age in the absence of definitive birth or medical records (e.g. Demirjian et al., 1973; Demirjian and Goldstein, 1976; Gustafson and Koch, 1985; Hunt and Gleiser, 1955; Moorrees et al., 1963a, b, 1965; Schour and Massler, 1941; Smith, 1991). Lewis and Garn (1960) highlight the strong correlation of dental development to chronological age compared to skeletal development.

For evaluation of juvenile dentition, dental maturity scales and calcification stages following Moorrees et al. (1963a, b), Ubelaker (1978) and Buikstra and Ubelaker (1994) were chosen due to the mixed, cross-sectional nature of these data as well as its population specificity.

For adults, dental wear standards were used for age estimation, as well as a combination of postcranial aging criteria including features of the pubic symphysis, auricular surface change, cranial suture closure and osteoarthritis (Brooks and Suchey, 1990; Buikstra and Ubelaker, 1994; Meindl and Lovejoy, 1985; Ubelaker, 1978).

Postcranial Data Collection

Linear measurements from the postcranial skeleton include maximum diaphyseal long bone lengths of the humeri, ulnae, radii, femora, tibiae and fibulae of all individuals. “Maximum length” is defined as the distance from the proximal most point to the distal most point for each element. Both right and left sides will be measured when available however the left elements will be used for all analyses; the right element was used if the left side was absent or fragmented. Measurements will be recorded to the nearest millimeter using an osteometric board. An individual is considered “adult” given closure of all postcranial long bone epiphyses.

Data Description and Considerations

Logarithmic Transformation

Numerous authors (e.g. Blackith and Reyment, 1971; Cochard, 1985; Corruccini, 1983, 1987; Falsetti and Cole, 1992; Holliday, 1997b; Holliday and Ruff, 2001; Jolicoeur, 1963; Jungers and German, 1981; Jungers, 1985; Jungers et al., 1988, 1995; McKinney and McNamara, 1991; Reyment et al., 1984; Shea, 1985a, b; Sokal and Rohlf, 1995) have required logarithmic transformation prior to applying statistically meaningful tests on growth data. Log-transformation corrects for outliers, skewedness and unequal variation that may exist among the data.

The log-transformed maximum length measure of each element is regressed against the geometric mean for that individual. Geometric mean [(ln(humeri)+ln(radii)+ln(ulnae)+ln(femora)+ln(tibiae)+ln(fibulae))/6)] will serve as a proxy for overall body size (Gould, 1971; Holliday, 1997b; Jungers et al., 1988, 1995).

Descriptive Statistics and Age Categories

Descriptive statistics are a preliminary analytical method of presenting a summary of the data. These methods reduce an immense wealth of information to a few summary measures outlining the parameters of the dataset through "simple" data manipulations. For each population, the post-cranial measurements will be separated by element and subjected to the following manipulations by age category (description of age categories is found in Table 4-1): number of observations, mean, standard deviation, coefficient of variation, range, minimum and maximum value. The mean represents the arithmetic average of a particular element in an age category. The standard deviation highlights how far the data points in a sample range as compared to the mean. The coefficient of variation is the standard deviation divided by the mean. This value represents the variation in a given pool of values. It is hypothesized that the

coefficient of variation will be relatively consistent across age groups, increasing as age categories approach maturity as sexual dimorphism will have a greater effect on the sample mean.

Table 4-1. Age categories.

Estimated dental age	Category
Birth – 1 yr	1
Birth – 6 months	1.1
6 months – 1 yr	1.2
1 yr – 2 yr	2
2 yr – 3 yr	3
3 yr – 5 yr	4
5 yr – 7 yr	5
7 yr – 9 yr	6
9 yr – 11 yr	7
12 yr – 15yr	8
15 yr – 17 yr	9
17 yr – 25 yr	10
20 yr – 40 yr	11
40 yr +	12

Age categories are employed for the descriptive statistics of each group to highlight the distribution of data across discrete segments of development. These categories are arbitrary and are not intended to connote analytical separation of the data. Categories were determined based on the data; as sample sizes varied, not all populations were subject to the same categorizations at this time. The remainder of the methods utilized in this investigation will view the juvenile data as a continuous sample.

The descriptive statistics for all populations are found in Appendix C.

Analysis of Adult Skeletal Remains

Demonstration of Population Variation: Tukey's Procedure

This investigation is based on the premise that populations of Native Alaskans, South Dakota Arikara, and Ancestral Puebloan groups of New Mexico vary significantly in long bone lengths. To demonstrate whether postcranial long bones vary significantly among the adults

between populations a Tukey's post hoc comparison of group means is conducted. Tukey's t-test (also called the T-method or Tukey's honestly significant difference method) is a highly conservative test of significance comparing group means designed to reduce the possibility of committing a Type I error; rejecting a true null hypothesis (Sokal and Rohlf, 1995).

For this analysis the following hypotheses will be tested:

- H_o: The null hypothesis will be accepted if no significant differences ($p>0.05$) are appreciated among the group means of any element between the three populations compared.
- H_a: The null hypothesis will be rejected if significant differences ($p<0.05$) are appreciated between any element between the three groups compared. Given the eco-geographic separation between these groups and the "rules" of both Allen (1877) and Bergmann (1847) it is predicted that these populations will vary significantly.
    - H_{a1}: Following Allen's (1877) rule it is predicted that the population inhabiting the lowest latitude (New Mexico Puebloan) will display the greatest extremity mean length than those occupying higher latitudes (Native Alaskan).
    - H_{a2}: Following Bergmann's (1847) rule it is predicted that those populations occupying the coldest (temperature-wise) climate (Native Alaskan) will display the smallest mean extremity length.

The calculations of the Tukey's comparison of population means were performed by the PROC GLM procedure in SAS (SAS Institute, Inc., 2004).

Principal Components Analysis

Principal components analysis (PCA) is a tool designed to reduce the dimensionality of the data without any *a priori* assumptions. When analyzing the degree of dissimilarity in a set of variables, PCA is used to focus on those variables which account for the largest portion of the sample's variability. Principal components analysis of the log-transformed variance-covariance matrix is used to describe "relative growth," size and/or size-related shape changes in growing elements (Corruccini, 1987; Falsetti, 1989; Jolicoeur, 1963; Jungers et al., 1988, 1995; Reyment et al., 1984; Sprent, 1972). Relative growth can be interpreted from the first principal component

when the first principal axis accounts for the "overwhelming" majority of the samples' variance and when all loadings are of the same sign (Jungers et al., 1988: 103). The second principal component which often accounts for a large portion of the variation describes size-related shape variation. PCA is implemented here to provide the clearest picture and description of the variation within and between groups.

Many authors have cited not only physical size as an integral factor in population variation, but also size-related shape variation; i.e. populations and/or species do not only vary in overall body size, but in the shape of their elements (Blackith and Reyment, 1971; Corruccini, 1987; Darroch and Mosimann, 1985; Falsetti, 1989; Jungers and German, 1981; Jungers et al. 1988, 1995; Reyment et al., 1984; Sprent, 1972; Waxenbaum et al., 2007). Size or relative growth can be defined as the "magnitude of a vector of measurements on an organism" (Corruccini, 1987: 289). Shape, also referred to as size-related shape or "relative size" (Corruccini, 1987: 289), is an alternative biological feature defined as a "ray in multidimensional hyper-space defined by many characters" whose variance is determined from the second principal axis (Corruccini, 1987: 290; Falsetti, 1989: 57). Shape variables can be analyzed individually and are calculated by subtracting the geometric mean from each log-transformed variable, e.g. shape(humeri) = ln(humeri)-ln(geometric mean). Principal components analysis will be conduced on both size and shape data of the adult and juvenile samples to determine whether shape and/or size represents a significant source of variation.

PCA does not result in a statistical test of significance. However null and alternative hypotheses concerning the variation within the data can be explored. For this analysis the following hypotheses will be tested:

- H_o: The null hypothesis will be accepted if the variation across all six variables is equal for both the analyses of size and shape.

- H_a: The null hypothesis will be rejected if the variation among the postcranial variables differs for the analyses of size and shape.
    - H_{a1}: Patterns of variation will exist within the upper and/or lower limb.
    - H_{a2}: Patterns of variation will exist between the upper and lower limb.

The calculations of the principal components were performed by the PROC PRINCOMP procedure in SAS (SAS Institute, Inc., 2004).

Canonical Discriminant Analysis

Canonical discriminant analysis is a multidimensional, data-reduction technique, similar to principal components analysis. As compared to PCA, in canonical discriminant analysis *a priori* assumptions concerning the data are considered (SAS Institute Inc., 2004). Canonical discriminant analysis is primarily used to highlight the interrelationships between multiple groups (populations) in morphometric studies (Blackith and Reyment, 1971; Falsetti, 1989). The canonical loadings measure the linear correlation between the original variables and the canonical variates and reflect the relative contribution of each variation to the separation across each axis (Reyment et al., 1984).

For this analysis the following hypotheses will be tested:

- H_o: The null hypothesis will be accepted if there is no significant ($p>0.05$) variation between these three populations.
- H_a: The null hypothesis will be rejected if significant variation ($p<0.05$) is appreciated within and between these three populations.
    - H_{a1}: All three populations will vary significantly from one another.
    - H_{a2}: When the total canonical structure is appreciated, patterns of variation will exist within the upper and/or lower limb.
    - H_{a3}: When the total canonical structure is appreciated, patterns of variation will exist between the upper and lower limb.

In the present analysis, this method will support the Tukey's procedure previously employed to test whether significant variation exists between the three populations of adults sampled. Significant patterns of variation would allow further investigation to determine (1) if similar variation is found among the juvenile sample and (2) if this variation is correlated to eco-geographic variation.

The calculations of the canonical discriminate variates were performed by the PROC CANDISC procedure in SAS (SAS Institute, Inc., 2004).

Examination of Skeletal Indices

Patterns of population variation have also been explored through an investigation of skeletal indices. Skeletal indices serve as an additional dimension for the analysis of population, regional and eco-geographic variation (Falsetti and Cole 1992; Holliday 1997a, b; Holliday and Ruff, 2001; Jantz and Owsley, 1984a; Jantz and Jantz, 1999; Warren, 1997). Three skeletal indices will be explored in the present analysis: brachial (radius/humerus), crural (tibiae/femora), and intermembral (humeri + radius)/(femur + tibia). Comparisons of index variation will be visually assessed through the use of box-plot analysis and tests of significant differences in these dimensions will be explored through Tukey's post hoc comparison of population index means.

For this analysis the following hypotheses will be tested:

- H_o: The null hypothesis will be accepted if there is no significant ($p>0.05$) variation exhibited between each population index compared.
- H_a: The null hypothesis will be rejected if significant variation ($p<0.05$) is appreciated among any of the three population indices compared.
    - H_{a1}: All three populations will exhibit significant variation among the brachial indices compared.
    - H_{a2}: All three populations will exhibit significant variation among the crural indices compared.

- H_{a3}: All three populations will exhibit significant variation among the intermembral indices compared.

The calculations of the Tukey's comparison of population means were performed by the PROC GLM procedure in SAS (SAS Institute, Inc., 2004).

Canonical Correlation Analysis

Comparisons between geographic/climatic and growth/population variation can be best investigated through canonical correlations analysis (Blackith and Reyment, 1971; Falsetti, 1989; Jantz et al., 1992; Reyment et al., 1984). This mode of statistical inquiry is often seen in the course of morphological and morphometrics studies when one set of variables, as a whole, is compared to another complete set of variables with no a priori assumptions concerning the nature of the data (Blackith and Reyment, 1971; Reyment et al., 1984). Such is the case in the present analysis comparing population long bone lengths to eco-geographic variables.

Canonical correlation analysis "offers a way of analyzing the interaction between variation in morphological characters and environmental factors" (Reyment et al., 1984: 80). This method determines the maximum correlation between linear functions of two distinct sets of variables. The components of the canonical vectors are determined through the coefficients defining these linear combinations. Successive linear combinations are explored so that the resultant variables display the strongest correlation between the two sets of data (Blackith and Reyment, 1971; Reyment et al., 1984). A significant or high correlation between linear postcranial dimensions and eco-geographic variables would indicate that variation in population postcranial dimensions is related to certain aspects of eco-geography.

For this analysis the following hypotheses will be tested:

- H_o: The null hypothesis will be accepted if the multivariate tests of the canonical correlation model are not significant ($p>0.05$).

- H_a: The null hypothesis will be rejected if the multivariate tests of the canonical correlation model are significant ($p<0.05$). The following alternative hypotheses will be explored:
    - H_{a1}: Postcranial elements will be highly correlated with latitude as compared to the other eco-geographic variables considered (Allen's rule).
    - H_{a2}: Postcranial elements will be highly correlated with temperature variations as compared to the other eco-geographic conditions considered (Bergmann's rule).
    - H_{a3}: Postcranial elements will be highly correlated with precipitation variation as compared to the other eco-geographic conditions considered (serving as outgroup).

The calculations of the canonical correlation variates were performed by the PROC CANCORR procedure in SAS (SAS Institute, Inc., 2004).

Analysis of Juvenile Skeletal Remains

Principal Components Analysis

As mentioned previously, a principal components analysis will be conducted on adult as well as juvenile sample to appreciate the degree of variation in the data accounted for by both size and shape components. Methodologically, Jolicoeur (1963: 497) highlights that the "most straightforward manner" in which to investigate the multivariate generalization of the allometric equation is to utilize the first principal component of the covariance matrix of log-transformed data. In looking at growth data, physical size is assumed to be the primary variable of change, however, shape variation will also be explored to determine whether this feature accounts for a significant degree of variation within the sample.

As mentioned previously, PCA does not result in a statistical test of significance. However null and alternative hypotheses concerning the variation within the data can be explored. The null and alternative hypotheses for PCA on the juvenile data set are the same as those for the adult analysis.

Reduced Major Axis Regression: Multiple comparison of growth trajectories

> Scientists examine a phenomenon, study its variation, and successively reduce its unexplained variation as more and more of its causes are understood

-- Sokal and Rohlf, *Biometry: The principles and practice of statistics in biological research*

Regression is a statistical tool using an independent variable to predict the value of a dependent variable. This analysis is used to determine the nature of a statistical relationship (linear or curved), the variability of a predicted value, whether variability is constant over a range of predictions, how informative an independent variable is in predicting the dependent variable and helps to predict the range of sampling error (Ott and Longnecker, 2001). However, numerous regression methods exist and are not all equally appropriate to analyze all data sets.

Sokal and Rohlf (1995) describe the two "modeling" systems of regression. Model I regression is based on the following assumptions: an independent variable X can be measured without error, expected value Y is a linear function, for a given value of X_i of X, Y values are independently and normally distributed and finally samples along the regression line have a common variance independent of the magnitude of X or Y. Model II regression scenarios are found when both variables display or have potential for random variation.

In Model II regressions both variables are subject to error and the regression line varies dependent upon the goal of the investigator, functional relationship or prediction. In this family of regression methods, both variables are normally distributed and the association between the two is determined by the magnitude of the parameter. In biology, these regression models are used when both variables deviate naturally, such as in the case of individual genetic differences or environmentally induced variation (Sokal and Rohlf, 1995).

Model II regression is also employed in situations where the sample does not follow a bivariate normal distribution. Sokal and Rohlf (1995) explain this through an example of an

investigation of relating chest width in men to their height. Classes of height may be arranged for the total height distribution and sample frequencies of men from each height class to gain an appreciation of this relation over the range of the data. Many biological examples fall into this class of regression models (Sokal and Rohlf, 1995).

Generally, if both variables have the same unit of measure, determining the slope of the major axis, or principal axis, overcomes of the issue of the X and Y error. If the two variables have different units of measure, as they often do in growth studies, major axis regression is not suitable. This unit dependence can be overcome through a standardization of the variables through logarithmic transformation of the data. The new principal axis of the standardized variables is known as the reduced major axis and is generally seen in allometric analyses.

Because the measures of the various postcranial elements differ in their dimensions throughout development, simple linear regression is no longer an appropriate statistical tool. Reduced major axis regression is specifically used when the dimensions or sizes being compared vary (McKinney and McNamara, 1991; Sokal and Rohlf, 1995; Vrba, 1998). This function, as stated, reduces the dimensionality or size component as a compounding element and standardizes the variables by minimizing their deviation from the regression line. Since different populations are being compared throughout development where physical size is constantly in flux, reduced major axis regression is the most appropriate statistical method for this analysis (Sokal and Rohlf, 1995).

The calculations and images used to perform a multiple comparison of slopes and intercepts through reduced major axis regression were performed in PAST, Version 1.68 (Hammer et al., 2001). Bonferroni's correction is a highly conservative method for reducing the experimentwise Type I error rate induced through multiple comparisons/permutations of a given

set of data; reducing the possibility of incorrectly rejecting a true null hypothesis (Ott and Longnecker, 2001). This correction factor is calculated by dividing the number of multiple comparisons by the alpha value selected; e.g. the number of multiple comparisons in this analysis is 18, hence the corrected alpha value = 0.05/18 = 0.002777 = 0.003.

For this analysis the following hypotheses will be tested:

- H_{o1}: The null hypothesis will be accepted if the multiple comparison of slopes for comparison of each element between populations shows no significant variation ($p>0.003$).
- H_{o2}: The null hypothesis will be accepted if the multiple comparison of intercepts for comparison of each element between populations shows no significant variation ($p>0.003$).
- H_{a1}: The null hypothesis will be rejected if the multiple comparison of slopes for any comparison of elements is found to be significant ($p<0.003$).
- H_{a1}: The null hypothesis will be rejected if the multiple comparison of intercepts for any comparison of elements is found to be significant ($p<0.003$).

Test of Isometry and Allometry

Allometry is a study of size and shape (e.g. Cheverud, 1982; Godfrey and Sutherland, 1995; McKinney and McNamara, 1991; Shea, 1983a, 1985a; Vinicius and Lahr, 2003; Wu et al., 2003). Mathematics and biology were not always as well acquainted as they are in the physical sciences today. Pioneers in allometric analysis, such as D'Arcy Thompson (1943) and Julian Huxley (1932), have been praised for their roles in focusing our attention on a new perspective and new questions in biological thought. Thompson (1943: 79, author's emphasis) noted:

> . . . it is obvious that the *form* of an organism is determined by its rate of *growth* in various directions; hence rate of growth deserves to be studied as a necessary preliminary to the theoretical study of form, and organic form itself is found, mathematically speaking, to be a *function of time*.
>
> Every growing organism, and every part of such a growing organism, has its own specific rate of growth, referred to this or that particular direction; and it is by the ratio between these rates in different directions that we must account for the external forms of all (Thompson, 1943: 82).

Thompson (1943: 81) was the first to draw attention to "rate of growth" as a feasible, tangible factor that can be quantified, given the appropriate variables and mathematical tools. Allometry, for the present analysis, is defined as the relative ratio between body parts within a particular individual or between populations.

Ontogenetic or growth allometry has become an integral component in "elucidating the developmental pathway utilized by natural selection to produce adaptive changes" (Shea, 1985a: 176; Sprent, 1972). Ontogenetic allometry, often termed relative growth, quantifies changing or differential growth within or between populations. The slightest variation in allometric growth during development can have significant morphological affects on final adult form (Gould, 1977; McNamara, 1986). Such an analysis of relative growth is employed to determine the extent of variation in the postcranial long bones as individuals' age within and between three Native North American populations.

For this analysis the following hypotheses will be tested:

- H_o: The null hypothesis suggests that these three groups grow at a constant rate of development indicated by isometry (slope not significantly different from 1.0).
- H_a: Rejection of the null hypothesis indicates that any of these three populations do differ significantly from isometry (slopes significantly different from 1.0). Five alternative models, modeled after those of Falsetti and Cole (1992) are presented:
    - H_{a1}: The three populations have a universal origin at birth and display ontogenetic scaling.
    - H_{a2}: The three populations have a universal size origin at birth and each group displays a unique growth trajectory.
    - H_{a3}: One or more groups display size differences at birth which are maintained through parallel isometry.
    - H_{a4}: One or more groups display size differences at birth and display parallel allometry.
    - H_{a5}: One or more groups display size differences at birth and one or more groups display a unique growth trajectory.

These five alternative models take two distinct forms: two having a universal postnatal origin and three having one or more groups beginning postnatal growth at a unique size. Model a1 predicts ontogenetic scaling. All three groups have a universal size origin at birth and similarly allometric growth trajectories, yet differences between the groups are a result of heterochrony and/or differences in duration of growth events. Model a2 hypothesizes that the three populations will display divergent growth trajectories. No appreciable size difference at birth, however final adult form is distinctly different through deviating patterns of growth over the course of development.

Models a3-a5 suggests that interpopulation differences will be apparent at birth. Model a3, parallel isometry, shows each population beginning postnatal development at a unique size and maintaining common isometric growth trajectories to maturity. Model a4 posits parallel allometry where the differences seen at birth are preserved through similar allometric growth trajectories. Finally, Model a5 predicts that adult variation is a result of not only unique postnatal development, but unique growth trajectories from one or more of the compared groups.

An example of how these methods are used in comparative limb growth in physical anthropology is demonstrated in the analysis conducted by Falsetti and Cole (1992). In a study of relative growth in the postcrania of callitrichines, Falsetti and Cole (1992) investigate whether significant differences exist in proportions of the postcranial skeleton of the three species (*Saguinus oedipus, Saguinus fuscicollis and Callithrix jacchus*), the ontogenetic histories of these differences, and whether these proportional differences reflect variation in functional behavior. These patterns of postcranial growth, or ontogenetic trajectories, were analyzed through the multivariate generalization of the bivariate allometric equation.

Similar to this author's investigation of relative growth, Falsetti and Cole (1992) looked to discern growth patterns as a means to analyze and reconstruct heterochronic models of evolutionary/genetic selective forces. The genetic and environmentally induced variation in the data as well as the need to reduce the dimensionality for comparative purposes through reduced major axis regression, logarithmic transformation and principal components analysis make the multivariate generalization of the Huxley's (1932) bivariate allometric equation the most appropriate method to analyze the data of the present analysis (e.g. Blackith and Reyment, 1971; Falsetti and Cole, 1992; Gould, 1977; Ravosa et al., 1995; Reyment et al., 1984).

"The most straightforward manner to generalize the allometry equation is to use the first principal component of the covariance matrix of logarithms" (Jolicoeur, 1963: 497). In this infamous quote, Jolicoeur (1963) describes the test of significance for the determination of allometry or deviation from isometry. Jolicoeur (1963) remarks that others have assessed allometric relationships using a single variate (an individual element) through a multiple linear regression as seen in the reduced major axis regression conducted presently. It is noted that this procedure sets a single variable apart from all others and subsequently does not express the allometric relationships that exist between all possible pairs as a single biological unit (Jolicoeur, 1963). Jolicoeur's (1963) method to test for the deviation from isometry evaluates all compared biological variates equally and holistically instead of isolating a single variable for all others to be considered against.

While nature readily demonstrates that humans grow and vary through time, it is expected that the null hypothesis will be easily rejected in favor of one of the alternate hypotheses previously discussed. However, discovering which alternate hypothesis or model the growth

trajectories these populations will follow is truly the goal of this analysis and will help direct what conclusions may be drawn concerning the differential development these three populations.

The statistical procedure to test for deviation from isometry was performed by the PROC IML procedure in SAS (SAS Institute, Inc., 2004). A comparable test for deviation from isometry, similarly following Jolicoeur (1963), was conducting in Microsoft Office Excel (2007) under the direction of Dr. Adam Sylvester, University of Tennessee, Knoxville (personal communication). The final test determining the degree of deviation from isometry was conducted following Jolicoeur (1963) in Microsoft Office Excel (2007) under the direction of Dr. Adam Sylvester (personal communication).

Interpretive Framework

Heterochrony and allometry are two similar and related terms in that they are often used to explain mechanisms of ontogeny, phylogeny, evolution and comparative or functional anatomy. Allometry relates to physical properties of size and shape which is tested for experimentally, whereas heterochrony is a developmental and theoretical mechanism used to explain phylogenetic, evolutionary or temporal changes in physical form. Allometry speaks to physical, mathematical principles of shape and size, whereas heterochrony is used to explain *how* form changes throughout evolution. In a sense, allometry is a mathematical representation of heterochrony. Despite their convoluted history and the debates that still reign today, allometry and heterochrony serve as integral and complementary tools in the study of development, biology and evolution.

Heterochrony is a change in relative timing of developmental events that has been used to explain population and evolution variation (e.g. Alberch et al., 1979; Bogin, 1997; de Beer, 1958; Godfrey and Sutherland, 1995, 1996; Gould, 1977; Haeckel, 1905; Hall and Miyake, 1995; Matsuda, 1987; McKinney, 1999; McKinney and McNamara, 1991; McNamara, 1986, 1995,

1997; Raff and Wray, 1989; Ravosa et al., 1995; Shea, 1981, 1983b, 1989; Smith, 2001; Stone, 2004; Vinicius and Lahr, 2003; Vrba, 1998; Wu et al., 2003). From Haeckel's (1905) cenogenesis to de Beer's morphogenetic modes (1958) to Gould's (1977) clocks, heterochrony has been intensely debated and constantly modified since its inception yet is repeatedly employed to interpret biological variation.

Heterochrony describes modifications of the relative timing of growth events as well as how the rate of growth is modified over time. The most simplified model of heterochronic variation is presented by McKinney and McNamara (1991; modified below). Heterochrony is often separated into two main categories: paedomorphosis (retention of ancestral "juvenile" traits in adults; "underdevelopment") and peramorphosis (development "beyond" the ancestral state; "overdevelopment") (Gould, 1977; McKinney and McNamara, 1991).

Table 4-2. Heterochrony: paedomorphosis vs. peramorphosis.

Paedomorphosis	
Neoteny	Reduced rate of growth
Post-displacement	Delayed onset of growth
Progenesis	Early offset of growth
Peramorphosis	
Acceleration	Increased rate of growth
Pre-displacement	Early onset of growth
Hypermorphosis	Delayed offset of growth

In this project, "onset" is set at birth. If these populations display unique size "origins," then patterns of pre-/post-displacement can be explored. "Offset" (progenesis/hypermorphosis) will be considered the point where all epiphyses of each element are completely fused to the

diaphysis. However, no evidence has been found to indicate that the age of physiological/hormonal maturity varies between these populations. Through the implementation of allometric analysis, variation in *rate* of growth (neoteny/acceleration) will be comparable between these populations through an analysis of their growth trajectories or the slope value analyzed in the reduced major axis regression.

Population variation in biological anthropology has often focused on variation in adult phenotypes. While historically focusing on ancestor-descendant relationships, heterochrony provides the present study a structured, theoretical framework to discuss how phenotypes evolve: through ontogeny. If variation is found to manifest during the developmental period, mechanisms of variation, from advances in developmental biology, may provide further insight into the true "origins" of variation.

CHAPTER 5
RESULTS AND DISCUSSION

Results of Adult Skeletal Analysis

Demonstration of Population Variation: Tukey's Procedure

The premise of my project is that if variation exists within and between the adults of these populations then an analysis of how juveniles differ can be explored. To this end, a demonstration of population variation was conducted through Tukey's *post hoc* comparison of the means for each of the six postcranial elements analyzed (humeri, ulnae, radii, femora, tibiae, fibulae). Tukey's t-test (also called the T-method or Tukey's honestly significant difference method) is a highly conservative test of significance designed to reduce the possibility of committing a Type I error; rejecting a true null hypothesis (Sokal and Rohlf, 1995).

This analysis will allow for a statistical assessment of hypotheses relating to population variation among archaeological human groups. In this case, the null hypothesis states that no significant differences ($p<0.05$) will be found among the comparison of mean long bone lengths between these three groups. If the null hypothesis is rejected, alternative hypotheses of how and why these populations differ will be explored. Bergmann's (1847) and Allen's (1877) "rules" dictate that these populations should vary to a degree based upon their eco-geographic separation. Bergmann's rule predicts that individuals occupying cooler climates will display relatively shorter extremities. Allen's rule postulates that individuals inhabiting lower latitudes (New Mexico Puebloan) will display longer extremities as compared to those occupying higher latitude (Native Alaskan). Once it is determined whether these groups truly differ significantly, the correlation of these differences to their geographic condition will be investigated.

These data were initially separated by sex to account for the sexual dimorphism inherent in modern humans. However, Tukey's comparison of postcranial element mean by sex within

populations produced comparable results to those presented here which pool the sexes within each of the three groups. Given the objective of determining whether these populations, as a whole, vary significantly pooling of males and females within each group is appropriate.

Results of this analysis highlight significant differences between populations for most elements compared. South Dakota Arikara were found to have population humeral means significantly different ($p<0.0001$) than from all other groups. However, some analyses were found to be nonsignificant at the alpha = 0.05 level. Among humeri of all adults sampled New Mexico (N.M.) Puebloan individuals and Native Alaskans sampled could not be statistically distinguished.

Table 5-1. Significance of differences among adult humeri (n=408)

	Native Alaskan	S.D. Arikara
S.D. Arikara	<0.0001	
N.M. Puebloan	0.5903	<0.0001

All comparisons were found to be significantly different ($p<0.05$) among the ulnae and radii of all adults sampled.

Table 5-2. Significance of differences among adult ulnae (n=330)

	Native Alaskan	S.D. Arikara
S.D. Arikara	<0.0001	
N.M. Puebloan	0.0026	<0.0001

Table 5-3. Significance of differences among adult radii (n=358)

	Native Alaskan	S.D. Arikara
S.D. Arikara	<0.0001	
N.M. Puebloan	<0.0001	<0.0001

Among the femora for the adults sampled, South Dakota Arikara were found to be significantly different ($p<0.0001$) from both Native Alaskan and New Mexico Puebloan groups. However, population means could not be distinguished between the Native Alaskan and New Mexico Puebloan populations as seen previously in the comparison of population mean for the humeri.

Table 5-4. Significance of differences among adult femora (n=421)

	Native Alaskan	S.D. Arikara
S.D. Arikara	<0.0001	
N.M. Puebloan	0.7485	<0.0001

Among the tibiae and fibulae of all adults sampled, all groups displayed statistically significant separation ($p<0.0001$).

Table 5-5. Significance of differences among adult tibiae (n=403)

	Native Alaskan	S.D. Arikara
S.D. Arikara	<0.0001	
N.M. Puebloan	<0.0001	<0.0001

Table 5-6. Significance of differences among adult fibulae (n=316)

	Native Alaskan	S.D. Arikara
S.D. Arikara	<0.0001	
N.M. Puebloan	<0.0001	<0.0001

The raw means by element which served as the basis for the Tukey's post hoc comparison are displayed in Table 5-7.

Table 5-7. Population means (mm) by element

	Humeri	Ulnae	Radii	Femora	Tibiae	Fibulae
Native Alaskan	294.362	235.600	216.137	406.373	325.868	318.880
S.D. Arikara	310.982	264.286	245.469	434.788	368.124	359.592
N.M. Puebloan	292.088	243.183	225.333	408.528	343.491	334.744

Given the results displayed in Tables 5-1 through 5-6, the null hypothesis of finding no significant differences among the six individual postcranial long bones compared between populations is rejected. Alternatively, these populations differ significantly, particularly the South Dakota Arikara which were found to be significantly different from all other groups among all postcranial elements compared. These results imply that Native Alaskan groups were more subject to cold stress (Bergmann's rule) resulting in their foreshortened limbs relative to the New Mexico Puebloan and South Dakota Arikara groups. Results for the South Dakota Arikara, with the largest population means for all postcranial elements compared, imply a lesser degree of cold stress with New Mexico Puebloan displaying a degree of cold stress intermediate between Native Alaskans and South Dakota Arikara. Following Allen's rule, these results suppose that the South Dakota Arikara lie at a lower latitude compared with the Native Alaskans which would occupy the higher latitude. Canonical correlation analysis of the eco-geographic condition among these groups will further evaluate these implied patterns of variation.

Interestingly, New Mexico Puebloan and Native Alaskans were found to significantly differ among the distal components of both the upper and lower limb (ulnae/radii, tibiae/fibulae), however the proximal limb elements (humeri and femora) could not be distinguished. Similarly patterns of distal vs. proximal limb segment variation have been identified in primate, hominid and modern human studies (Falsetti and Cole, 1992; Holliday 1997a, b; Holliday and Falsetti, 1995; Holliday and Ruff, 2001; Trinkaus, 1981). These patterns of variation will be analyzed for further confirmation of these results and to determine whether they are correlated to the distinct eco-geographic conditions of these three groups.

The results demonstrate that these "rules" are not absolute and indicate that these trends have a threshold. Given the strict interpretation of these rules in light of the eco-geographic and

morphological data presented here it would be expected that New Mexico Puebloan groups with the lowest latitude and highest temperature variables would display the greatest extremity length, however this is not the case. There may be other factors not explored in the present analysis that may account for this deviation including growth potential and plasticity or other genetic and morphological restrictions (Garruto, 1995; Eveleth and Tanner, 1990; McNamara, 1986; Pritchard, 1995). Investigation into the source of variation within and between these groups and how they correlate to eco-geographic variables will provide further insight into how the rules of Bergmann (1847) and Allen (1877) may affect these populations.

Principal Components Analysis

Principal components analysis (PCA) is a statistical method which highlights that portion of the data, without a priori assumptions, accounting for the largest components of sample variation (Blackith and Reyment, 1971; Jolicoeur, 1963; Reyment et al., 1984). By pooling all individuals from each of the three populations, PCA will allow for a focus specifically on which of the six postcranial elements compared accounts for the greatest portion of the sample's variability.

In growth studies, physical size is assumed to be the most variable character. However, given the results of the Tukey's comparison of the group means for each postcranial element compared, PCA analysis of log-transformed data can help determine whether this variation is a product of size alone or whether the shape accounts for the variation noted (Blackith and Reyment, 1971; Corruccini, 1987; Darroch and Mosimann, 1985; Falsetti, 1989; Reyment et al., 1984; Sprent, 1972). Log-transformation is imposed on the data to correct for unequal variation in the sample based on the known discrepancy of physical size between and within each population (e.g. Blackith and Reyment, 1971; Corruccini, 1983, 1987; Falsetti and Cole, 1992; Jolicoeur, 1963; Jungers et al., 1988, 1995; Reyment et al., 1984; Sokal and Rohlf, 1995). This

correction is important when comparing growth data as well as among those samples where variation in physical size variation is a known to be significant.

For this analysis, "shape" is calculated by subtracting the geometric mean from each log-transformed variable: e.g. shape(humeri) = ln(humeri) – ln(geometric mean) (Corruccini, 1987; Falsetti, 1989). In the absence of a true age or body size of an individual, geometric mean is often employed as a holistic estimate of overall body size (Gould, 1971; Holliday, 1997b; Jungers et al., 1988, 1995; Reno et al. in prep). The geometric mean is calculated by: [(ln(humeri)+ln(ulnae)+ln(radii)+ln(femora)+ln(tibiae)+ln(fibulae))/6)]. Subsequently the sample size for this analysis is significantly smaller than seen in the Tukey's analysis on the adult sample as all individuals for this analysis require a complement of all six postcranial elements which is not consistent among archaeological assemblages.

While there is no explicit test of statistical significance in PCA, null and alternative hypotheses of the data can still be appreciated. The null hypothesis for this investigation states that the variation among the variables will be equal across all six postcranial elements for both the analysis of size and shape. The alternative hypothesis of divergent patterns of variation among the data allows for an investigation into the causation of whether variation is patterned within each limb or between the upper and lower extremities. If patterns of variation occur how and why certain elements would vary in size and/or shape over others will be explored. This analysis will provide the clearest picture of the variation that exists among these data.

The first six principal components from the analysis of adult size and shape (n=227) including eigenvectors, eigenvalues, percentage of variation and total variance presented in Tables 5-8 and 5-9. In the principal components analysis of the adult size variables, the first principal component (PC1) accounts for 92.2% of the total within-group variation with all

positive eigenvector loadings. The second principal accounts (PC2) for only 3.3% of the variation indicating a significantly reduced component of size-related shape variation within the adult sample.

Table 5-8. Principal components analysis of adult size variables

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
L(humeri)	0.3169	0.7054	0.3088	-0.5531	-0.0067	-0.0201
L(ulnae)	0.4231	-0.2666	0.4488	0.1353	-0.3874	0.6163
L(radii)	0.4656	-0.4074	0.4089	-0.0089	0.3763	-0.5551
L(femora)	0.3234	0.4952	-0.0572	0.7837	0.1784	-0.0260
L(tibiae)	0.4443	-0.0493	-0.4728	-0.0505	-0.6541	-0.3821
L(fibulae)	0.4490	-0.1320	-0.5558	-0.2424	0.4983	0.4058
Eigenvalue	0.0339	0.0012	0.0011	0.0004	0.0001	0.0001
% variation	92.2	3.3	2.9	1.0	0.4	0.3

These results further highlight that variation in physical size plays a significant role in the variation found not only between groups (as seen in the Tukey's comparison of group means) but within the sample as a whole. From an analysis of the loadings from PC1 a pattern emerges. As seen in the previous analysis, the proximal vs. distal segments of both the upper and lower limbs display a unique pattern of variation. The loadings for distal segments (ulnae, radii, tibiae, fibulae) exhibit consistent and larger values than the proximal components (humeri, femora) indicating that size plays a larger role in the variation among distal segments. These results are statistically confirmed in the previous analysis where group separation was imposed on the data. For the Native Alaskan and New Mexico Puebloan samples, group means for the proximal limb segments, humeri and femora, could not be statistically distinguished. These results in conjunction with those from the Tukey's analysis indicate that the distal portion of both the upper and lower limb is more highly variable than the proximal elements of each limb.

Table 5-9. Principal components analysis of adult shape variables

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
S(humeri)	0.6477	-0.1633	-0.6210	0.0095	-0.0350	0.4082
S(ulnae)	-0.2019	-0.4916	0.1575	0.3693	0.6242	0.4082
S(radii)	-0.4089	-0.4743	-0.0073	-0.3608	-0.5574	0.4082
S(femora)	0.4839	0.1464	0.7364	-0.1696	-0.0806	0.4082
S(tibiae)	-0.2244	0.4594	-0.0562	0.6644	-0.3567	0.4082
S(fibulae)	-0.2964	0.5235	-0.2093	-0.5128	0.4056	0.4082
Eigenvalue	0.0018	0.0010	0.0003	0.0001	0.0001	0.0000
% variation	52.6	29.4	10.2	4.0	3.5	0.0

In the principal components analysis of adult shape variation, the first principal axis (PC1) accounts for 52.6% of within-sample variation; just over half of the variation appreciated in the sample. In this case, all eigenvector loadings on the first principal component are not of the same sign. All loadings are negative expect for the humeri and femora. The second principal component from the analysis on adult size variation shows comparable results to the first principal component of the adult shape analysis. Both PC2 from the size analysis and PC1 from the shape investigation indicate that the proximal segments of the upper and lower limb share a larger degree of shape conservation than evidenced in the distal portion of each limb. The second principal component (PC2) for within-sample shape accounts for 29.4% of the total variation. These results indicate that while shape does play some role in the variation apparent within this study's sample, it is significantly less so than among the size variables alone.

Canonical Discriminant Analysis

Canonical discriminant analysis is a multidimensional, data-reduction technique used to highlight the relationship between multiple groups (Blackith and Reyment, 1971; Falsetti, 1989). As compared to PCA, canonical discriminant analysis allows for the a priori designations of group separation. The canonical loadings in this analysis reflect the degree of variation among the elements compared which contributes the greatest degree to overall group separation. The

null hypothesis for this analysis would find that there is no significant separation among these three populations. However, the previous results from the Tukey's analysis and PCA indicate that the null hypothesis will easily be rejected in support for one of the alternative hypotheses. Alternative hypotheses explored for this analysis will examine whether significant variation ($p<0.05$) is appreciated between these three population. Similarly an analysis of overall canonical structure will determine whether any specific patterns of variation can be appreciated among the elements. Given the results of the PCA and Tukey's analysis it is suspected that patterns of variation will vary between proximal and distal components within both the upper and lower limbs.

The canonical discriminant analysis of three populations shows that significant differences exist within and between populations for the measures used in this study. All tests of multivariate significance provide a p-value of <0.0001 as seen in Table 5-10. The first two canonical variates are both significant and account for 100% of the morphological variation among the adult sample.

Table 5-10. Canonical discriminant analysis test of significance for adult postcrania within population

Statistics	Value	F value	p-value
Wilks' Lambda	0.3363	26.44	<0.0001
Pillai's Trace	0.7546	22.22	<0.0001
Hotelling-Lawley Trace	1.7028	30.98	<0.0001
Roy's Greatest Root	1.5255	55.94	<0.0001

Table 5-11. Statistical results of canonical discriminant analysis for adult postcrania within population

Canonical Variate	Eigenvalue	% of Variation	F-value	P-value
1	1.5225	89.59	26.44	<0.0001
2	0.1774	10.41	7.80	<0.0001

The total canonical structure found in Table 5-12 represents the re-scaled canonical discriminant scores. A pattern of variation can be appreciated among the first canonical scores.

Distal limb segments exhibit appreciably higher loadings (0.6 or greater) than those of the proximal limb elements. This lends further support toward the conclusion that a large majority of the variation among the adult sample is accounted for in the distal elements among both the upper and lower extremities.

Table 5-12. Total canonical structure of adult postcranial variables within population

Variable	Can1	Can2
humeri	0.4821	0.6019
ulnae	0.7900	0.5252
radii	0.8333	0.3860
femora	0.5899	0.5890
tibiae	0.8390	0.3704
fibulae	0.8439	0.4025

Table 5-13.Class means on canonical variables within population

Population	Can1	Can2
Native Alaskan	-1.4599	0.1692
South Dakota Arikara	1.3326	0.3024
New Mexico Puebloan	0.3005	-0.7326

Table 5-13 displays the class means within and between the three populations examined. Between-group separation by class means are visually appreciated in Figure 5-1. The Native Alaskan (represented by "1") group mean is represented by the red circle, the South Dakota Arikara ("2") is represented in blue and the New Mexico Puebloan ("3") class mean is represented in Figure 5-1 in green. The dotted circles surrounding each group mean represent no designation of significance, however provide visual appreciation of the separation of the scatter for each population and their degree of overlap.

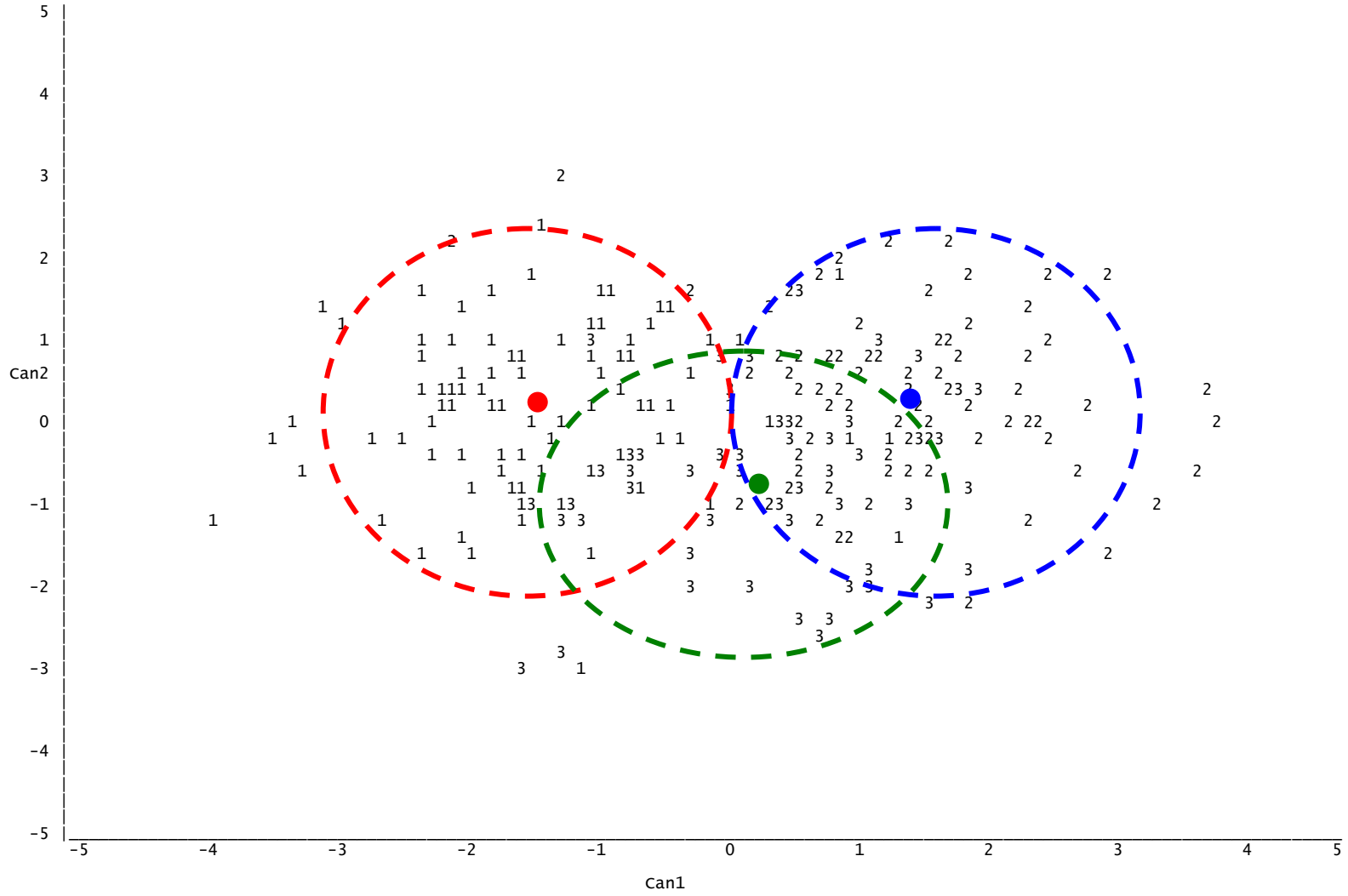


Figure 5-1. Canonical discriminant analysis of three populations – Plot of class means

Examination of Skeletal Indices

Patterns of population variation have also been examined through proportionality or limb indices (Falsetti and Cole 1992; Holliday 1997a, b; Holliday and Ruff, 2001; Jantz and Owsley, 1984a; Jantz and Jantz, 1999; Warren, 1997). Intermembral (humeri + radius)/(femur + tibia), brachial (radius/humeri), and crural (tibia/femur) indices are highlighted in this investigation as they appreciate variation within upper and lower limb as well as between the extremities. These indices serve as an additional dimension for the analysis of population, regional and eco-geographic variation.

These patterns of variation are appreciated in the box-plots of index means by population found in Figures 5-2 through 5-4. Box-plots are a method of visually comparing two or more groups without assumptions of the statistical distribution between them (substantiated here through Tukey's comparison of index means presented in Tables 5-14 and 5-15). Another invention of John Tukey, box-plots are a useful tool used to display the dispersion of the data (parameters of box as well as median line within), skewness (asymmetry of upper and lower portions within the box), the lower and upper quartile of the data (displayed in the lines extending from each box) and highlight outliers (Sokal and Rohlf, 1995). The samples are separated by sex to appreciate how sexual dimorphism accounts for the variation in the pattern of population variation.

These patterns of variation will then be tested for statistical significance through a Tukey's post hoc comparison of index means between these three populations. For this analysis, the null hypothesis dictates that no significant variation will be appreciated among the brachial, crural and intermembral indices compared. Given the results of the previous analyses it is predicted that the null hypothesis will be rejected in favor of one or more of the alternative hypotheses indicating that significant variation will exist among one or all of the indices compared. With the

results of the initial Tukey's analysis, particularly among the comparisons between Native Alaskan and New Mexico Puebloan populations, it is suspected that significant variation will be appreciated in the crural and brachial index comparisons given the nonsignificant results for the proximal limb elements (humeri and femora) and the significant differences appreciated between the distal limb components (ulnae, radii, tibiae, fibulae). If so, this alternative method of postcranial analysis will lend further statistical support those previous results and hypotheses.

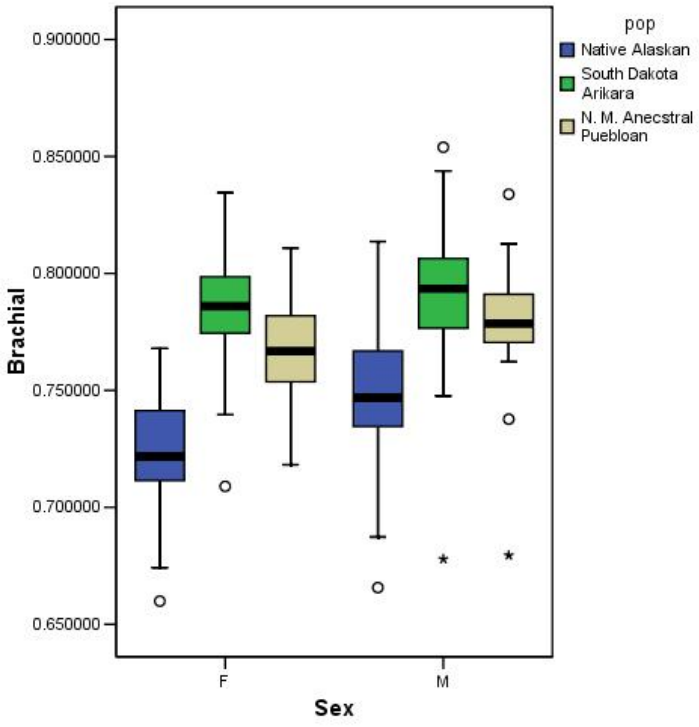


Figure 5-2. Box plot of adult brachial index against sex by population

The results of the box-plot comparison of brachial indices among the adults of the three populations are seen in Figure 5-2. South Dakota Arikara were found to have higher brachial indices (radius/humeri) than any other population, followed by New Mexico Ancestral Puebloan groups and with Native Alaskans displaying the lowest brachial index. In other words, the South Dakota Arikara have longer distal upper limb segments relative to their proximal upper limbs;

Native Alaskans have relatively shorter distal limb components relative to proximal upper limb. Comparable patterns are appreciated between both the males and females of each group indicating that although males and females within each group differ in physical overall size the pattern of variation between populations remains the same.

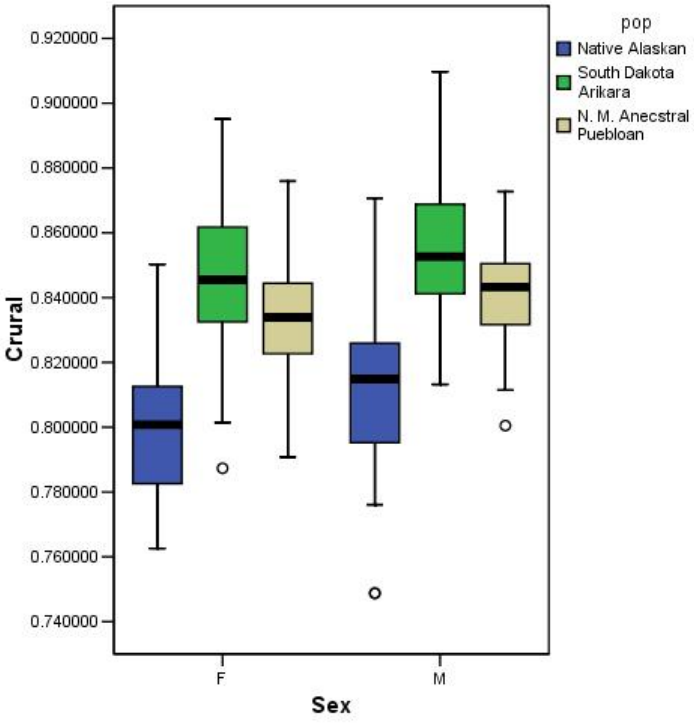


Figure 5-3. Box plot of adult crural index against sex by population

A similar pattern to the brachial index is found among the crural index (tibia/femora) comparison found in Figure 5-3. The South Dakota Arikara display overall higher crural indices than those found among the Native Alaskan or Ancestral Puebloan populations. This indicates that the South Dakota Arikara possess a relatively longer tibia as compared to their femora with Native Alaskans displaying a relatively short tibia compared to their femoral length. Once again, separation of the sexes had no effect on the pattern of variation between populations.

These two comparisons of indices across populations fit the previously appreciated pattern of morphological population variation among the distal components of both the upper and lower limb. This hypothesis of variation being accounted for primarily among distal limb components is further appreciated by the box plot of the adult intermembral index [(humeri+radii)/(femora+tibia)] found in Figure 5-4. The plots for each sex within each population highlight that among intermembral index patterns of sexual dimorphism are quite similar as compared to other indices. These results show an overall higher range for the Native Alaskan intermembral index than the other two populations as well as a greater spread between males and females. These results indicate that the Native Alaskans analyzed here have a larger upper limb relative to their lower limb and display a greater degree of sexual dimorphism in intermembral index than South Dakota Arikara and New Mexico Puebloan groups.

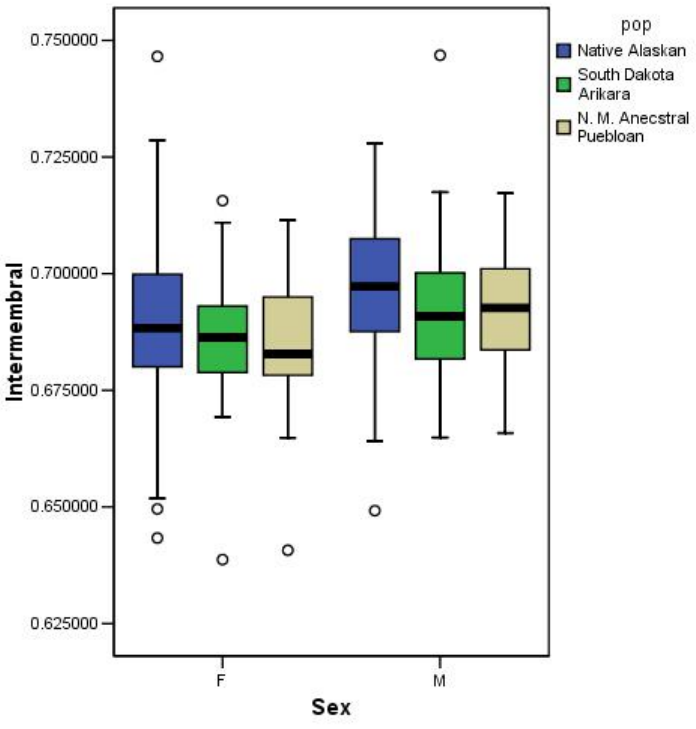


Figure 5-4. Box plot of adult intermembral index against sex by population

These trends were analyzed for statistical significance ($p<0.05$) through Tukey's post hoc comparison of the means or T-method. This highly conservative test accounts for the multiple comparisons these data have been subject to by limiting the potential of making a Type I error, rejecting a true null hypothesis (Sokal and Rohlf, 1995). For this test of significance, the sexes were once again pooled within each of the three populations to highlight the overall structure of each group. The models for both the Tukey's analysis of both brachial and crural indices were significant ($p<0.0001$), however the model of intermembral comparisons was nonsignificant; i.e. not separation could be achieved among the data. Given the box-plot of intermembral comparison displayed in Figure 5-4, these results are not unexpected. The results of Tukey's analysis of statistical significant separation of brachial and crural index means are displayed in Tables 5-14 and 5-15.

Table 5-14. Significance of differences among brachial indices

	Native Alaskan	S.D. Arikara
S.D. Arikara	<0.0001	
N.M. Puebloan	<0.0001	0.0036

Table 5-15. Significance of differences among crural indices

Population	Native Alaskan	S.D. Arikara
S.D. Arikara	<0.0001	
N.M. Puebloan	<0.0001	0.0027

These result of the Tukey's post hoc comparison of index means indicate that these three populations show significant separation in terms of both brachial and crural indices. Given the visual separation of the groups by sex displayed in Figures 5-3 and 5-4, these results are not unexpected. Now that the population variation between these groups have been established and patterned through three separation methods of analysis, correlation of this variation to eco-geographic condition can be explored.

Canonical Correlation Analysis

Canonical correlations analysis is a statistical method used to analyze the interaction between two sets of data. This mode of analysis allows for one set of variables, as a whole, to be compared to another distinct set of data without a priori assumptions concerning the nature of either data set. Comparisons between environmental features and morphological characters are best appreciated through canonical correlations analysis (Blackith and Reyment, 1971; Falsetti, 1989; Jantz et al., 1992; Ralph et al., 1998; Reyment et al. 1984; Wilson et al. 2005). In this case, adult postcranial long bone lengths are compared to eco-geographic variables (descriptions of these variables are found in Table 3-21).

For this comparison the six postcranial elements (humeri, ulnae, radii, femora, tibiae, fibulae) are canonically correlated against six eco-geographic variables (latitude, mean annual temperature, month high mean temperature, month low mean temperature, average precipitation, month high mean precipitation; the lowest month precipitation variable was identical for all populations in pilot research and was removed from subsequent analysis). The null hypothesis for this investigation states that the correlation of postcranial measurements and eco-geographic conditions will not show any significant pattern of correlation. If a significant correlation is found and the null hypothesis is rejected, it can be determined what pattern of variation exists among the eco-geographic variables chosen and whether variation in these populations is consistent with those patterns previously highlighted and predicted by Bergmann's and Allen's rules.

In the canonical correlation analysis between postcranial linear dimensions and eco-geographic variables, all four multivariate tests of significance (i.e. Wilks' Lambda, Pillai's Trace, Hotelling-Lawley Trace and Roy's Greatest Root) were found to be significant ($p<0.0001$) for all adult samples ($n=227$). These results demonstrate a significant relationship

between the six postcranial elements examined and six measures of eco-geography. Given the first canonical variable accounting for 89.59% of sample variation and overall model significance these results indicate that the eco-geographic variables explored here are a strong predictor of linear limb measurements for the populations in question. The second canonical variable accounts for an additional 10.41% of the shared variance between postcranial measurements and eco-geographic variables.

The total canonical correlation structure used to describe the relationship between postcranial measurements and eco-geographic variables are found in Table 5-16, 5-17, 5-18. Table 5-16 displays the correlation among postcranial measurements. Unsurprisingly there is an overall high degree of correlation displayed among the variables. The length of a single element is highly correlated to the length of other elements within a given individual. However, there is a trend for slightly higher loadings within the distal limb segments (ulnae correlation values range from 0.8496 to 0.9808; radii correlation values range from 0.8352 to 0.9808; tibiae correlation values range from 0.8443 to 9802; fibulae correlation values range from 0.8293 to 0.9802) than proximal limb (humeri correlation values range from 0.8293 to 0.8975; femora correlation values range from 0.8760 to 0.9079). Though the pattern displayed here is slight, this may be a further indication that there is a greater degree of variation accounted for by the distal segments of each limb than the proximal elements.

Table 5-16. Canonical correlation among postcranial measurements

	humeri	ulnae	radii	femora	tibiae
ulnae	0.8496				
radii	0.8352	0.9808			
femora	0.8975	0.8760	0.8636		
tibiae	0.8443	0.9197	0.9251	0.9079	
fibulae	0.8293	0.9107	0.9220	0.8889	0.9802

Table 5-17 displays the canonical structure among the eco-geographic variables analyzed. A strong negative correlation is found between geographic latitude and all temperature variables. This is expected as the father north (increasing latitude) one travels, the cooler (decreased annual mean temperature) the overall temperature becomes. An appreciably lower correlation is found between latitude or temperature and precipitation. These results indicate that temperature or latitude alone is not necessarily a strong indicator of precipitation.

Table 5-17. Canonical correlation among eco-geographic variables

		Temperature			Precipitation
	Latitude	Annual mean	High month mean	Low month mean	Annual mean
Annual mean	-0.9959				
High month mean	-0.9809	0.9593			
Low month mean	-0.9255	0.9559	0.8341		
Annual mean	0.5010	-0.5770	-0.3230	-0.7915	
High month mean	0.3694	-0.4517	-0.1815	-0.6939	0.9893

Table 5-18 displays the correlation values between postcranial measurements and eco-geographic variables. While the correlation loadings in Table 5-18 are moderate as compared to the within-variable variation, patterns of significance are appreciated. The most obvious trend in the canonical correlation between postcranial measurements and eco-geographic variables is the overall negative correlation of latitude with all elements examined. This indicates that as latitude increases, all elements decrease in physical size. However, as previously noted, a unique pattern of distinction is found between distal and proximal limb segments for both the upper and lower extremities. Higher correlation loadings are found among ulnae (-0.3269), radii (-0.3879), tibiae (-0.3952) and fibulae (-0.3898) than the humeri (-0.1275) and femora (-0.1937). These results indicate a stronger correlation of the distal limb segments with changing latitude. This, along

with the higher variation found within the distal segment reflected in the canonical discriminant analysis, suggests that the distal segments of the upper and lower limbs is a main feature of interest in the analysis of population variation.

Table 5-18. Canonical correlation between postcranial measurements and eco-geographic variables

		Temperature			Precipitation	
	Latitude	Annual mean	High month mean	Low month mean	Annual mean	High month mean
humeri	-0.1275	0.0888	0.2073	-0.0422	0.3021	0.3458
ulnae	-0.3269	0.2752	0.4293	0.0910	0.3194	0.3981
radii	-0.3879	0.3376	0.4855	0.1544	0.2730	0.3584
femora	-0.1937	0.1501	0.2823	-0.0004	0.3134	0.3692
tibiae	-0.3952	0.3450	0.4924	0.1618	0.2679	0.3542
fibulae	-0.3898	0.3386	0.4894	0.1523	0.2809	0.3673

A similar correlation of variation among the proximal vs. distal limb components is found in the temperature variables examined. Given the high correlation between temperature and latitude, these similar patterns of variation are not unexpected. Annual mean temperature correlation loadings are comparably higher for the ulnae (0.2752), radii (0.3376), tibiae (0.3450) and fibulae (0.3386) than for the humeri (0.0888) and femora (0.1501). Comparable findings are seen among the high and low month mean temperature for the humeri and femora loadings with both variables displaying a negative value (-0.0422 and -0.0004 respectively) while all other temperature variable loadings are positive. This overall positive correlation indicates a general trend in my data: as temperature increases, postcranial long bone measurements lengthen.

Little information is gained from the correlation of postcranial measurements to the precipitation variables selected. No specific patterns of variation are appreciated as annual mean precipitation displays a loadings range of 0.2679 to 0.3194 and high month precipitation mean ranging from 0.3458 to 0.3981. However, given the statistical significance of this correlation

model and positive loadings for all precipitation variables, a positive correlation between increased precipitation and longer postcranial elements is concluded.

As mentioned previously patterns of variation between proximal vs. distal segments within the limbs are aligned with eco-geographic condition and have been explored previously varied organisms as well as specifically on primates, hominids and modern human groups (Holliday, 1997a, b; Holliday and Falsetti, 1995, 1999; Holliday and Ruff, 1997, 2001; Lee et al. 1969; Mayr, 1956; Murphy, 1985; Newman and Munro, 1955; Roberts, 1978; Ruff, 1993; Trinkaus, 1981; Vrba, 1996; Warren, 1997; Weaver and Ingram, 1969).

These experiments have been most notably tested against the "rules" for homeothermic animals postulated by Bergmann (1847) and Allen (1877). Murphy's 1985 study on the effects of geographic variation and seasonality on House Sparrow body size found that annual temperature range is of greater importance on predicting physical size than another other climatic variable; conforming to the predictions of Bergmann's rule. Trinkaus (1981) found that Neandertals displayed a relative foreshortening of the distal limb segments particularly in the lower limb. This pattern of variation is considered a reflection of cold adaptation to the periglacial climate of Europe during the last glacial period (Trinkaus, 1981). Similarly, Trinkaus (1981) documented a significant, positive relationship between brachial and crural indices among modern human populations and mean annual temperature. Lee and colleagues (1969) found that distal limb segments were more variable than proximal elements with tibia lengths reduced in animals raised in experimentally cooler climates as compared to those reared under warm conditions. Holliday and Ruff (2001) analyzed human populations from varied groups across four continents to determine whether these previously reported patterns of distal limb segment variation held and whether it was correlated to environmental condition. It was concluded that variation among

widely dispersed human populations was largely due to differences in distal limb segments and this variation was a result of both environmental and genetic factors (Holliday and Ruff, 2001). The present analysis finds that these conclusions are true not only of widely varied human groups but are similarly true of three Native North American groups of temporally conserved, spatially distinct individuals with a relative common evolutionary history.

Results of Juvenile Skeletal Analysis

Principal Components Analysis

Among growth analyses, physical size is presumed to be the primary variable of change. The first principal component of the log-transformed covariance matrix is used to account for "relative growth" or size related change in growing elements (Corruccini, 1983, 1987; Falsetti, 1989; Jolicoeur, 1963; Jungers and German, 1981; Jungers et al., 1988). However, many authors have focused not only on size variation between inter-/intraspecific groups but on shape variation of individual elements (Blackith and Reyment, 1971; Corruccini, 1987; Darroch and Mosimann, 1985; Falsetti, 1989; Jungers and German, 1981; Jungers et al. 1988, 1995; Reyment et al., 1984; Sprent, 1972; Waxenbaum et al., 2007). Shape variables are calculated by subtracting the geometric mean from each log-transformed variable, e.g. shape(humeri) = ln(humeri)-ln(geometric mean). Principal components analysis will confirm whether size or shape accounts for a greater percent of variation in the given sample. By employing the geometric mean for an analysis of shape variation, the sample size of the overall analysis greatly reduced due to the need for each individual included to have data for each of the six element variables. Given the archaeological nature of this investigation, these requirements excluded many individuals from analysis. However, a second PCA analysis for each population will be conducted subsequently for the purposes of testing deviations from isometry. The patterns of these results (Table 5-29, 5-31, 5-33) are comparable to those found in Table 5-19. The first six principal component scores

from the analysis of juvenile size and shape (n=172) including eigenvectors, eigenvalues, percentage of variation and total variance presented in Tables 5-19 and 5-20.

In the principal components analysis of the juvenile size variables, the first principal component (PC1) accounts for 99.6% of the total within-sample variation with all positive eigenvector loadings. The second principal component (PC2), defining size-related shape variation accounts for only 0.2% of the within-group variation. This demonstrates that a majority of the variation in the juvenile sample is purely a result of size alone.

Table 5-19. Principal components analysis of juvenile size variables

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
L(humeri)	0.3967	-0.2921	0.5874	0.1428	0.6221	-0.0683
L(ulnae)	0.3510	0.5776	0.2366	0.0633	-0.1153	0.6853
L(radii)	0.3632	0.5370	0.1586	-0.1465	-0.1735	-0.7091
L(femora)	0.4575	-0.5362	0.1725	-0.0919	-0.6797	0.0522
L(tibiae)	0.4367	-0.0684	-0.4940	-0.6652	0.3217	0.1201
L(fibulae)	0.4327	-0.0154	-0.5476	0.7093	0.0627	-0.0745
Eigenvalue	1.2733	0.0026	0.0011	0.0005	0.0003	0.0001
% variation	99.6	0.2	0.0	0.0	0.0	0.0

A pattern of variation exists between the upper and lower limb with the upper limb elements (humeri, ulnae, radii) displays comparable, lower loading coefficients (ranging from 0.3510 to 0.3967) than the lower limb (ranging from 0.4327 to 0.4575). This indicates that a larger majority of the variation among the juvenile analysis is accounted for in the lower limb as compared to the upper limb. The pattern of variation between proximal and distal segments seen in the adult sample is not substantiated in the juvenile analysis. From this analysis the alternative hypothesis that variation will be patterned between the upper and lower limb as opposed to patterns of variation within the upper and lower extremity. These results indicate that the lower limb increases to a greater extent over the course of juvenile development as compared to the upper limb.

In the principal components analysis of the juvenile shape variables, the first principal components accounts for 84.5% of the variation among the shape variable for the elements within the juvenile sample. As similarly seen in the adult analysis, the eigenvector coefficients are do not all share the same loading signs. The upper limb elements (humeri, ulnae, radii) are positive and the lower limb elements (femora, tibiae, fibulae) are negative. This variation in eigenvector size indicates that there is a greater degree of shape conservation within the upper limb which is distinct from that of the lower limb.

Table 5-20. Principal components analysis of juvenile shape variables

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
S(humeri)	0.0510	0.7129	0.1460	-0.5413	0.0896	0.4082
S(ulnae)	0.5802	-0.0555	0.0295	0.1852	-0.6769	0.4082
S(radii)	0.4635	-0.1353	-0.1818	0.2423	0.7129	0.4082
S(femora)	-0.5386	0.3281	-0.1213	0.6447	-0.0713	0.4082
S(tibiae)	-0.3000	-0.4008	-0.6150	-0.4347	-0.1238	0.4082
S(fibulae)	-0.2561	-0.4493	0.7427	-0.0962	0.0696	0.4082
Eigenvalue	0.0140	0.0014	0.0005	0.0003	0.0001	0.0000
% variation	84.5	8.8	3.4	2.3	0.7	0.0

The principal components analysis of the within-juvenile population between log-size and log-shape indicates that less variation is demonstrated when shape is the main focus as compared to size. However, both size and shape vary greatly over the course of the juvenile growth period. Among the juvenile sample, as anticipated given the range of juvenile data, size accounts for the gross majority of variation.

Initially, it was unusual to find that the juvenile sample did not display a similar pattern of differential variation between the proximal and distal components of each limb as seen in the adult sample instead for both shape and size the juvenile sample was separated between the upper vs. lower limb. To determine the origins of adult variation, it was expected that the juvenile component of the data would mirror the adult sample. However, it seems likely that this

variation is a product of the natural flux of growth in conjunction with the wide age range examined. The human lower limb tends to be physically longer in length as compared to the upper limb (this can be appreciated in the descriptive statistics outlined in Appendix C). Hence, it would be expected that during development, the lower limb across populations would display a higher degree of variation than the upper limb. Potential developmental mechanisms for why and how the patterns differ between the adult and juvenile sample will be explored in subsequent sections of this chapter.

To investigate these results further, additional principal component analyses were performed separating the data into four discrete growth segments to discern whether patterns of variation can be appreciated. These growth periods highlight some of major phases of human growth: birth – 2 years of estimated age, the postnatal growth spurt; 3-7 years of estimated age, childhood period; 8-11 early pubescent period; 12-21 pubescent period (adopted from Gasser et al., 2000; Gasser et al., 2001a, b; Smith and Buschang, 2004).

Table 5-21. Principal components analysis of juveniles – Birth-2 estimated years of age (n=41)

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
L(humeri)	0.3973	-0.3109	0.3198	0.7603	0.2472	-0.0623
L(ulnae)	0.3410	0.5534	0.3114	-0.0205	-0.0171	0.6925
L(radii)	0.3526	0.5045	0.2923	-0.1645	0.0157	-0.7129
L(femora)	0.4689	-0.5829	0.3103	-0.5695	-0.1181	0.0755
L(tibiae)	0.4284	0.0241	-0.4696	0.2211	-0.7385	-0.0309
L(fibulae)	0.4448	0.0445	-0.6311	-0.1456	0.6156	0.0400
Eigenvalue	0.2527	0.0010	0.0005	0.0002	0.0001	0.0000
% variation	99.24	0.41	0.20	0.08	0.04	0.00

The PCA results for both the birth-2 and 3-7 estimate age ranges display comparable results as seen in Tables 5-21 and 5-22. The patterns of variation among the first principal components scores match those of the previous PCA on the total juvenile sample with a

separation between the upper and lower limb; an overall higher variation displayed among the lower limb when compared to the upper limb.

Table 5-22. Principal components analysis of juveniles – 3-7 estimated years of age (n=37)

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
L(humeri)	0.3723	-0.5185	0.4892	0.2650	0.5259	0.0782
L(ulnae)	0.3751	0.3828	0.3649	-0.0549	-0.3033	0.6960
L(radii)	0.3893	0.4396	0.3615	-0.3464	0.0897	-0.6295
L(femora)	0.4363	-0.5862	-0.1587	-0.3913	-0.5285	-0.0907
L(tibiae)	0.4477	0.1577	-0.6415	-0.2240	0.5161	0.2155
L(fibulae)	0.4221	0.1502	-0.2449	0.7767	-0.2783	-0.2417
Eigenvalue	0.1252	0.0020	0.0009	0.0005	0.0003	0.0000
% variation	96.9	1.56	0.77	0.46	0.23	0.06

A unique pattern of variation is appreciated when look at early pubescent (Table 5-23; 8-11 years of estimated age) and pubescent (Table 5-24; 12-21 estimated years of age) stages of development. The 12-21 estimated age category mirrors the adult pattern of differential variation between the proximal and distal elements within both the upper and lower limb.

Table 5-23. Principal components analysis of juveniles – 8-11 estimated years of age (n=19)

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
L(humeri)	0.3875	-0.4342	0.4934	0.0648	0.6391	-0.0710
L(ulnae)	0.3292	0.4824	0.3849	-0.0591	-0.0843	0.7071
L(radii)	0.3603	0.4893	0.3008	-0.1379	-0.1818	-0.6986
L(femora)	0.4465	-0.5150	0.0726	0.2152	-0.6943	0.0391
L(tibiae)	0.5102	-0.0755	-0.5419	-0.6465	0.1310	0.0705
L(fibulae)	0.3895	0.2610	-0.4678	0.7133	0.2280	-0.0179
Eigenvalue	0.0860	0.0037	0.0014	0.0002	0.0002	0.0000
% variation	93.71	4.06	1.59	0.3	0.23	0.00

An unusual pattern of variation is found in the 8-11 estimated age category for the PCA results. A consistent trend for the younger juvenile sample is revisited in the consistent first principal component loadings for the upper limb elements. However, no consistent pattern of variation is appreciated among the lower limb elements. These results may be a product of the

small sample size available for this age category, but it may also be indicative of a transitional period between early development and adolescence marked by a transition from juvenile to adult skeletal characteristics.

Table 5-24. Principal components analysis of juveniles – 12-21 estimated years of age (n=76)

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
L(humeri)	0.3721	0.5032	0.5059	-0.4574	-0.3521	-0.1375
L(ulnae)	0.4102	-0.3713	0.3703	0.2468	-0.1540	0.6869
L(radii)	0.4296	-0.4818	0.2527	0.1752	0.1660	-0.6790
L(femora)	0.3552	0.5568	0.0045	0.3921	0.6342	0.0876
L(tibiae)	0.4232	0.1571	-0.5794	0.3490	-0.5715	-0.1090
L(fibulae)	0.4508	-0.2046	-0.4551	-0.6507	0.3094	0.1687
Eigenvalue	0.0945	0.0022	0.0015	0.0006	0.0003	0.0002
% variation	95.06	2.24	1.51	0.60	0.35	0.23

Reduced Major Axis Regression: Multiple comparison of growth trajectories

Regression is a statistical tool using an independent variable to predict a dependent variable (Ott and Longnecker, 2001). Reduced major axis regression is a specific regression format used when both variables are subject to error and vary naturally, such as genetic differences, allometric investigations or when individuals are subject to environment-induced variation. Most biological comparisons are examined through this method (Sokal and Rohlf, 1995).

Reduced major axis regressions on log-transformed data were executed on the juvenile sample (birth to 21 estimated years of age) for each element against log(size) for each population. The slopes and intercepts for each element were subject to t-tests to determine whether they differ significantly. A Bonferroni correction was applied to the traditional alpha value of 0.05 to determine significance given the multiple comparisons being employed on the data (Sokal and Rohlf, 1995). This highly conservative correction is performed by dividing the

standard alpha value (0.05) by the number of comparisons imposed on the data (3) to produce a new alpha value of 0.0167. The sample sizes for this analysis are greatly reduced given the restrictions of the size variable.

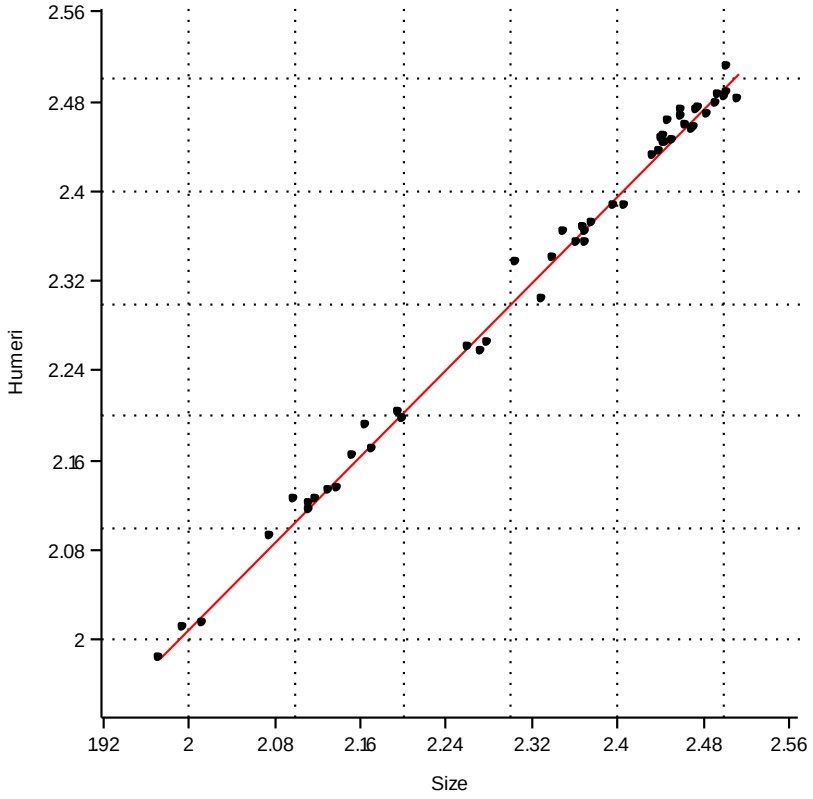


Figure 5-5. Reduced major axis regression for Native Alaskan (n=52) log(humeri) on log(size)

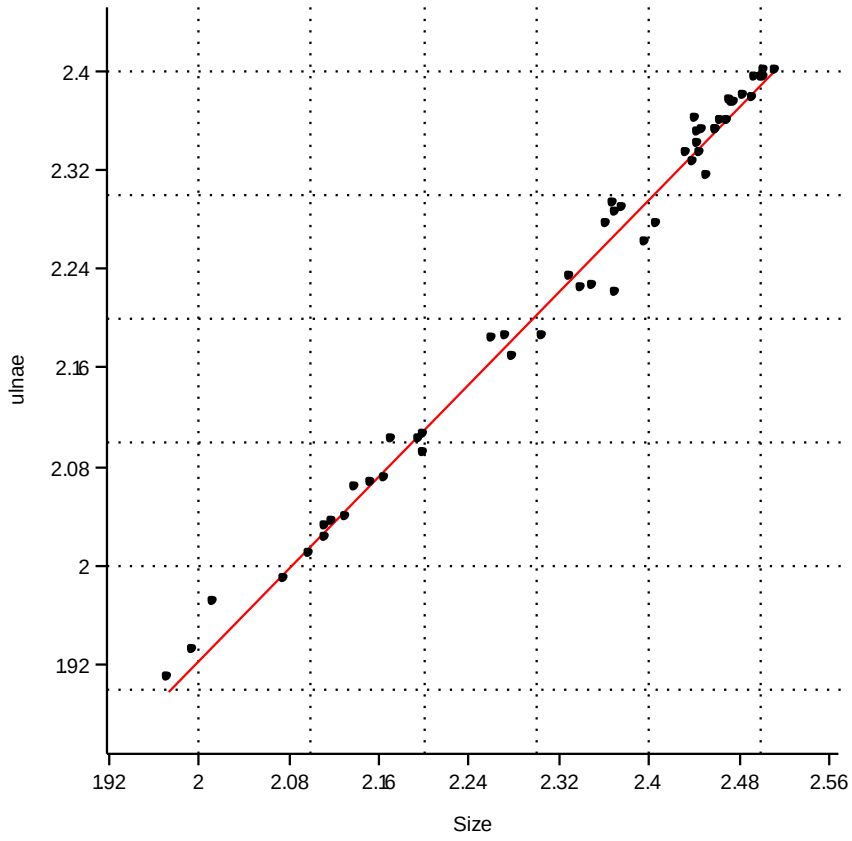


Figure 5-6. Reduced major axis regression for Native Alaskan (n=52) log(ulnae) on log(size)

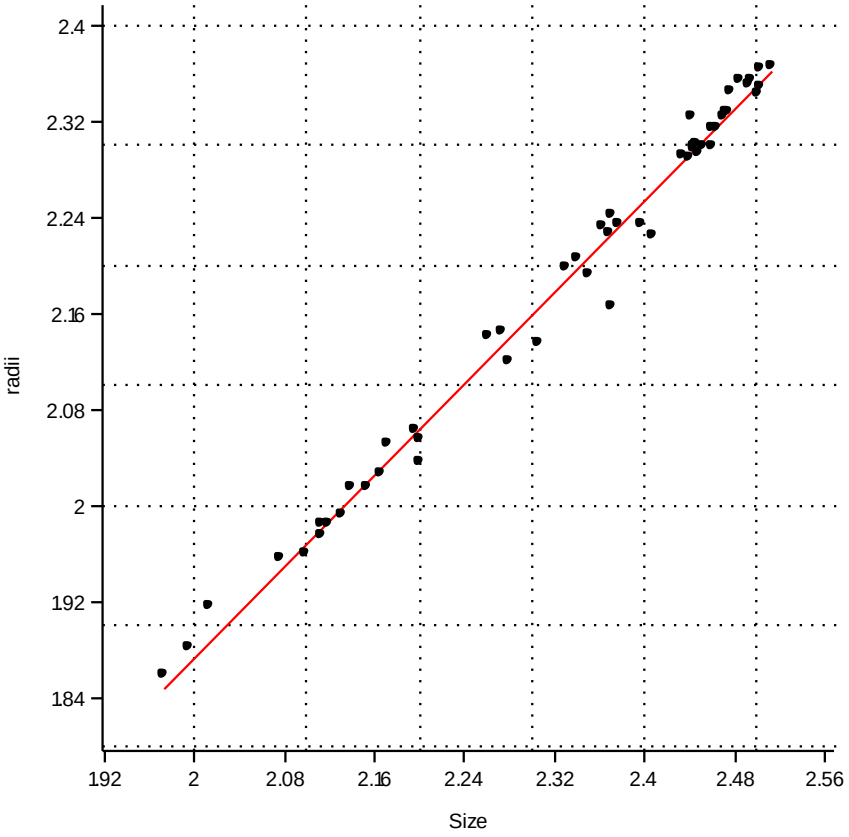


Figure 5-7. Reduced major axis regression for Native Alaskan (n=52) log(radii) on log(size)

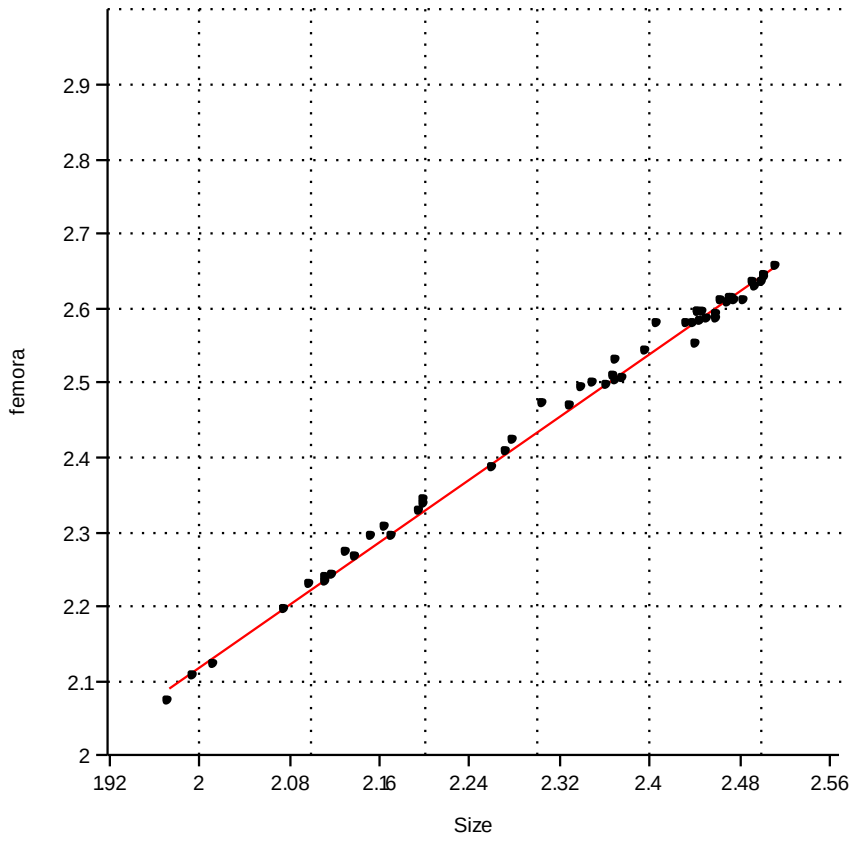


Figure 5-8. Reduced major axis regression for Native Alaskan (n=52) log(femora) on log(size)

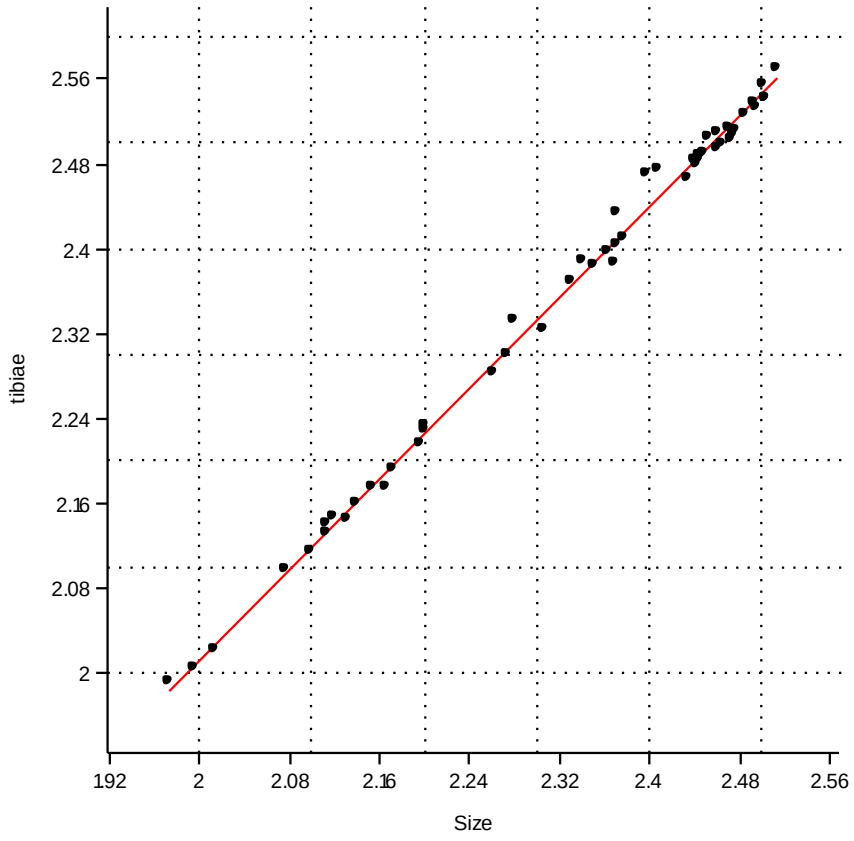


Figure 5-9. Reduced major axis regression for Native Alaskan (n=52) log(tibiae) on log(size)

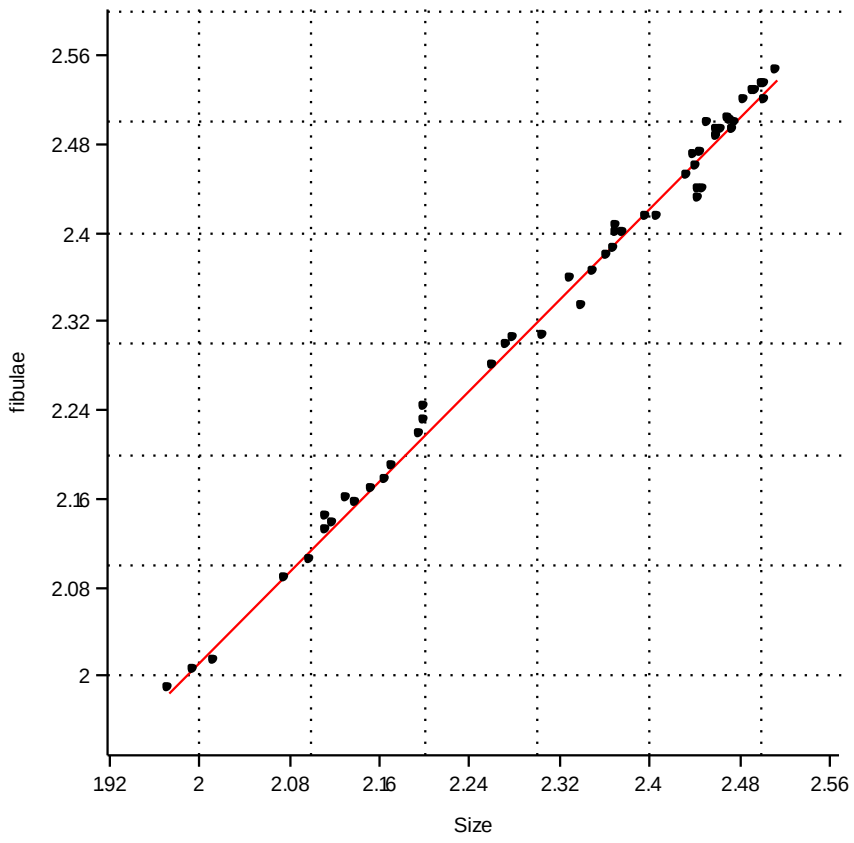


Figure 5-10. Reduced major axis regression for Native Alaskan (n=52) log(fibulae) on log(size)

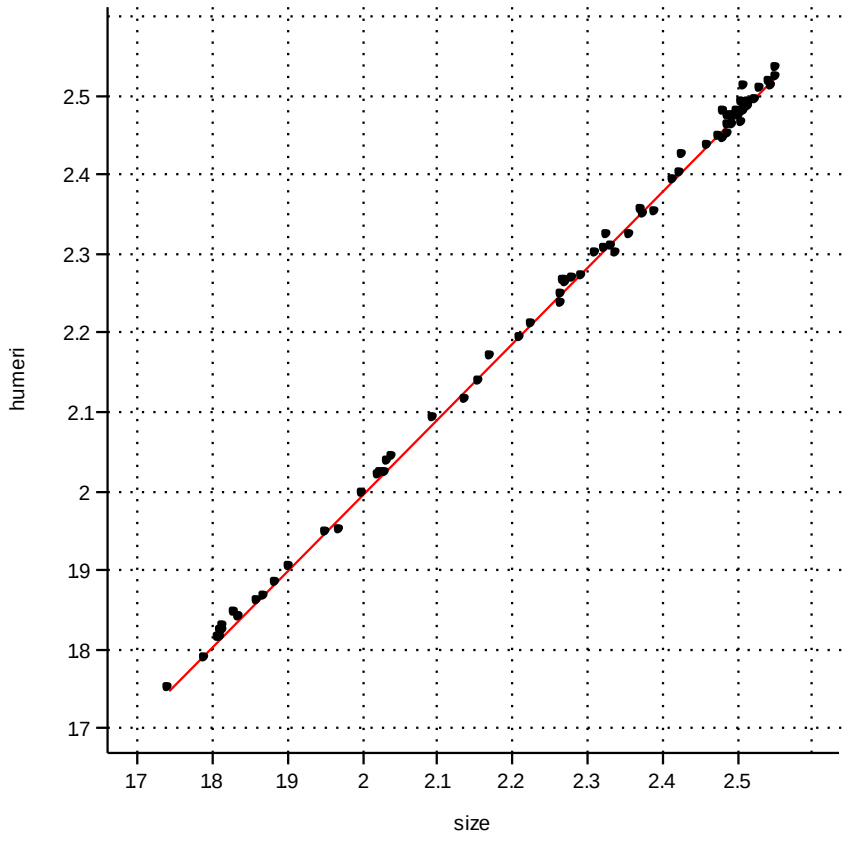


Figure 5-11. Reduced major axis regression for South Dakota Arikara (n=76) log(humeri) on log(size)

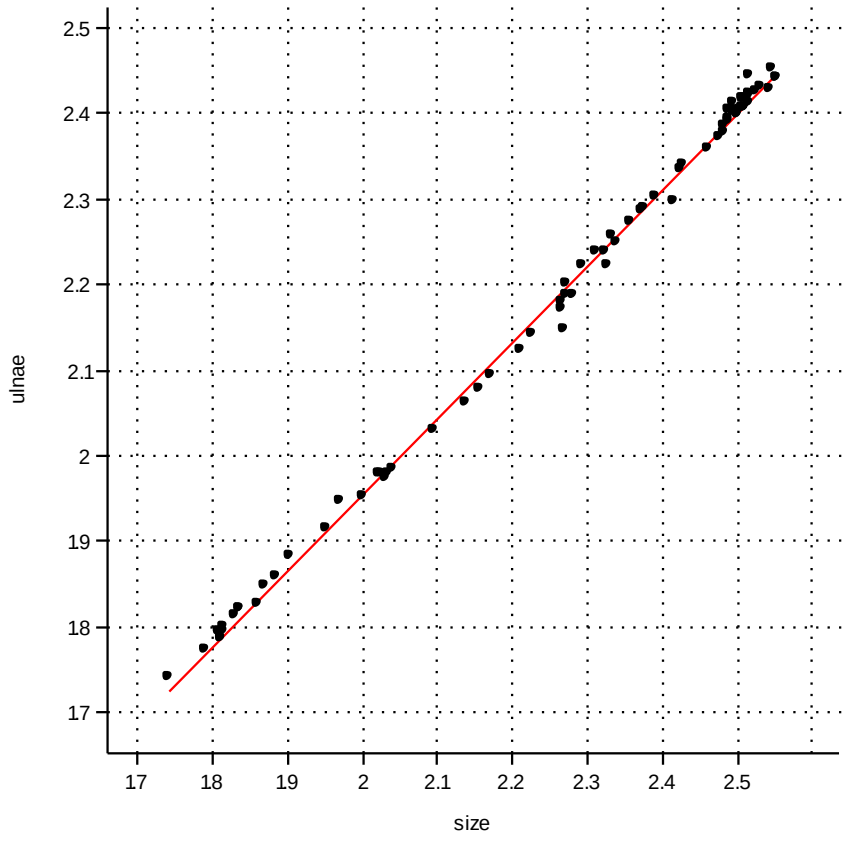


Figure 5-12. Reduced major axis regression for South Dakota Arikara (n=76) log(ulnae) on log(size)

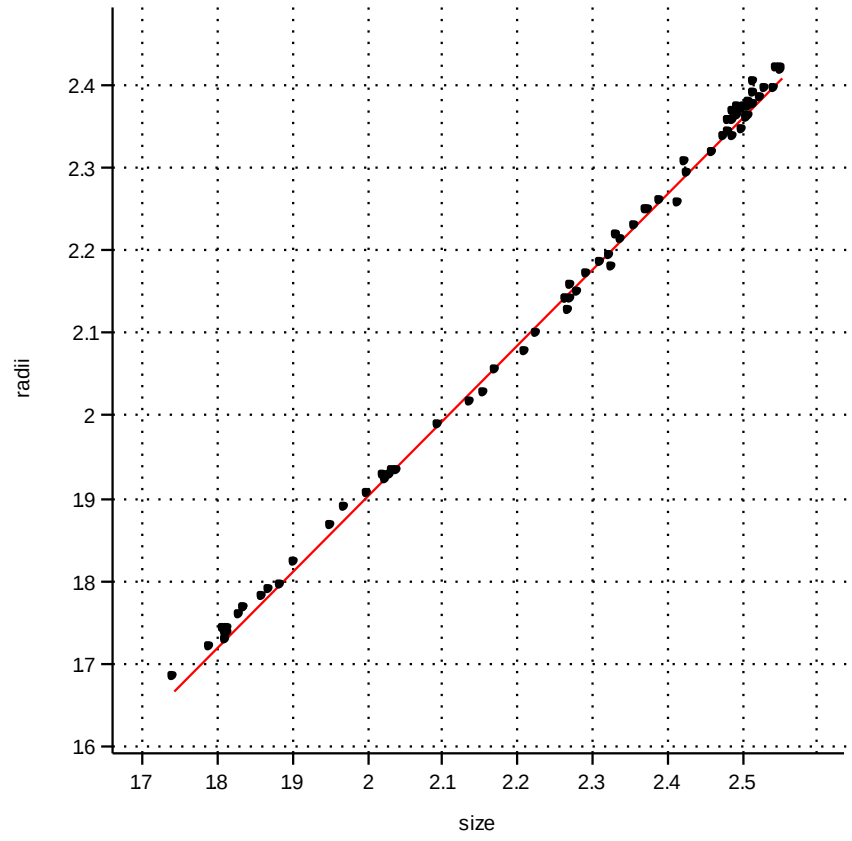


Figure 5-13. Reduced major axis regression for South Dakota Arikara (n=76) log(radii) on log(size)

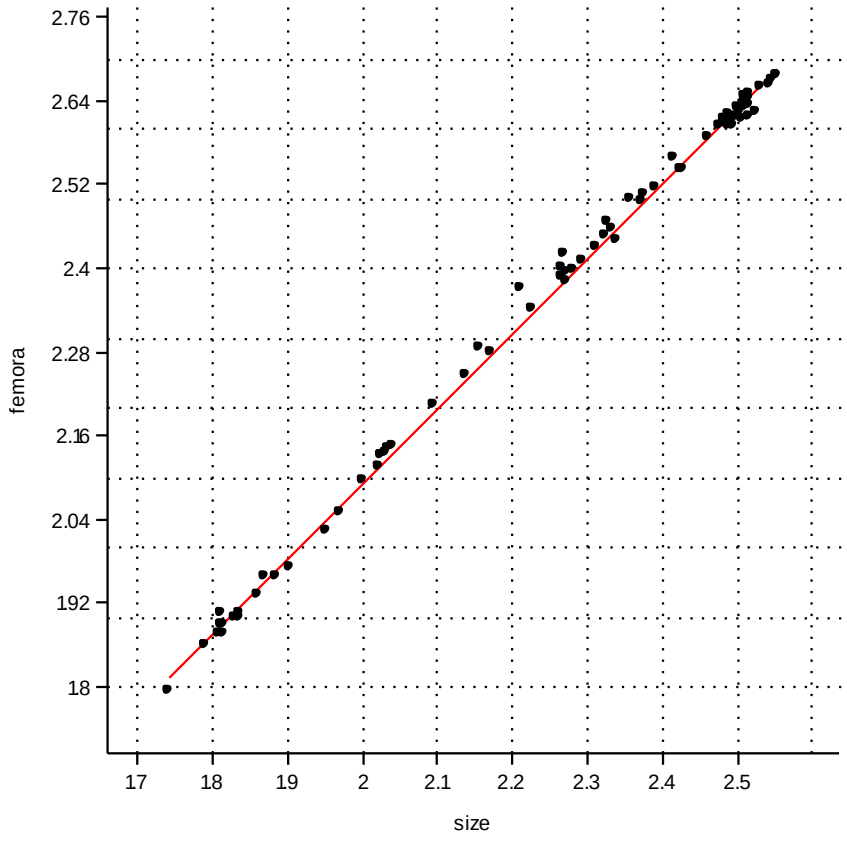


Figure 5-14. Reduced major axis regression for South Dakota Arikara (n=76) log(femora) on log(size)

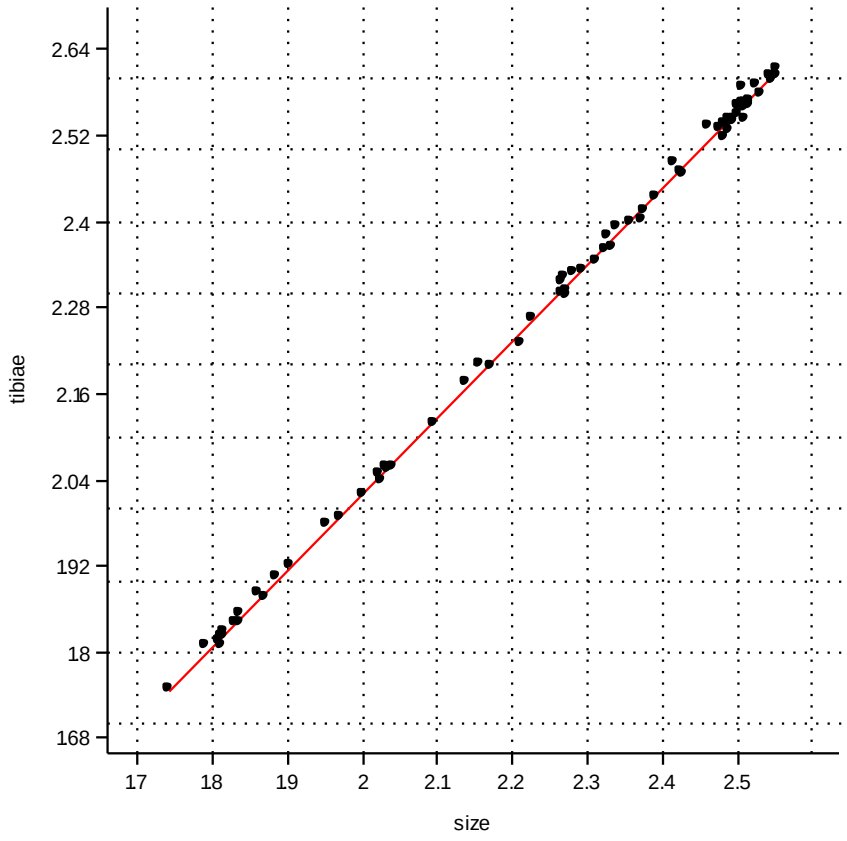


Figure 5-15. Reduced major axis regression for South Dakota Arikara (n=76) log(tibiae) on log(size)

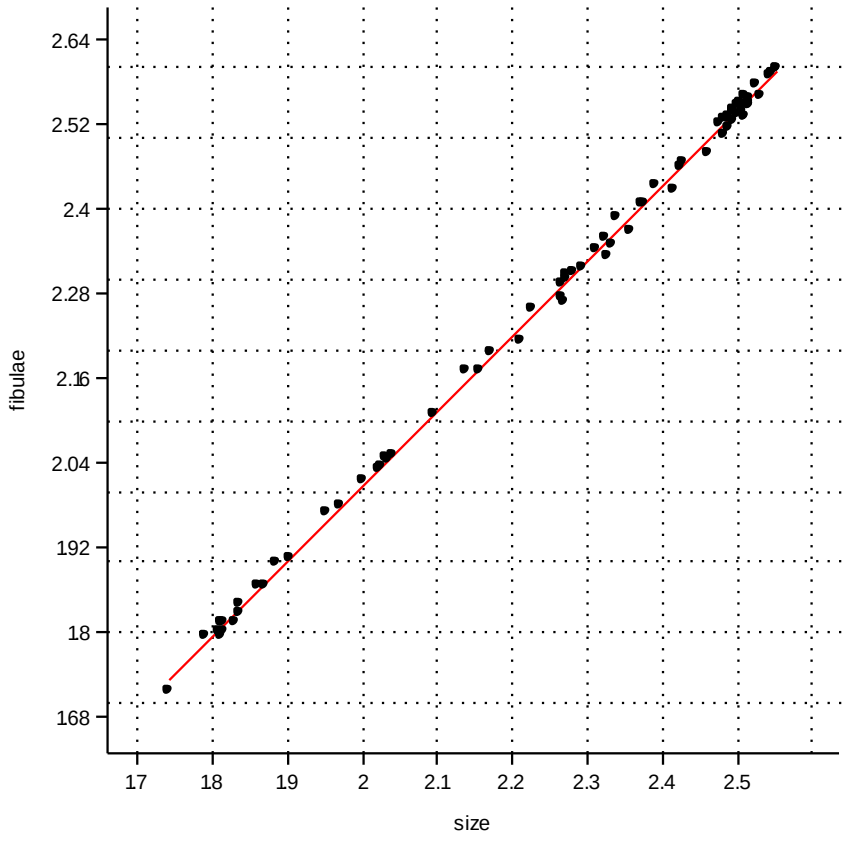


Figure 5-16. Reduced major axis regression for South Dakota Arikara (n=76) log(fibulae) on log(size)

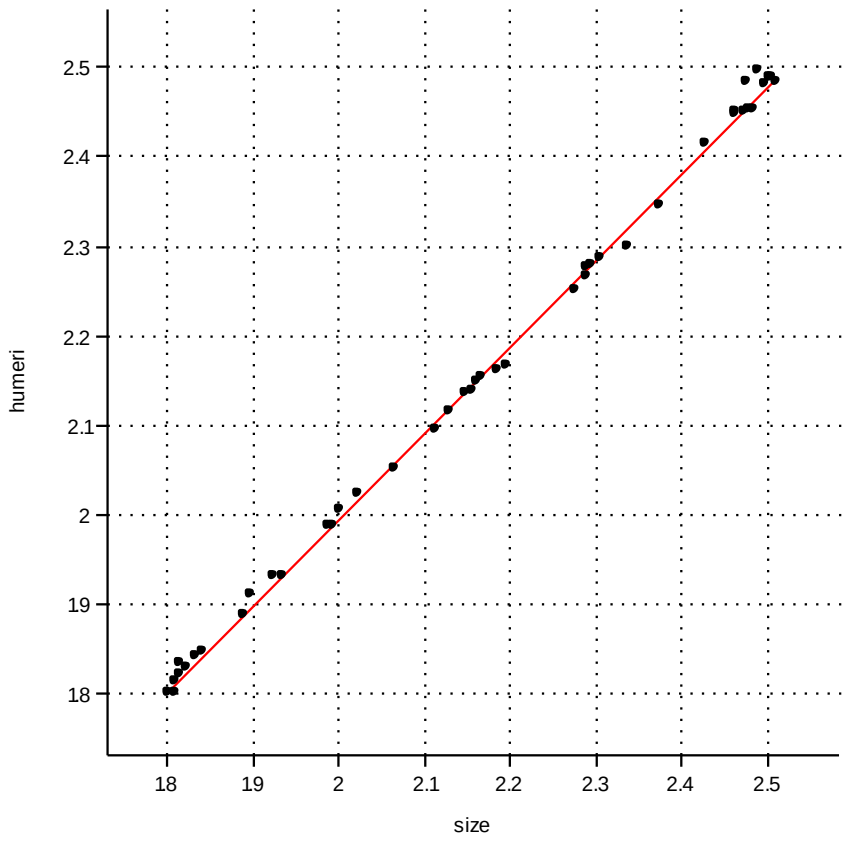


Figure 5-17. Reduced major axis regression for N.M. Puebloan (n=44) log(humeri) on log(size)

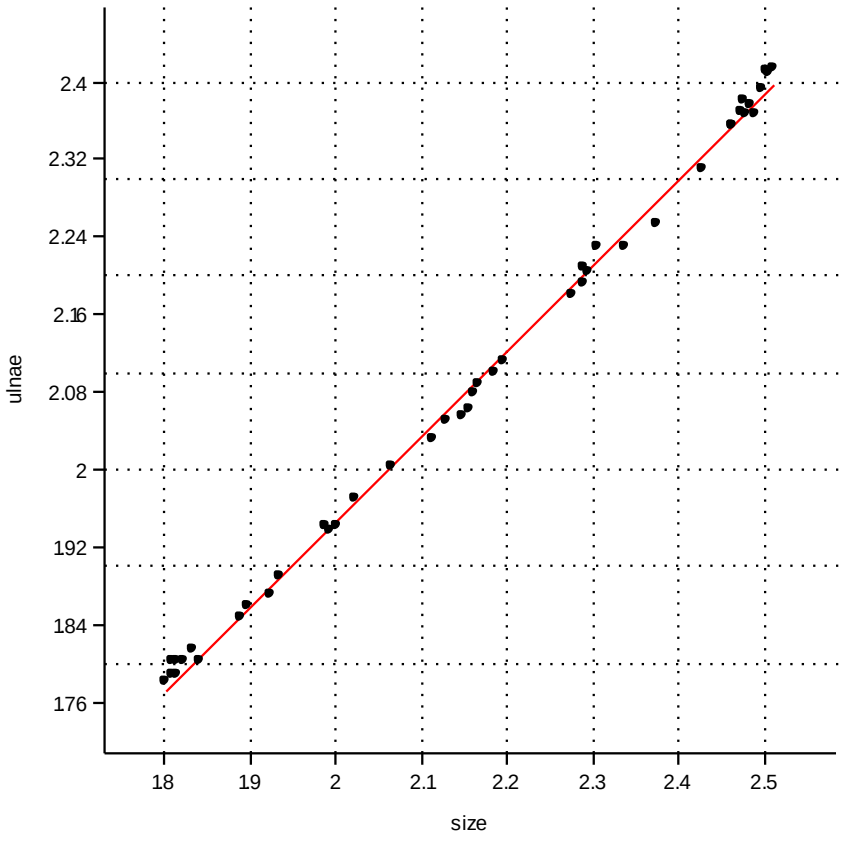


Figure 5-18. Reduced major axis regression for N.M. Puebloan (n=44) log(ulnae) on log(size)

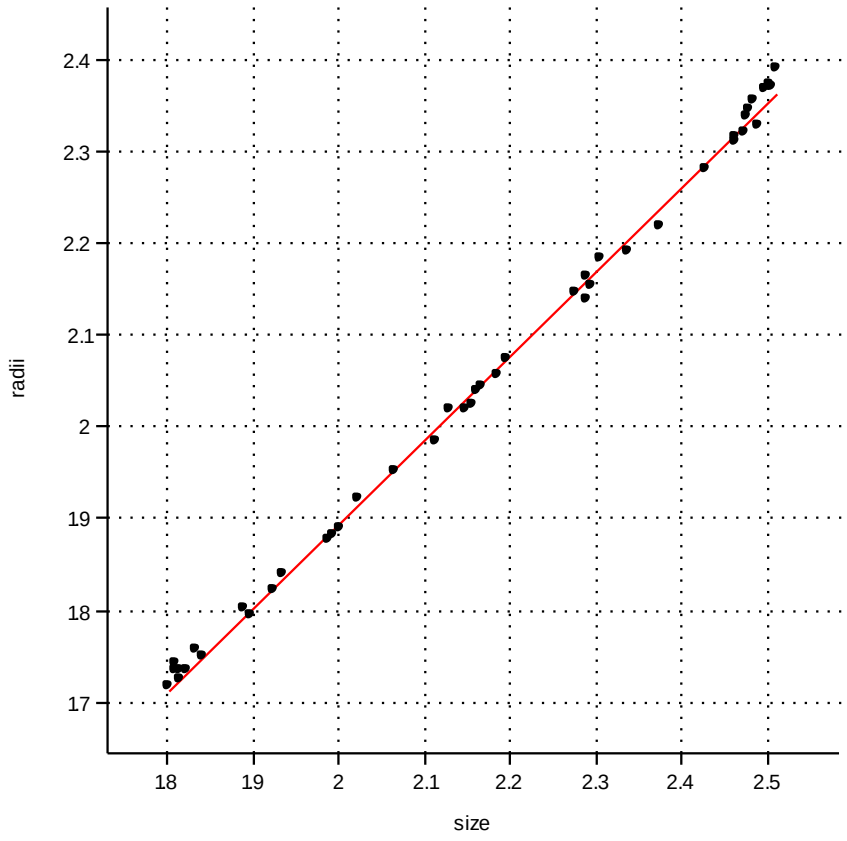


Figure 5-19. Reduced major axis regression for N.M. Puebloan (N=44) log(radii) on log(size)

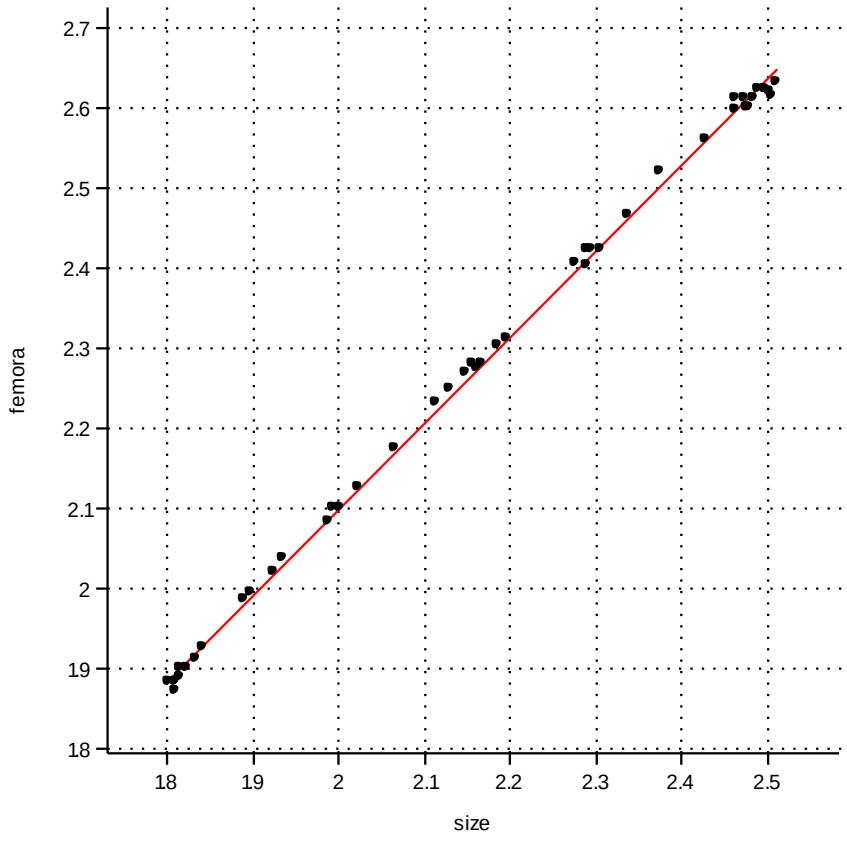


Figure 5-20. Reduced major axis regression for N.M. Puebloan (n=44) log(femora) on log(size)

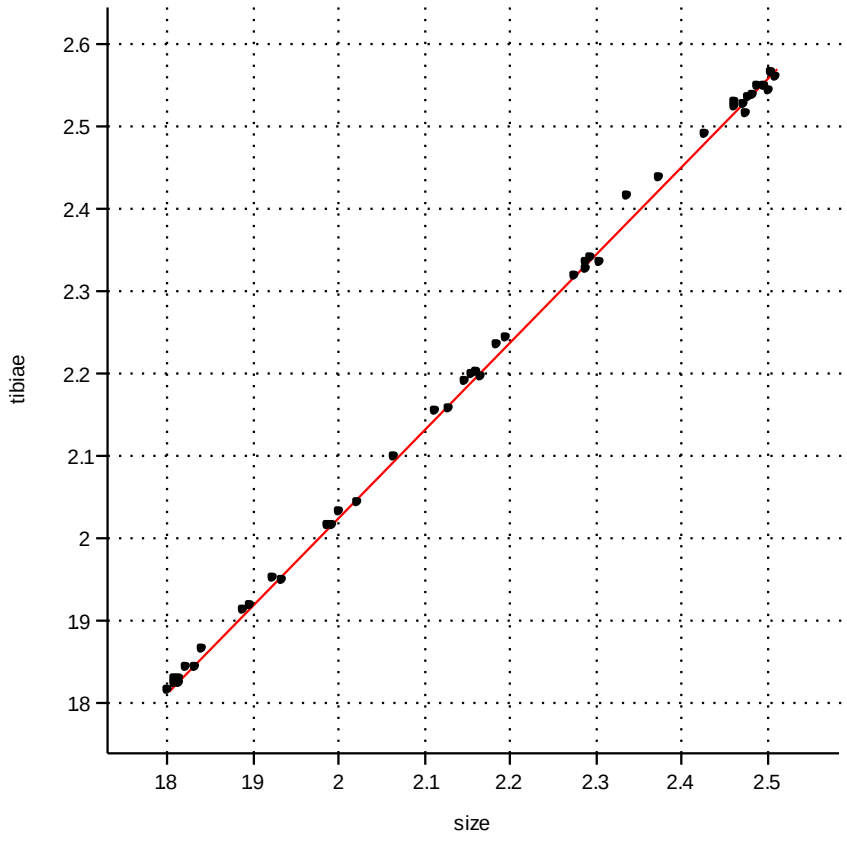


Figure 5-21. Reduced major axis regression for N.M. Puebloan (n=44) log(tibiae) on log(size)

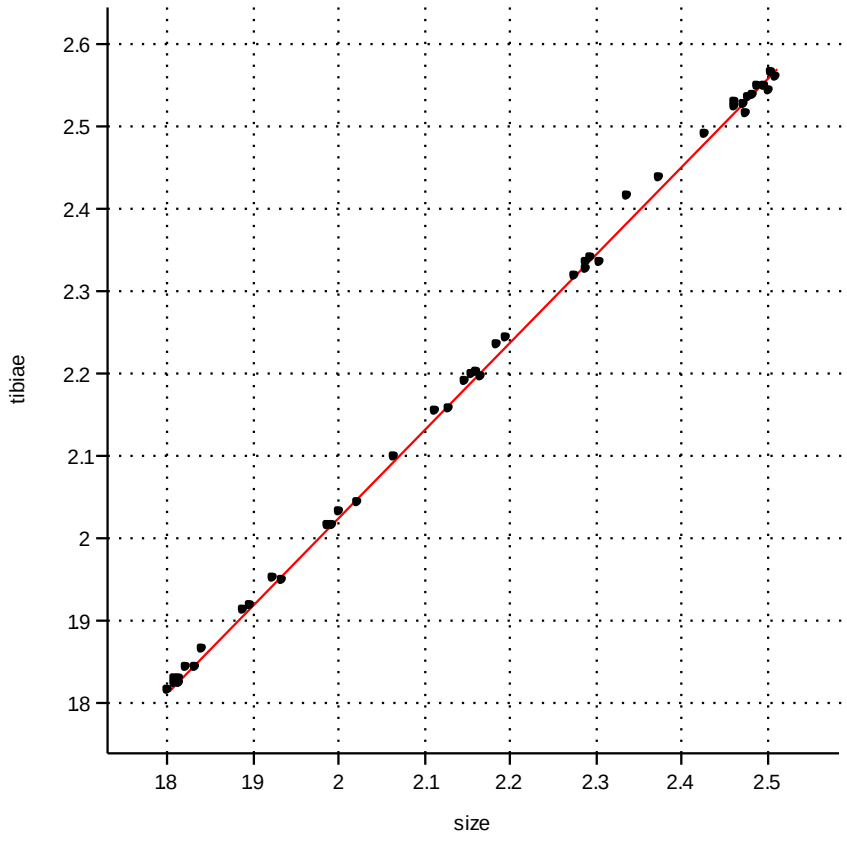


Figure 5-22. Reduced major axis regression for N.M. Puebloan (n=44) log(fibulae) on log(size)

Table 5-25. Slope by element within population

	Native Alaskan	South Dakota Arikara	N.M. Puebloan
Humeri	0.9629	0.9548	0.9637
Ulnae	0.9304	0.8856	0.8774
Radii	0.9501	0.9149	0.9132
Femora	1.0432	1.0720	1.0721
Tibiae	1.0655	1.0606	1.0603
Fibulae	1.0201	1.0575	1.0532

Table 5-26. Intercept values by element within population

	Native Alaskan	South Dakota Arikara	N.M. Puebloan
Humeri	0.0838	0.0858	0.0677
Ulnae	0.0626	0.1838	0.1911
Radii	-0.0272	0.0737	0.0682
Femora	0.0334	-0.0530	-0.0467
Tibiae	-0.1186	-0.1001	-0.0950
Fibulae	-0.0275	-0.1081	-0.0962

These slopes and intercepts of each element by population will be analyzed to determine whether they differ significantly from each other (alpha = 0.0167). The slope represents the growth trajectory for each element within a population and the intercept representing the origin or size at birth.

Table 5-27. Multiple comparisons of slopes and intercepts: p-values for humeri

Slope	Native Alaskan	South Dakota Arikara
South Dakota Arikara	0.6062	
N.M. Puebloan	0.9655	0.5220

Intercept	Native Alaskan	South Dakota Arikara
South Dakota Arikara	0.9999	
N.M. Puebloan	0.5599	0.3785

Table 5-28. Multiple comparisons of slopes and intercepts: p-values for ulnae

Slope	Native Alaskan	South Dakota Arikara
South Dakota Arikara	0.0162	
N.M. Puebloan	0.0122	0.5930

Intercept	Native Alaskan	South Dakota Arikara
South Dakota Arikara	0.0000	
N.M. Puebloan	0.0001	0.7455

Table 5-29. Multiple comparisons of slopes and intercepts: p-values for radii

Slope	Native Alaskan	South Dakota Arikara
South Dakota Arikara	0.0571	
N.M. Puebloan	0.0776	0.9087

Intercept	Native Alaskan	South Dakota Arikara
South Dakota Arikara	0.0005	
N.M. Puebloan	0.0027	0.8019

Table 5-30. Multiple comparisons of slopes and intercepts: p-values for femora

Slope	Native Alaskan	South Dakota Arikara	Intercept	Native Alaskan	South Dakota Arikara
South Dakota Arikara	0.0920		South Dakota Arikara	0.0010	
N.M. Puebloan	0.1262	0.9948	N.M. Puebloan	0.0051	0.7790

Table 5-31. Multiple comparisons of slopes and intercepts: p-values for tibiae

Slope	Native Alaskan	South Dakota Arikara	Intercept	Native Alaskan	South Dakota Arikara
South Dakota Arikara	0.7508		South Dakota Arikara	0.4285	
N.M. Puebloan	0.7672	0.9821	N.M. Puebloan	0.3705	0.7976

Table 5-32. Multiple comparisons of slopes and intercepts: p-values for fibulae

Slope	Native Alaskan	South Dakota Arikara	Intercept	Native Alaskan	South Dakota Arikara
South Dakota Arikara	0.0262		South Dakota Arikara	0.0018	
N.M. Puebloan	0.0837	0.7631	N.M. Puebloan	0.0169	0.5703

The results of this comparative analysis of slopes and intercepts for each element by populations find significant difference between the slopes (growth trajectories) only for the ulnae when Native Alaskan juveniles are compared to both South Dakota Arikara and New Mexico Puebloan populations. However, the null hypothesis cannot be rejected for the remaining elements compared. Significant differences were appreciated among the intercepts (size at birth) between multiple comparisons. The intercepts of Native Alaskans were distinguished from those of both South Dakota Arikara and New Mexico Puebloan among the radii, ulnae and femora. Similarly, the Native Alaskans and South Dakota Arikara were found to have significantly distinct intercepts for the fibulae compared.

These individual comparisons of slopes cannot provide a comprehensive analysis of allometry for each population. A test of overall isometry will provide a more holistic interpretation of whether these populations display allometric or isometric trajectories.

Test of Isometry

To provide a more comprehensive statistical assessment of individual or population allometry, Jolicoeur's (1963) test for isometry is employed. This procedure will evaluate whether the null hypothesis of isometry (slope = 1.0) holds or whether the alternative hypotheses of positive (slope > 1.0) or negative (slope < 1.0) allometry better fits the data (Corruccini, 1983; Falsetti and Cole, 1992; Jolicoeur, 1963, 1984; Jungers and German, 1981; Jungers et al., 1988; Sprent, 1972). Jolicoeur's (1963) procedure involves the principal components analysis on the log-transformation covariance matrix for all variables in the given data set. All loadings for the first principal component much be of the same sign and account for an "overwhelming" majority of the variance (Jungers and German, 1981; Sprent, 1972).

Multivariate isometry exists when all *p* dimensions increase at the same rate and "this can only be true if the vector of direction cosines of the first principal component of the logarithmic covariance matrix is equal to $(1/\sqrt{p})$" (Jolicoeur, 1963: 498). Hence the number of variables evaluated dictates isometry. In this case, 6 postcranial dimensions are evaluated making multivariate isometry equal to 0.408.

A principal components analysis was also conducted on the juvenile sample for each population. The covariance matrix for each population is displayed in Tables 5-34, 5-36, and 5-38 as they will be an integral component of the isometry analysis.

Table 5-33. Principal components analysis of Native Alaskan juveniles (n=52)

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
L(humeri)	0.3946	-0.0950	0.6004	0.5885	-0.3535	0.0586
L(ulnae)	0.3806	0.5593	0.1165	-0.1718	0.2931	0.6429
L(radii)	0.3887	0.5744	-0.0537	-0.1486	-0.1719	-0.6815
L(femora)	0.4274	-0.4590	0.3020	-0.2770	0.6091	-0.2601
L(tibiae)	0.4369	-0.3521	-0.2290	-0.4898	-0.5850	0.2249
L(fibulae)	0.4180	-0.1165	-0.6924	0.5342	0.2152	0.0240
Eigenvalue	0.7851	0.0029	0.0012	0.0006	0.0039	0.0002
% variation	99.32	0.37	0.16	0.08	0.05	0.03

Table 5-34. Principal components analysis of Native Alaskan juveniles – Covariance matrix

	L(humeri)	L(ulnae)	L(radii)	L(femora)	L(tibiae)	L(fibulae)
L(humeri)	0.1230	0.1176	0.1202	0.1326	0.1352	0.1292
L(ulnae)	0.1178	0.1148	0.1170	0.1271	0.1300	0.1246
L(radii)	0.1202	0.1170	0.1197	0.1297	0.1328	0.1274
L(femora)	0.1326	0.1271	0.1297	0.1444	0.1469	0.1401
L(tibiae)	0.1352	0.1300	0.1328	0.1469	0.1506	0.1435
L(fibulae)	0.1292	0.1246	0.1274	0.1401	0.1435	0.1380

Table 5-35. Principal components analysis of South Dakota Arikara juveniles (n=76)

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
L(humeri)	0.3923	-0.0701	0.4546	-0.1190	0.7843	-0.0726
L(ulnae)	0.3637	0.4932	0.2376	0.1237	-0.1903	0.7187
L(radii)	0.3758	0.4323	0.2511	0.1622	-0.3338	-0.6863
L(femora)	0.4401	-0.7188	0.2686	-0.1014	-0.4480	0.0805
L(tibiae)	0.4358	-0.1528	-0.5546	0.6653	0.1910	0.0037
L(fibulae)	0.4346	0.1579	-0.5424	-0.7009	0.0021	-0.0277
Eigenvalue	2.1528	0.0020	0.0008	0.0004	0.0003	0.0001
% variation	99.83	0.09	0.04	0.02	0.02	0.01

Table 5-36. Principal components analysis of South Dakota Arikara juveniles – Covariance matrix

	L(humeri)	L(ulnae)	L(radii)	L(femora)	L(tibiae)	L(fibulae)
L(humeri)	0.3318	0.3072	0.3174	0.3718	0.3680	0.3669
L(ulnae)	0.3072	0.2854	0.2947	0.3440	0.3410	0.3403
L(radii)	0.3174	0.2947	0.3046	0.3556	0.3524	0.3516
L(femora)	0.3718	0.3440	0.3556	0.4183	0.4130	0.4114
L(tibiae)	0.3680	0.3410	0.3524	0.4130	0.4094	0.4077
L(fibulae)	0.3669	0.3403	0.3516	0.4114	0.4077	0.4070

Table 5-37. Principal components analysis of New Mexico Puebloan juveniles (n=44)

	Eigenvectors					
Element	PC1	PC2	PC3	PC4	PC5	PC6
L(humeri)	0.3962	0.2042	0.6773	-0.3755	-0.4232	-0.1894
L(ulnae)	0.3606	0.5476	-0.0169	0.1224	0.1391	0.7318
L(radii)	0.3753	0.4918	-0.2604	0.1681	0.3187	-0.6477
L(femora)	0.4408	-0.5023	0.2406	-0.1773	0.6781	0.0650
L(tibiae)	0.4361	-0.3486	0.0377	0.7470	-0.3588	-0.0099
L(fibulae)	0.4331	-0.2067	-0.6536	-0.4757	-0.3337	0.0692
Eigenvalue	1.9707	0.0020	0.0008	0.0003	0.0002	0.0001
% variation	99.82	0.10	0.04	0.02	0.01	0.01

Table 5-38. Principal components analysis of New Mexico Puebloan juveniles – Covariance matrix

	L(humeri)	L(ulnae)	L(radii)	L(femora)	L(tibiae)	L(fibulae)
L(humeri)	0.3100	0.2818	0.2931	0.3441	0.3403	0.3378
L(ulnae)	0.2818	0.2569	0.2673	0.3128	0.3095	0.3075
L(radii)	0.2931	0.2673	0.2783	0.3256	0.3223	0.3203
L(femora)	0.3441	0.3128	0.3256	0.3836	0.3791	0.3763
L(tibiae)	0.3403	0.3095	0.3223	0.3791	0.3752	0.3722
L(fibulae)	0.3378	0.3075	0.3203	0.3763	0.3722	0.3702

Results of this analysis for each population including eigenvector, eigenvalues, percent of variation and covariance matrix for the first six principal components are found in Tables 5-33 through 5-38. For each of the populations examined, the first principal component (PC1) displays all positive loadings and accounts for over 99% of the variation of the within-sample variation. These results find that a gross majority of the variation within each sample is accounted for through size variation. Since this analysis focus solely on juvenile remains beginning at birth and throughout development, it is not surprising to find size would account for a majority of the variation even after the data is normalized through log-transformation.

The pattern among the loadings for the first principal component for each population analyzed shows comparable trends to those seen in Table 5-19. For each population loadings among the upper limb elements (humeri, ulnae, radii) display a maximum range of 0.3669-0.3946 and the lower limb components (femora, tibiae, fibulae) display a maximum PC1

loadings of 0.4180-0.4408. This pattern distinguishes the upper and lower limbs finding a consistently greater increase in the lower limb as compared to the upper limb. Though variation between the adult components of these three populations is undeniable, the patterns of developmental variation are comparable between these groups.

Table 5-39 displays the p-values for the test of the hypothesis of whether any of these three populations deviate significantly from isometry. Despite the results of the individual elements examined, when appreciated together these results show that all three populations examined deviate significantly from isometry. These results are not surprising for anyone who has watched a child grow. Rates of growth and change throughout the human developmental period are often in flux with a high growth velocity immediately after birth which decreases significantly from ages 3-10 years and then increasing again during the prepubertal growth spurt (Gasser et al., 2000; Gasser et al., 2001a, b; Smith and Buschang, 2004).

Table 5-39. Results for the test of isometry

Population	p-value
Native Alaskan	<0.0001
South Dakota Arikara	<0.0001
New Mexico Puebloan	<0.0001

While these results are not surprising when appreciated in conjunction with the previous analysis depicting unique origins for certain elements it provides a clearer picture of how and why these groups vary as adults.

The extent or degree of deviation from isometry is calculated using the isometry vector in conjunction with the first principal component vector for all six postcranial elements. Table 5-40 displays the deviation from isometry in degrees. These results confirm the significant deviation from isometry demonstrated above and reflect the pattern of variation previously appreciated in these populations. The South Dakota Arikara and New Mexico Puebloan are comparable in their

deviation from isometry while Native Alaskans are appreciably different. Given the permutations this data have already been subject to, determination of the separation of these values is statistically inappropriate.

Table 5-40. Deviation from isometry

Population	Deviation (degrees)
Native Alaskan	2.94
South Dakota Arikara	4.44
New Mexico Puebloan	4.42

When all the results of the juvenile analysis are taken together, these results do not exactly match any of the five alternative hypotheses posed. In this case, the juvenile results best match a combination of ontogenetic scaling and divergent growth trajectories. The South Dakota Arikara and New Mexico Puebloan groups displayed no significant variation of slope or growth trajectory for any of the individual elements compared. These two groups also share a comparable deviation from isometry displaying no significant variation in intercept or "origin" for any of the six postcranial elements. However, the results from initial Tukey's analysis highlight that the Arikara and Puebloan groups do display significant size differences in all postcranial elements compared. Hence given the comparable origin and slope for all elements, ontogenetic scaling best fits the juvenile results. The Native Alaskan sample displayed significant intercept differences in four out of the six postcranial elements compared and present a separation in deviation from isometry as compared to both the Arikara and Puebloan populations. Given these results a combination of ontogenetic scaling and divergent growth trajectories is concluded for the juvenile comparison between these three populations.

The results for the juvenile component of this data set find that heterochronic, interspecific growth models presented here may not be appropriate for an intraspecific analysis of human

growth. Growth and development are multifaceted processes with eco-geographic, evolutionary factors highlighting only a small factor of its complexity.

The Origins of Variation: Which Came First, the Chicken or the Egg?

The goal of this investigation was to refocus an analysis of human variation on what I proposed to be the most influential and informative medium to determine how and why these specific groups might differ: variation in ontogeny. The results of my investigation find that the morphology of Native Alaskans, South Dakota Arikara, and New Mexico Puebloan adult populations examined vary significantly and these differences are highly correlated to their eco-geographic condition. There is also a unique pattern to this variation: the distal segments of both the upper and lower limb account for a majority of the group distinction found among both analyses of the individual elements as well as through analysis of indices of the upper and lower limb components. An analysis of the juvenile segment of each population finds that the variation between these three populations is maintained in the developmental period and may even manifest before birth; beyond the scope of the present data. However, advances in developmental biology have addressed questions similar to those posed in anthropology: How and where do variation between groups manifest? What can this tell us about the evolution of novel characters? With a particular focus on limb patterning and development, analysis of Hox gene expression, and the ways in which the "plan" for limb is determined we are just beginning to uncover the answers.

"Which came first, the chicken or the egg? Neither; the embryo gave rise to both" (McKinney and Gittleman, 1995: 21). McKinney and Gittleman (1995) pose this question as the quintessential example of way questions in evolution have historically been framed. Physical anthropologists and evolutionary theorists tend to examine trends among adult population variation or cite major transitions through genetic mutation. "Ontogenies evolve, not genes or

adults" (McKinney and Gittleman, 1995: 21). The present investigation attempts to refocus population variation on the growth and development of the individuals within populations to highlight the true "origin" of human variation. While this investigation did not focus specifically on the developmental history of these groups, it can help to bridge the gap between studies of human variability and developmental biology to speculate as to which factors may be the probable source of variation.

Limb Development

"It seems that nature only figured out how to make appendages once. Moreover, nature seems to like to use the same pathways over and over again. . ." (Gilbert et al., 1996: 366). "All limbs are built from the same set of 'construction rules' which limit the amount and kind of variation that can be generated" (Oster et al. 1988: 874). Despite what Darwin called the "unity of type" in the structural organization of tetrapod limbs, developmental studies have provided insight into mechanisms responsible for the vast diversity that is created among the highly conserved patterns of limb morphogenesis (Gilbert, 2003; Oster et al., 1988; Shubin and Alberch, 1986; Shubin et al., 1997; Vorobyeva and Hinchliffe, 1996; Wolpert, 1991, 2007). Despite the great range of specialization among vertebrate appendages, the same underlying pattern is maintained (Wolpert, 2007).

The concept of "morphogenetic fields" or "modularity" is one of the major outcomes of experimental embryology that not only reassessed the traditional understanding of developmental biology but also allowing for an appreciation of discrete units of morphological variation and plasticity (Akam, 1998; Gilbert et al., 1996; Gilbert, 2003; Lovejoy et al., 2000; Raff 1996; Reno et al. in submission). Distinction of the autonomous developmental components in the embryo has allowed for a better appreciation of phenotypic plasticity and variation in isolated body segments such as the limb (Gilbert and Bolker, 2003; Lewontin, 2001; Nijhout, 2003; Pritchard,

1995; Raff and Raff, 2000; Raff, 1996; Roberts, 1995; Schlichting and Pigliucci, 1998; Schlichting, 2003; Schmalhausen, 1949; Shubin et al., 1997). Given the wide range of variation and specializations seen in tetrapods, it is fitting that the limb would be modulated in even smaller components (Reno et al., in prep). Limb development is separated into three distinct regions: the stylopod (humeri/femora), the zeugopod (radius/ulnae, tibiae/fibulae), and autopod (wrist elements and digits).

Broad Mechanism of Change: Hox genes

Transplantation and experimental studies have shown that the limb is specified long before limb bud outgrowth and the pattern is specified long before cartilage differentiation begins (e.g. Coates and Cohn, 1998; Gilbert et al., 1996; Lovejoy et al., 1999, 2000). These analyses provide potential mechanisms relevant to the present investigation. Hox genes are only just beginning to be fully appreciated. However given the known control of Hox genes during the earliest phases of limb initiation and development they served as a strong potential mechanism responsible for variation between and within population and species.

The Hox complex is an ancient group of genes which encode for transcription factors fundamentally responsible for the development and patterning animal body plans (e.g. Akam, 1998a, b; Capecchi, 1997; Cohn, 2001; Gilbert, 2003; Reno et al., in submission; Spitz et al., 2007). Hox genes have been specifically highlighted for their integral role in limb initiation, patterning and development (Capecchi, 1997; Cohn, 2001; Cohn et al., 1995, 1997; Davis et al., 1995; Davis and Capecchi, 1996; Deschamps, 2004; Freitas and Cohn, 2006; Goff and Tabin, 1997; Kmita et al, 2005; Nelson et al., 1996; Reno et al., in submission; Sordino et al., 1995; Spitz et al., 2007; Tarchini and Duboule, 2006; Tarchini et al., 2006; Zakany and Duboule, 1999; Zakany et al., 2004). Investigation into Hox gene expression has drawn attention to not only the domains under Hox control but the importance of the temporal and spatial position of gene

expression in the diversity of limb patterns (Cohn, 2001; Davis et al., 1995; Freitas and Cohn, 2006; Tarchini and Duboule, 2006).

Hox genes are expressed in bounded domains which specify identity for different regions of the basic body plan and specifically within the limb field (e.g. Akam, 1998b, Wolpert, 2007). Morphology is determined by the time that a gene is activated in the embryo (termed temporal collinearity) and the positioning of the gene on the embryo's anteroposterior axis (termed spatial collinearity) (Capecchi 1997; Coates and Cohn, 1998; Davis et al., 1995; Freitas and Cohn, 2006; Nelson et al., 1996; Spitz et al., 2007; Tarchini and Duboule, 2006; Tarchini et al., 2006; Zakany and Duboule, 1999).

Hox genes were first identified in the *Drosophila* (detailed in Wolpert, 2007). This cluster of genes were subsequently discovered in mammals but was found to have undergone an evolutionary duplication event resulting in four Hox clusters labeled A-D. Clusters A and D have been experimentally shown to be integral to limb formation while clusters B and C are involved in patterning other body regions (Capecchi, 1997; Davis and Capecchi, 1996; Goff and Tabin, 1997; Kmita et al., 2006; Tarchini and Duboule, 2006; Wolpert, 2007).

Duboule, Capecchi and colleagues, through experimental perturbations of Hox gene expression in mice limbs, found that Hox genes 9-13 are responsible for patterning the limb skeleton. Hox A and D genes belonging to groups 9 and 10 pattern stylopod formation, 10-12 control zeugopod development and 11-13 are responsible for autopod development (Carroll, 1997; Davis et al. 1995; Davis and Capecchi, 1996; Goff and Tabin; 1997; Kmita et al., 2006; Reno et al., in submission; Tarchini et al., 2006; Zakany and Duboule, 1999). These domains of Hox gene expression control length and shape of skeletal elements (Davis et al., 1995).

Patterns of Limb Variation: Forelimb and hindlimb variability

Forelimbs and hindlimbs in tetrapods (often referred to as "upper" and "lower" limbs in humans) evolved from the pectoral and pelvic fins of our aquatic ancestors (Gibson-Brown et al., 1996; Shubin et al., 1997). While unique adaptations have occurred simultaneously in the fore- and hindlimbs linking their development from as early as the Devonian, "secondary differences in gene expression and interaction may have served as the basis for [their] independent evolution" (Shubin et al., 1997: 639).

Many transcription and genetic factors have been implicated in the variation between the forelimb and hindlimb (Gibson-Brown et al., 1996, 1998; Goff and Tabin, 1997; Nelson et al., 1996; Shubin et al., 1997). Hox genes have been found to exhibit specific fore- or hindlimb expression patterns: Hoxc-6 is expressed in the mesenchyme of the forelimb while Hoxc-9, Hoxc-10 and Hoxc-11 are restricted to the hindlimb (Gibson-Brown et al., 1996, 1998; Nelson et al. 1996). Goff and Tabin (1997) note that while some Hox gene mutations affect both the fore- and hindlimb, some show more specified effects: Hoxd-9 and Hoxd-12 mutations result in forelimb defects only while Hoxa-10 mutations only have implications in the hindlimb. Experimental analysis has determined that two T-box transcription factors, Tbx5 and Tbx4, are responsible and required for forelimb and hindlimb specification and limb axis determination respectively (Gibson-Brown et al., 1996, 1998; Wolpert, 2007).

"Independent modification" (Shubin et al., 1997: 640) of the forelimb vs. the hindlimb may be responsible for the pattern of variation found in the present analysis, specifically the differential variation of the upper vs. lower limb in the juvenile sample.

Patterns of Limb Variation: Proximal stability and distal variability

Experimental studies and analysis of evolutionary trends have found a differential pattern of variation within the limb (Capecchi, 1997; Davis and Capecchi, 1996; Freitas and Cohn, 2006;

Hinchliffe, 1991; Kmita et al., 2006; Shubin et al., 1997; Tarchini and Duboule, 2006; Vorobyeva and Hinchliffe, 1996). This "modularity" may be responsible for the appreciation that patterns among distal limb segments, notably the autopod, are prone to more significant experimental manipulation and natural variation than proximal limb structures (Capecchi, 1997; Davis and Capecchi, 1996; Kmita et al., 2006: 1116; Reno et al., in submission; Shubin et al., 1997; Sordino et al. 1995: 681; Tarchini and Duboule, 2006). Vorobyeva and Hinchliffe (1996) found that while microsurgery can readily produce either loss or addition of digits, the stylopod and zeugopod are more stable with the zeugopod displaying a slightly higher degree of experimental manipulation. These trends have similarly been revealed not only in the present investigation, but among the natural variation found in primate, hominid and human studies (e.g. Holliday, 1997a, b; Holliday and Falsetti, 1995, 1999; Holliday and Ruff, 1997, 2001; Roberts, 1978; Ruff, 1993; Trinkaus, 1981; Vrba, 1996; Weaver and Ingram, 1969).

Given the theory and experimentation surrounding morphogenetic fields of development and Hox genes, mechanisms for independent modification within the limb can be appreciated through differential plasticity and constraint (Maynard Smith et al., 1985; Oster et al. 1988; Raff, 1996; Schlichting and Pigliucci, 1998; Shubin et al., 1997). Numerous authors have divided the limb into the proximal, "ancestral" component which is highly conserved as compared to the "neomorphic", distal segments that have evolved independently in various taxa (Capecchi, 1997; Davis and Capecchi, 1996; Kmita et al., 2006: 1116; Sordino et al. 1995: 681; Tarchini and Duboule, 2006). Capecchi (1997: 280; David and Capecchi, 1996) notes that distal limb structures, directed by the last Hox genes transcribed have "the greatest sensitivity to potential modulation that have been randomly accrued during evolution."

Freitas and Cohn (2006) highlight that this pattern of proximal stability/distal variability correlates to the temporal and spatial collinearity of Hox expression. This variation may results not only from collinearity, but separate regulatory control of limb development (Freitas and Cohn, 2006). This "independent modification" may be a product of the distinction and separation of limb regions under Hox control (Freitas and Cohn, 2006; Reno et al., in submission; Shubin et al., 1997: 640; Sordino et al., 1995).

While not supplying all the answers yet, the exploding field of developmental biology has made significant contributions to our understanding of variation and development and having the greater potential to explain the underlying mechanisms for many of the observations made and questions asked by practitioners of biological anthropology. Despite the variation appreciated throughout molecular analyses of limb development, it is remarkable that many different animals, including humans, display comparable patterns of variation. The modules defined by Hox genes imply a variety of responses that correlate to not only the variation appreciated in distal limb components but to the creation of significant evolutionary novelties. In the future, developmental and evolutionary biology studies will provide even further insight into why these population and species level variations in limb development originate and how they become canalized in embryonic development.

Long Bone Development

Mesenchyme is a part of the embryonic mesoderm, consisting of unspecialized loosely packed cells from which connective tissue, cartilage and bone are formed. Bone formation begins when mesenchymal cells begin to cluster and condense. Most of the condensed cells become chondrocytes, the primary cell type of cartilage and precursor of bone. Chondrocytes have a characteristic shape and secrete a rich type II collagen, a fibrous protein matrix. While

most of these condensation cells become chondrocytes, the cells surrounding the borders of the condensation form the perichondrium (Kronenberg, 2003).

The cartilage cells continue to enlarge and multiply through a combination of matrix production and chondrocyte proliferation. Chondrocytes in the center are the first to stop proliferation and begin hypertrophy. This process alters the trajectory of their genetic program and initiates the synthesis of type X collagen. These hypertrophic chondrocytes in the center are the "principle engine of bone growth" and become the regulatory "brain" of further development (Kronenberg, 2003: 333). These cells attract blood vessels and chondroclasts and begin the mineralization process of the surrounding matrix. The hypertrophic chondrocytes adjacent to the perichondrium cease proliferation and become osteoblasts secreting a characteristic matrix which forms a bone collar forming scaffolding around the developing bone. This scaffolding supports the osteoblast activity that invades the cartilage as well as blood vessels and begins the initial laying down of the true bone matrix (Karsenty and Wagner, 2002; Kronenberg, 2003).

As the chondrocytes continue to proliferate, the ends of the developing bone lengthens. Bone growth is perpetuated rapidly throughout fetal and postnatal life through this proliferation process. During this period of enlargement and elongation, secondary ossification centers are established as chondrocytes toward the ends stop proliferation, hypertrophy and begin increased vascularization. In long bones, proliferation continues at both the primary and secondary ossification sites. The cartilage between these cites is called the growth plate, forming a distinct layer of cells between ossification centers acting as the primary center of bone elongation (Wolpert, 2007). The columnar chondrocytes are flat and are termed resting or reserve chondrocytes as they serve as precursors for later, continued bone development between the primary and secondary ossification centers (Kronenberg, 2003). The growth plate disappears just

after puberty in humans which marks the end of bone lengthening and formation (Karsenty and Wagner, 2002; Kronenberg, 2003; Wolpert, 2007).

Local Mechanisms of Change

Bones change, grow and are remodeled throughout ontogeny and throughout evolution. This change is orchestrated and regulated through many local and systemic, molecular and cellular agents (Kronenberg, 2003) with the final morphology acting as "the ultimate read-out of [these] complex molecular interactions" (Lovejoy et al., 1999: 13247). An understanding of skeletogenesis and bone growth is required to appreciate how the slightest variation in these cellular interactions can alter the adult phenotype. Some of the most integral components in the developmental process are the morphogenetic agents required for growth, maturation, proliferation and apoptosis. Some of which will be examined here as potential mechanisms responsible for the population-wise modifications within these three groups.

For growth to be extended or retarded the rate of cellular proliferation and expansion of the hypertrophic zone needs to outweigh apoptosis or vice versa. There are a number of growth factors that have been attributed to the control and regulation of cell division, increase and/or death. A few of these integral players will be presented here as potential mechanisms responsible for variation in long bone length.

Indian hedgehog (Ihh) and Parathyroid-hormone-related protein (PTHrP)

Ihh is a "master regulator" of bone development responsible for chondrocyte proliferation as well as chondrocyte and osteoblast differentiation (Karsenty and Wagner, 2002; Kronenberg, 2003: 332; Liu et al. 2002). During development Ihh is secreted by pre- and early hypertrophic chondrocytes. Experimental studies of mice that have an inactivation of Ihh display pronounced abnormalities in bone growth marked by small cartilage elements due to decreased chondrocyte proliferation and an absence of osteoblast activity (Kronenberg, 2003).

PTHrP is a protein similarly secreted embryonically by pre/early hypertrophic chondrocytes toward the ends of the developing bone (Kronenberg, 2003; Liu et al., 2002). This factor has been found to be primarily responsible for keeping proliferating chondrocytes in the proliferative pool thereby delaying their hypertrophy and subsequent mineralization. Experimental disruption of PTHrP results in premature maturation of chondrocytes and short-limbed dwarfism (Karsenty and Wagner, 2002; Liu et al., 2002).

PTHrP and Ihh are found to work in concert to control extension at the ends of the developing bone. Mice who have an experimental inactivation of Ihh fail to produce PTHrP. Together Ihh and PTHrP are responsible for the determination of the extent and boarders of the proliferative zone of the developing bone (Kronenberg, 2003).

Fibroblast growth factors (FGFs)

FGFs are a family of polypeptides which serve multiple roles integral to cell growth and differentiation (Liu et al., 2002). *Fgfr3* is expressed in proliferating and prehypertrophic chondrocytes inhibiting further proliferation (Karsenty and Wagner, 2002; Kronenberg, 2003). A null mutation of this gene results in an expanded growth plate and increased cell proliferation. A similar phenotype results from a null mutation in *Fgf18*. *Fgfr1* and *Fgfr2* are expressed in hypertrophic chondrocytes (Kronenberg, 2003; Liu et al. 2002).

Bone morphogenetic proteins (BMPs)

BMPs, also called growth and differentiation factors (GDFs), serve multiple roles in skeletal development (Karsenty and Wagner, 2002; Kronenberg, 2003; Sears et al., 2006). BMP2 and -6 are expressed in hypertrophic chondrocytes and BMP7 is expressed in proliferating chondrocytes. BMPs also are responsible for increasing the expression of Ihh by prehypertrophic chondrocytes and are subsequently responsible for chondrocyte proliferation (Kronenberg, 2003; Sears et al., 2006). A mutation in GDF5, in both mice and humans, causes multiple types of

chondrodysplasia characterized by shortened limbs, abnormal joint development and digit reduction (Karsenty and Wagner, 2002).

Sears and colleagues (2006) found that BMP signaling is responsible for the increased digit length in bats. Similarly, their results show that bat embryonic forelimbs display an upregulation of BMP production and activity relative to both mice as well as bat hindlimbs (Sears et al., 2006). As in bats, BMP may be a key mechanism responsible for an increase/decrease of limb length in other species.

Insulin-like growth factors (IGF)

IGF-1 and 2 are protein growth factors, closely resembling insulin (as they are so named), which play an integral role in embryonic and post-natal growth and development (Conlon and Raff, 1999; Lupu et al., 2001; Sutter et al., 2007; Wolpert, 2007). IGF-1 is considered a strong determinant of body size across mammals by controlling the rate of chondrocyte proliferation (Karsenty and Wagner, 2002; Sutter et al. 2007). Sutter and colleagues (2007) investigated whether IGF-1 was an integral factor responsible for the variation of body size among dog breeds. A specific IGF-1 polymorphism was found to be common to all small dog breeds by absent from large breeds. Sutter et al. (2007) concluded that this specific variant found only in small breeds was a probable mechanism responsible for small breed body size.

Growth hormone (GH)

Growth hormone is a post-embryonic protein hormone required for postnatal growth in humans and mammals (Conlon and Raff, 1999; Karsenty and Wagner, 2002; Lupu et al., 2001; Wolpert, 2007). Humans found to be deficient in GH become dwarfed while those with an excess of GH become giants (Conlon and Raff, 1999). Similarly, GH also acts by inducing the liver and other organs to produce IGF-1 (Conlon and Raff, 1999). Lupu and colleagues (2001) tested the roles of both IGF-1 and GH in the postnatal development of mice. It was found that

GH and IGF-1 have independent and overlapping functions in chondrocyte development. Individuals with an inactivation of IGF-1 were small than individuals with an inactiviation of GH, however double mutants for both factors were the most affected (Lupu et al. 2001).

Final Thoughts

Small changes in molecular patterning can lead to dramatically different phenotypes. In the present analysis it is not possible to definitively determine what, if any, of the above morphogenetic agents are responsible for the variation between these three populations. However, it is probable that one or a combination of these factors may have been affected by the eco-geographic or extrinsic "stressors" that these populations were subject to over the course of their occupation and evolution. This physical isolation from one another and eco-geographic factors may have led to an "independent modification" of those factors responsible for long bone development and variation.

CHAPTER 6
SUMMARY

The objective of this analysis was to test whether three spatially distinct Native North American populations vary significantly by eco-geographic condition, with the particular goal of highlighting patterns of variation among juvenile skeletal remains. These data were derived from 871 individuals from three archaeological populations of skeletal remains: Native Alaskan groups, South Dakota Arikara and New Mexico Puebloan groups. These data are particularly compelling and serve as an integral contribution to population skeletal biology as approximately 50% of these individuals, at this time, have already been signed-off for repatriation from academic institutions (Public Law 101-601, 1990) and are currently off limits to future analysis. Within the next few years this figure will probably reach 100%. The results of this investigation have shown that significant variation can be appreciated among archaeological remains of juveniles and that population disparities in physical dimensions are significantly correlated to eco-geographic condition.

Juvenile skeletal analyses based on archaeological assemblages have inherent limitations. The juvenile individuals of the present analysis represent the cross-sectional growth patterns of three groups. As the young of any populations are not "expected" to die, it is uncertain as to whether these individuals followed "normal" patterns of growth prior to death and whether these patterns are representative of their native groups. Many bacterial and viral conditions are acute, leaving no substantial or lasting manifestation on the developing skeleton. Similarly, children are incredibly resilient. After overcoming illness or growth arrest due to dietary constraint children are often able to "catch up" with previous growth trajectories. These limitations are outweighed by the probative value these data have for the understanding of human growth patterns and how this period may affect the morphology of a population.

Given the nature of archaeological populations, numerous theoretical and methodological considerations were assumed. It is assumed that the sex and age of each individual was estimated as best as possible given the literature and methodology available at this time. The individuals from each population are considered to be members of that cultural group, sharing a common evolutionary history and immediate life history traits including eco-geographic condition. For the juvenile sample analyzed, it is assumed that all individuals display representative growth patterns for that specific population and that their growth was not adversely affected by their cause of death; all individuals displaying gross pathological conditions were excluded from these analyses. It is also assumed that, following the paradigms and models established in the literature, the most appropriate analytical methods for the data are being employed. Finally, it is assumed that given these theoretical and methodological considerations, these three groups were appropriate for comparative analysis against the selected eco-geographic variables.

Many previous investigators have focused on geography (longitude and latitude) and climate as integral factors influencing morphological form. Bergmann's and Allen's "rules" for homeothermic animals have been substantiated in analyses of hominids as well as other vertebrates. For this project, eco-geographic variables from three spatially distinct populations were compared. Eco-geographic variables consisted of a single geographic variable (latitude), three temperature variables (annual mean temperature, highest month mean, lowest month mean) and three climatic variables (annual mean precipitation, highest month mean, lowest month mean). These measures approximated the conditions of the region of the three populations examined at their time of occupation. These eco-geographic conditions were compared to the linear measurements of six postcranial long bones (humeri, ulnae, radii, femora, tibiae, fibulae)

from each distinct population: Native Alaska groups (n=242), South Dakota Arikara (n=379) and Ancestral Puebloan groups from New Mexico (n=250).

The principal components structure of the logged linear dimensions of both adults and juveniles provide measures of within population variation due to differences among both size and shape variables. For both adult and juvenile groups, the first principal component of log size and log shape accounted for a majority of the within group variation. This axis, representing size, was found to account for a majority of the variation among both adults and juveniles sampled. Shape variables described significantly less of the within population variation in the sample.

The structure of the principal variates provided interesting results for both the adult and juvenile categories examined. The pattern of variation for the adult sample was separated between the proximal and distal components for both the upper and lower limbs. For both limbs the distal elements displayed a consistent and higher variate loading on the first principal axis indicating that the distal segments were responsible for a large portion of variation within the adult sample. Altneratively, the pattern of variation among the juvenile sample was separated between the upper versus lower limb with no further internal variation between the proximal and distal components within each limb. In this case, the lower limb displayed the higher loadings indicating that a larger portion of the juvenile sample variation is manifest in the lower limb. At this time the reason for this variation between the adult and juvenile sample is unclear. It is possible and highly likely that the juvenile sample variation is due to the natural variation in human development as well as cross-sectional nature of the data and the wide age range incorporated into the juvenile sample; this section of the data spans the entire postnatal growth period from infancy through adolescence.

Further investigation into this quandary revealed adolescence as a period of juvenile development. Analysis of smaller, discrete juvenile age categories find that while birth-2 and 3-7 estimated years of age mirror the previous juvenile sample results, 8-11 and 12-21 age categories mark a transition to adult patterns of postcranial variation.

The relationship between populations after accounting for within group differences was also examined through a canonical discriminant analysis. The patterns of between-group associations derived from linear postcranial dimensions suggest that these groups are readily distinguishable. The structure of the first canonical axis served to discern a unique pattern of variation among the elements examined. This analysis found that the distal limb segments (ulnae/radii, tibiae/fibulae) exhibited significantly higher canonical coefficients than found in the proximal limb components (humeri, femora). This pattern suggests that a majority of the variation between these populations is due to changes in the distal limb segments. Given a significant pattern of variation the correlation of these trends to environmental conditions were explored.

Human morphological patterning of distal elements by climate/geography have been noted in the literature (e.g. Falsetti, 1989; Holliday and Falsetti, 1995; Holliday and Ruff, 2001; Trinkaus, 1981). In an analysis within and between 20 geographically distinct skeletal samples of modern humans Holliday and Ruff (2001) concluded that the relative variance of the distal limb was significantly great than those of the proximal; the tibia found to be the most variable. While not explicitly tested, climatic factors are highlighted as the probable factor responsible for distal segment variation among human populations (Holliday and Ruff, 2001).

To determine whether eco-geographic variables in any way affect the morphological variation outlined from previous analyses, canonical correlations analysis was conducted.

Canonical correlation between the six linear measurements and five eco-geographic conditions (low month mean precipitation was removed as it was the same value for all populations compared) were significant. The first canonical axis accounted for almost 90% of the sample variation and displayed a high coefficient loading of 0.77. This indicates that, overall, the eco-geographic variables selected for analysis are a relatively strong predictor of linear dimensions. The eco-geographic variables show a higher correlation to the distal limb segments than proximal ones; a trend similarly found among population variation in the canonical discriminant analysis.

The most obvious pattern found in the canonical correlation analysis is the negative correlation of latitude against all linear dimensions compared; higher correlations are found for distal skeletal elements than proximal ones. Similarly, latitude exhibited the highest correlation coefficients for all eco-geographic conditions investigated. Precipitation variables showed a positive correlation with linear measurements however no specific patterns of variation were appreciated. These results support the climatic "rules" of Bergmann and Allen.

The reduced major axis regression and test of isometry rejects the null hypothesis of isometry for all elements within the juvenile component of the three populations examined. While the slopes, or growth trajectories, for all elements were not found to differ significantly from each other across populations, collectively they were found to deviate significantly from multivariate isometry (for 6 variables, slope = 0.408). The intercepts for some elements compared did display a significant variation in intercept or size origin. The ulnae, radii, femora and fibulae were found to display common growth trajectories with unique size origins between populations with the humeri and tibiae exhibiting common allometric trajectory with common origin. It is uncertain why the tibiae did not follow previously identified trends among the distal

limb seen here in the regressions of ulnae, radii and fibulae. However, for these three elements, the pattern of variation in the distal segments of the upper and lower limb found in previous analyses is revealed. The variation in adult form is a product of deviation not in rate of growth, but size at birth.

Developmental biology has set the stage for a true understanding of the mechanisms responsible for population variation and evolutionary change. While a true understanding of why and how these populations came to vary is beyond the scope of this project, the identification of the extent and pattern of variation allows for a better understanding of evolutionary trends and opens the door to future investigations that will undoubtedly provide a deeper appreciation of morphological change.

In conclusion, size of postcranial skeletal long bones is found to be significantly patterned by the eco-geographic variables outlined here. This picture of morphological variation is indicative of the genetic and developmental variation between these three populations related to their evolutionary relationships, separation and patterning by local conditions. Hopefully the results of this investigation will encourage further analysis into developmental patterning among archaeological and extant human populations as well as providing a platform for a deeper exploration into the mechanisms that give rise to skeletal and developmental variation.

APPENDIX A
POSTCRANIAL DATA

Appendix A represents the raw post-cranial measurements taken on three populations of Native North Americans: Native Alaskans, South Dakota Arikara, and New Mexico Puebloan groups. All post-cranial long bone measurements are listed in millimeters. The code for each population is found in Table A-1.

Table A-1. Code for population assessment

Population	Code
Native Alaskan	1
South Dakota Arikara	2
New Mexico Puebloan	3

The sex is also coded into three categories found in Table A-2: male, female and undetermined. The group of undetermined individuals comprises the juvenile population. All adult individuals were assigned either a male or female sex assessment.

Table A-2. Code for sex assessment

Sex	Code
Male	1
Female	2
Undetermined	3

Table A-3. Post-cranial data by population, estimated dental age and sex

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
377826	1	6m +/- 3m	3	70	68	59	82	.	.
378385	1	6m +/- 3m	3	72	.	60	85	73	69
378660	1	9m +/- 3m	3	84	76	68	105	87	.
377827	1	1 yr +/- 4m	3	103	93	82	132	105	103
378434	1	1.5 yr +/- 6m	3	96	81	72	118	98	97
363601	1	1.5 yr +/- 6m	3	102	85	76	127	101	101
279211	1	2 yr +/- 8m	3	.	.	.	.	.	.
342513	1	2 yr +/- 8m	3	.	.	.	158	.	.
345339	1	2 yr +/- 8m	3	136	.	.	.	161	.
345386	1	2 yr +/- 8m	3	100	.	.	128	.	.

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
378386	1	2 yr +/- 8m	3	.	91	82	134	106	105
378496	1	2 yr +/- 8m	3	110	92	85	135	.	111
378494	1	2.5 yr +/- 10m	3	123	97	90	156	125	122
351286	1	3 yr +/- 12m	3	130	107	96	170	138	135
351325	1	3 yr +/- 12m	3	155	117	106	201	149	150
363537	1	3 yr +/- 12m	3	.	.	.	182	.	.
363543	1	3 yr +/- 12m	3	118	93	83	150	115	.
363602	1	3 yr +/- 12m	3	125	.	82	164	129	.
377823	1	3 yr +/- 12m	3	133	102	91	169	130	127
378492	1	3 yr +/- 12m	3	109	91	82	134	114	.
379716	1	3.5 yr +/- 12m	3	132	105	94	172	135	139
345708	1	3.5 yr +/- 12m	3	.	.	.	.	162	.
345375	1	4 yr +/- 12m	3	.	.	.	.	163	.
363536	1	4 yr +/- 12m	3	150	.	.	187	154	.
363544	1	4 yr +/- 12m	3	135	109	98	186	139	144
363566	1	4 yr +/- 12m	3	140	111	100	180	145	.
377822	1	4 yr +/- 12m	3	133	108	96	173	140	137
378384	1	4.5 yr +/- 12m	3	136	115	103	183	144	143
345358	1	5 yr +/- 16m	3	147	126	112	196	155	154
345376	1	5 yr +/- 16m	3	145	116	103	195	149	147
345726	1	5 yr +/- 16m	3	157	123	108	219	171	174
351323	1	5 yr +/- 16m	3	159	126	115	212	164	165
377824	1	5 yr +/- 16m	3	150	122	.	195	154	151
345365	1	6 yr +/- 24m	3	153	.	.	208	.	.
351229	1	6 yr +/- 24m	3	157	127	113	216	169	169
378379	1	6 yr +/- 24m	3	135	112	.	.	139	.
378383	1	6 yr +/- 24m	3	.	.	.	187	145	143
351228	1	7 yr +/- 24m	3	173	.	121	232	180	180
378382	1	7 yr +/- 24m	3	145	123	.	.	.	.
345759x	1	7 yr +/- 24m	3	183	147	131	263	214	201
339051	1	8 yr +/- 24m	3	216	153	136	294	210	202
339754	1	8 yr +/- 24m	3	192	148	135	.	206	.
363542	1	8 yr +/- 24m	3	177	.	130	239	183	185
363546	1	8 yr +/- 24m	3	198	.	.	283	188	.
378394	1	8 yr +/- 24m	3	.	.	.	235	198	196
345729	1	9 yr +/- 24m	3	206	162	147	317	252	.
378381	1	9 yr +/- 24m	3	182	152	138	241	191	190
339749	1	10 yr +/- 30m	3	243	182	171	346	294	259

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
363564	1	10 yr +/- 30m	3	.	.	134	273	.	.
342507	1	10 yr +/- 30m	3	.	.	.	312	241	240
345711	1	11 yr +/- 30m	3	.	.	149	323	268	241
363565	1	11 yr +/- 30m	3	206	.	.	331	247	.
363572	1	11 yr +/- 30m	3	224	.	137	291	228	214
379697	1	11 yr +/- 30m	3	180	153	139	254	199	198
378342	1	11 yr +/- 30m	3	225	188	170	312	249	238
345725	1	12 yr +/- 36m	3	230	166	146	338	271	254
345753	1	12 yr +/- 36m	3	230	168	155	315	241	231
351285	1	12 yr +/- 36m	3	233	195	179	365	262	.
365907	1	12 yr +/- 36m	3	199	167	150	.	.	.
377912	1	12 yr +/- 36m	3	232	.	173	.	.	.
378380	1	12 yr +/- 36m	3	232	196	168	321	243	242
378650	1	12 yr +/- 36m	3	218	167	160	310	244	215
381108	1	12 yr +/- 36m	3	234	194	171	319	256	250
381105	1	12 yr +/- 36m	3	225	192	174	317	252	250
363539	1	13.5 yr +/- 36m	3	224	.	162	354	264	251
378489	1	13.5 yr +/- 36m	3	263	217	.	358	296	294
345368	1	13.5 yr +/- 36m	3	.	.	.	327	258	.
363563	1	13.5 yr +/- 36m	3	240	.	165	335	.	.
377918	1	13.5 yr +/- 36m	3	200	171	157	292	233	227
345736	1	15 yr +/- 36m	1	.	237	211	421	335	325
363581	1	15 yr +/- 36m	1	286	205	185	404	301	.
363562	1	15 yr +/- 36m	1	295	224	198	383	322	305
351299	1	18 yr +/- 36m	1	323	247	221	.	.	.
363525	1	18 yr +/- 36m	1	.	.	.	405	.	.
342416	1	18 yr +/- 36m	1	309	241	208	426	.	.
342415	1	15 yr +/- 36m	2	267	.	179	383	314	276
345735	1	15 yr +/- 36m	2	274	205	.	383	308	269
345750	1	15 yr +/- 36m	2	243	188	167	378	297	258
345359	1	18 yr +/- 36m	2	277	219	198	390	306	274
345361	1	18 yr +/- 36m	2	269	215	195	378	292	281
378696	1	18 yr +/- 36m	2	296	236	212	408	321	309
379173	1	18 yr +/- 36m	2	.	.	.	362	314	272
363571	1	18 yr +/- 36m	2	.	.	.	398	298	.
351198	1	18 yr +/- 36m	2	270	.	.	401	315	299
377923	1	17-25 yrs	1	288	210	.	393	.	.
351305	1	17-25 yrs	1	.	.	.	376	.	.

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
378694	1	17-25 yrs	1	293	241	214	408	298	.
345316	1	17-25 yrs	1	284	228	210	401	326	317
363577	1	17-25 yrs	1	308	.	217	403	295	.
379713	1	17-25 yrs	1	302	251	231	451	370	350
332611	1	17-25 yrs	1	306	251	230	435	348	340
339124	1	17-25 yrs	1	305	247	225	421	340	336
345303	1	17-25 yrs	1	323	247	222	438	348	330
351201	1	17-25 yrs	1	328	.	.	416	.	.
363568	1	17-25 yrs	1	303	247	219	429	357	340
339062	1	17-25 yrs	2	.	.	.	353	274	.
345357	1	17-25 yrs	2	278	206	198	383	319	314
345721	1	17-25 yrs	2	292	224	205	389	311	310
363603	1	17-25 yrs	2	.	.	.	.	316	.
378369	1	17-25 yrs	2	260	211	.	.	.	.
378695	1	17-25 yrs	2	289	224	196	392	308	273
381091	1	17-25 yrs	2	276	.	.	380	306	296
363587	1	17-25 yrs	2	286	228	205	405	315	309
377752	1	17-25 yrs	2	293	239	225	405	335	329
345331	1	17-25 yrs	2	300	238	223	427	343	336
345306	1	17-25 yrs	2	272	211	194	378	304	294
339059	1	17-25 yrs	2	297	236	220	404	324	314
339032	1	17-25 yrs	2	276	215	199	380	306	295
345728	1	17-25 yrs	2	.	.	.	337	.	.
345743	1	17-25 yrs	2	280	223	197	391	304	268
342504	1	17-25 yrs	2	.	222	199	383	.	.
345394	1	17-25 yrs	2	279	229	210	354	301	287
345751	1	17-25 yrs	2	285	237	212	408	317	315
345302	1	20-30 yrs	1	318	247	228	432	352	347
345701	1	20-30 yrs	1	293	242	220	410	336	325
339120	1	20-30 yrs	1	296	230	210	414	310	310
345349	1	20-30 yrs	1	378	.	.	475	376	.
332503	1	25-35 yrs	1	296	265	242	.	.	329
332511	1	25-35 yrs	1	287	.	225	417	.	.
351215	1	25-35 yrs	1	.	.	235	433	.	.
332514	1	25-35 yrs	1	309	250	227	424	349	329
345310	1	25-35 yrs	1	305	235	212	413	339	330
345347	1	25-35 yrs	1	317	.	240	433	353	346
351289	1	25-35 yrs	1	296	253	229	423	330	313

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
332501	1	30-40 yrs	1	300	238	222	418	343	339
339750	1	30-40 yrs	1	307	.	.	413	347	340
17479	1	30-40 yrs	1	318	267	244	445	358	340
332507	1	30-40 yrs	1	315	248	227	430	353	340
333467	1	30-40 yrs	1	308	260	239	410	357	341
333468	1	30-40 yrs	1	302	253	227	430	345	332
339034	1	30-40 yrs	1	299	238	220	404	315	310
339119	1	30-40 yrs	1	.	233	219	425	331	315
339121	1	30-40 yrs	1	313	248	230	423	333	328
339123	1	30-40 yrs	1	280	230	211	393	305	294
345378	1	30-40 yrs	1	336	268	250	450	360	345
345738	1	30-40 yrs	1	274	237	217	398	298	290
351224	1	30-40 yrs	1	298	245	222	411	328	.
339061	1	20-30 yrs	2	290	228	202	393	323	308
345360	1	20-30 yrs	2	321	.	.	435	.	332
345391	1	20-30 yrs	2	311	248	228	384	313	.
345710	1	20-30 yrs	2	296	228	206	397	320	.
351207	1	20-30 yrs	2	298	.	.	405	324	.
332506	1	20-30 yrs	2	268	216	199	373	295	286
333471	1	20-30 yrs	2	281	236	202	408	333	327
339125	1	20-30 yrs	2	290	231	212	401	310	305
345300	1	20-30 yrs	2	287	236	213	403	330	329
345307	1	20-30 yrs	2	297	.	.	414	342	332
345745	1	20-30 yrs	2	293	238	217	393	313	312
351217	1	20-30 yrs	2	297	.	220	414	324	304
333470	1	25-35 yrs	2	288	226	206	397	323	313
339060	1	25-35 yrs	2	274	224	203	371	302	291
339116	1	25-35 yrs	2	281	215	196	397	308	302
345333	1	25-35 yrs	2	295	231	212	413	326	324
345383	1	25-35 yrs	2	298	246	226	427	330	320
345397	1	25-35 yrs	2	276	.	216	388	317	311
345703	1	25-35 yrs	2	277	211	191	385	294	290
339033	1	25-35 yrs	2	324	246	230	419	346	332
339114	1	25-35 yrs	2	284	221	203	411	327	316
345301	1	25-35 yrs	2	.	220	203	392	.	.
345312	1	25-35 yrs	2	292	229	210	407	318	310
345733	1	25-35 yrs	2	275	220	204	388	312	311
351200	1	25-35 yrs	2	.	.	.	361	272	.

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
351237	1	25-35 yrs	2	263	209	188	343	276	270
345330	1	25-35 yrs	2	289	222	.	406	334	.
332504	1	30-40 yrs	2	314	255	236	436	350	339
339031	1	30-40 yrs	2	292	232	213	407	316	311
342417	1	30-40 yrs	2	282	222	207	408	323	313
345309	1	30-40 yrs	2	295	231	211	399	317	311
345355	1	30-40 yrs	2	275	215	198	379	303	.
333472	1	30-40 yrs	2	292	.	210	415	334	318
342414	1	30-40 yrs	2	.	.	.	395	.	.
345304	1	30-40 yrs	2	319	257	234	433	343	335
345311	1	30-40 yrs	2	283	219	197	388	.	.
345343	1	30-40 yrs	2	275	216	195	390	305	296
345370	1	30-40 yrs	2	285	236	212	395	311	308
345702	1	30-40 yrs	2	310	229	209	439	360	345
345715	1	30-40 yrs	2	247	187	163	332	260	251
345754	1	30-40 yrs	2	290	235	213	417	318	308
351211	1	30-40 yrs	2	290	.	.	403	315	.
351225	1	30-40 yrs	2	.	.	.	374	292	289
351219	1	30-40 yrs	2	.	.	.	395	.	.
279202	1	40+ yrs	1	307	256	240	436	.	.
225255	1	40+ yrs	1	308	.	234	.	.	.
339058	1	40+ yrs	1	314	.	228	427	323	.
342482	1	40+ yrs	1	318	.	.	438	385	375
345334	1	40+ yrs	1	301	250	228	415	349	337
345348	1	40+ yrs	1	300	251	230	425	369	356
345731	1	40+ yrs	1	310	265	238	446	.	347
351204	1	40+ yrs	1	312	.	.	420	328	319
351226	1	40+ yrs	1	.	.	228	433	348	.
332502	1	40+ yrs	1	309	260	237	414	347	339
332512	1	40+ yrs	1	321	258	238	438	363	349
339118	1	40+ yrs	1	316	259	236	427	351	342
345400	1	40+ yrs	1	287	.	.	408	.	.
351220	1	40+ yrs	1	318	.	231	433	344	339
345388	1	40+ yrs	1	294	252	231	403	339	.
351202	1	40+ yrs	1	305	262	.	.	.	.
351199	1	40+ yrs	1	304	242	218	.	.	.
351203	1	40+ yrs	1	.	.	215	410	318	.
339115	1	40+ yrs	1	273	.	201	408	315	308

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
345308	1	40+ yrs	1	326	267	255	446	355	338
345351	1	40+ yrs	1	291	228	212	380	311	307
345369	1	40+ yrs	1	333	280	256	455	383	368
345379	1	40+ yrs	1	320	243	229	440	354	.
345707	1	40+ yrs	1	301	.	228	426	348	333
345724	1	40+ yrs	1	280	240	219	397	315	307
345730	1	40+ yrs	1	292	234	216	391	313	305
345739	1	40+ yrs	1	338	246	225	467	376	352
345744	1	40+ yrs	1	279	244	227	402	344	333
351205	1	40+ yrs	1	.	.	.	420	336	.
351208	1	40+ yrs	1	290	234	213	409	322	310
351212	1	40+ yrs	1	291	246	222	398	331	318
332505	1	40+ yrs	2	287	240	219	406	331	324
345337	1	40+ yrs	2	304	.	.	407	329	323
345366	1	40+ yrs	2	306	250	225	425	344	338
345384	1	40+ yrs	2	252	.	.	353	294	.
345395	1	40+ yrs	2	279	.	.	404	306	.
351213	1	40+ yrs	2	291	.	208	426	327	.
351236	1	40+ yrs	2	273	231	.	403	304	.
351347	1	40+ yrs	2	296	.	.	415	334	315
351218	1	40+ yrs	2	279	227	205	396	317	.
279204	1	40+ yrs	2	290	.	.	.	344	.
332508	1	40+ yrs	2	287	226	212	410	324	312
333469	1	40+ yrs	2	292	213	200	408	.	.
339751	1	40+ yrs	2	299	238	215	415	326	323
345727	1	40+ yrs	2	270	218	199	400	329	325
351221	1	40+ yrs	2	283	235	212	400	310	300
345390	1	40+ yrs	2	280	216	199	376	302	287
345752	1	40+ yrs	2	277	244	.	394	315	.
345313	1	40+ yrs	2	280	218	.	.	313	.
351214	1	40+ yrs	2	270	221	195	382	310	301
339117	1	40+ yrs	2	273	212	187	373	281	.
345315	1	40+ yrs	2	277	218	190	397	308	301
345341	1	40+ yrs	2	265	.	.	382	.	.
345373	1	40+ yrs	2	283	223	202	395	318	299
345377	1	40+ yrs	2	305	259	234	430	354	336
345392	1	40+ yrs	2	282	217	196	381	308	300
345396	1	40+ yrs	2	.	235	210	392	322	315

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
345719	1	40+ yrs	2	269	.	.	375	296	.
345742	1	40+ yrs	2	300	244	218	414	340	.
351197	1	40+ yrs	2	.	.	205	396	304	.
351234	1	40+ yrs	2	276	225	203	395	319	313
381403	2	birth +/- 2m	3	.	62	.	.	.	.
381447	2	birth +/- 2m	3	65	62	55	75	65	63
381448	2	birth +/- 2m	3	63	.	.	74	.	63
382733	2	birth +/- 2m	3	70	.	58	78	68	.
382957	2	birth +/- 2m	3	.	66	57	80	70	.
382963	2	birth +/- 2m	3	70	.	59	83	71	.
382966	2	birth +/- 2m	3	.	64	.	78	68	.
382987	2	birth +/- 2m	3	.	.	.	77	69	.
382989	2	birth +/- 2m	3	69	.	.	79	69	68
382992	2	birth +/- 2m	3	64	.	.	70	.	60
383059	2	birth +/- 2m	3	68	65	.	81	69	.
383109	2	birth +/- 2m	3	64	62	52	73	.	.
383110	2	birth +/- 2m	3	66	61	54	80	64	62
383134	2	birth +/- 2m	3	66	63	56	74	.	63
383168	2	birth +/- 2m	3	70	65	57	79	69	65
382908	2	birth +/- 2m	3	57	55	49	.	.	.
383169	2	birth +/- 2m	3	56	55	48	62	56	52
381461	2	birth +/- 2m	3	61	59	52	72	64	62
381639	2	birth +/- 2m	3	66	61	55	78	.	.
381647	2	birth +/- 2m	3	64	62	.	73	64	.
381650	2	birth +/- 2m	3	66	64	56	74	.	.
381720	2	birth +/- 2m	3	65	.	.	.	.	.
382725	2	birth +/- 2m	3	60	58	51	69	60	.
382998	2	birth +/- 2m	3	.	59	.	75	64	61
383037	2	birth +/- 2m	3	.	65	.	80	.	.
383147	2	birth +/- 2m	3	.	.	.	69	61	.
382730	2	3m +/- 3m	3	.	64	57	.	.	.
383060	2	3m +/- 3m	3	.	.	55	.	.	.
383084	2	3m +/- 3m	3	.	.	.	75	65	.
383099	2	3m +/- 3m	3	.	67	58	80	.	.
383111	2	3m +/- 3m	3	66	.	55	75	67	.
383114	2	3m +/- 3m	3	69	66	58	80	71	67
381433	2	3m +/- 3m	3	68	65	56	.	.	67
381468	2	3m +/- 3m	3	65	61	53	77	66	65

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
382952	2	3m +/- 3m	3	72	67	59	80	72	.
383028	2	3m +/- 3m	3	73	70	61	90	75	73
383083	2	3m +/- 3m	3	65	63	55	73	67	.
383105	2	3m +/- 3m	3	73	69	.	89	71	.
383115	2	3m +/- 3m	3	67	63	55	75	66	63
383140	2	3m +/- 3m	3	70	66	57	83	73	.
381409	2	6m +/- 3m	3	64	61	53	.	.	64
381361	2	6m +/- 3m	3	69	66	58	79	69	69
381324	2	6m +/- 3m	3	.	65	57	77	67	65
381331	2	6m +/- 3m	3	70	63	55	79	69	.
381364	2	6m +/- 3m	3	76	72	62	90	80	79
381416	2	6m +/- 3m	3	67	65	.	.	69	.
381424	2	6m +/- 3m	3	.	.	52	68	60	.
381426	2	6m +/- 3m	3	.	65	58	77	69	.
381427	2	6m +/- 3m	3	.	.	.	79	71	.
381460	2	6m +/- 3m	3	82	72	63	96	.	.
382695	2	6m +/- 3m	3	80	76	66	93	83	80
382697	2	6m +/- 3m	3	78	73	62	94	82	.
383024	2	6m +/- 3m	3	80	.	64	93	81	76
383042	2	6m +/- 3m	3	72	67	60	85	76	73
383081	2	6m +/- 3m	3	83	.	66	.	.	.
381406	2	6m +/- 3m	3	66	62	54	77	67	65
325413	2	9m +/- 3m	3	92	.	.	.	.	.
381436	2	9m +/- 3m	3	85	.	.	.	.	.
381446	2	9m +/- 3m	3	69	.	.	84	.	.
381466	2	9m +/- 3m	3	88	82	73	105	95	93
381467	2	9m +/- 3m	3	87	76	67	101	86	.
382902	2	9m +/- 3m	3	96	.	.	.	.	.
382970	2	9m +/- 3m	3	.	.	.	120	102	97
383031	2	9m +/- 3m	3	79	.	64	.	.	.
383064	2	9m +/- 3m	3	92	84	75	114	96	.
381325	2	1 yr +/- 4m	3	.	.	.	.	105	.
381335	2	1 yr +/- 4m	3	85	76	68	99	86	.
381368	2	1 yr +/- 4m	3	90	.	.	.	89	.
381419	2	1 yr +/- 4m	3	89	88	77	112	97	95
381439	2	1 yr +/- 4m	3	.	.	79	129	108	.
382927	2	1 yr +/- 4m	3	.	.	.	120	102	.
382930	2	1 yr +/- 4m	3	96	.	78	.	.	.

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
382937	2	1 yr +/- 4m	3	.	.	.	124	.	.
382960	2	1 yr +/- 4m	3	101	.	.	124	.	.
382988	2	1 yr +/- 4m	3	93	87	.	112	.	.
385946	2	1 yr +/- 4m	3	94	.	75	112	96	.
382892	2	1 yr +/- 4m	3	107	96	85	.	111	.
381334	2	1.5 yr +/- 6m	3	115	.	92	.	.	.
381370	2	1.5 yr +/- 6m	3	109	96	87	.	.	.
381408	2	1.5 yr +/- 6m	3	100	.	.	.	.	.
381434	2	1.5 yr +/- 6m	3	99	89	80	124	104	103
382700	2	1.5 yr +/- 6m	3	110	96	85	139	114	112
382718	2	1.5 yr +/- 6m	3	106	.	87	131	112	.
382870	2	1.5 yr +/- 6m	3	104	95	84	130	111	107
382893	2	1.5 yr +/- 6m	3	116	100	90	.	.	.
382899	2	1.5 yr +/- 6m	3	.	100	.	.	.	.
382984	2	1.5 yr +/- 6m	3	.	.	87	.	111	111
383066	2	1.5 yr +/- 6m	3	93	.	75	.	98	.
383175	2	1.5 yr +/- 6m	3	105	94	84	136	114	111
381444	2	2 yr +/- 8m	3	105	95	83	135	109	108
381664	2	2 yr +/- 8m	3	134	116	104	173	144	.
382716	2	2 yr +/- 8m	3	119	106	.	148	.	.
382743	2	2 yr +/- 8m	3	123	104	98	154	.	.
382756	2	2 yr +/- 8m	3	.	105	93	151	130	126
382928	2	2 yr +/- 8m	3	.	105	92	.	134	130
383017	2	2 yr +/- 8m	3	108	95	85	138	113	110
381387	2	3 yr +/- 12m	3	135	114	102	174	.	.
381659	2	3 yr +/- 12m	3	125	109	.	159	136	133
382671	2	3 yr +/- 12m	3	128	110	98	162	132	.
382685	2	3 yr +/- 12m	3	130	115	103	176	149	147
382727	2	3 yr +/- 12m	3	122	.	.	158	.	.
382936	2	3 yr +/- 12m	3	124	108	94	.	.	.
383043	2	3 yr +/- 12m	3	124	.	95	160	.	.
383091	2	3 yr +/- 12m	3	133	.	.	.	.	.
383096	2	3 yr +/- 12m	3	123	107	97	159	131	128
383139	2	3 yr +/- 12m	3	.	.	102	171	138	.
383142	2	3 yr +/- 12m	3	116	.	.	.	.	.
381181	2	3 yr +/- 12m	3	.	.	.	.	.	164
381462	2	4 yr +/- 12m	3	143	125	112	192	.	.
381340	2	4 yr +/- 12m	3	.	.	106	177	146	143

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
381687	2	4 yr +/- 12m	3	137	119	106	192	158	147
381719	2	4 yr +/- 12m	3	.	116	104	.	.	.
382668	2	4 yr +/- 12m	3	.	.	.	183	151	.
382729	2	4 yr +/- 12m	3	.	124	109	193	163	162
383143	2	4 yr +/- 12m	3	157	.	118	.	.	.
385947	2	4 yr +/- 12m	3	143	125	112	194	.	160
385951	2	4 yr +/- 12m	3	.	.	120	212	174	.
381349	2	5 yr +/- 16m	3	.	.	.	236	188	.
381445	2	5 yr +/- 16m	3	147	124	113	189	157	157
382675	2	5 yr +/- 16m	3	155	135	123	203	172	.
382708	2	5 yr +/- 16m	3	161	138	125	218	183	181
382721	2	5 yr +/- 16m	3	161	139	124	.	190	187
381418	2	5 yr +/- 16m	3	150	.	.	.	171	.
381425	2	5.5 yr +/- 20m	3	148	127	115	.	155	153
381366	2	6 yr +/- 24m	3	145	133	119	.	165	160
381380	2	6 yr +/- 24m	3	.	.	.	225	187	185
381394	2	6 yr +/- 24m	3	.	150	.	.	.	.
381440	2	6 yr +/- 24m	3	.	.	138	239	203	200
382698	2	6 yr +/- 24m	3	162	135	125	210	182	.
382754	2	6 yr +/- 24m	3	155	132	119	234	169	163
382996	2	6 yr +/- 24m	3	182	153	138	247	201	201
383107	2	6 yr +/- 24m	3	179	145	132	.	200	193
381455	2	7 yr +/- 24m	3	158	142	.	255	206	209
381658	2	7 yr +/- 24m	3	172	148	138	251	207	187
382666	2	7 yr +/- 24m	3	184	143	143	247	.	210
382696	2	7 yr +/- 24m	3	173	.	133	233	201	200
382705	2	7 yr +/- 24m	3	178	.	.	240	197	196
382751	2	7 yr +/- 24m	3	183	140	133	261	210	185
382867	2	7 yr +/- 24m	3	176	151	138	243	199	196
383113	2	7 yr +/- 24m	3	183	158	143	240	197	198
384819	2	7 yr +/- 24m	3	185	153	140	249	212	203
382749	2	7.5 yr +/- 24m	3	209	166	150	292	239	214
381465	2	8 yr +/- 24m	3	203	180	165	285	230	223
381680	2	8 yr +/- 24m	3	203	.	157	258	.	.
381686	2	8 yr +/- 24m	3	188	150	137	260	.	.
382689	2	8 yr +/- 24m	3	199	173	152	267	220	219
382709	2	8 yr +/- 24m	3	186	166	148	257	214	207
382726	2	8 yr +/- 24m	3	184	157	140	263	.	.

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
382728	2	8 yr +/- 24m	3	.	.	.	273	.	.
381213	2	9 yr +/- 24m	3	.	.	.	285	.	.
382929	2	9 yr +/- 24m	3	216	.	.	299	251	.
325402	2	9 yr +/- 24m	3	.	.	.	281	236	231
325344	2	10 yr +/- 30m	3	202	.	.	287	243	.
325401	2	10 yr +/- 30m	3	199	177	162	275	247	243
385948	2	10 yr +/- 30m	3	.	191	171	300	246	244
382744	2	11 yr +/- 30m	3	233	195	.	346	293	264
382757	2	11 yr +/- 30m	3	245	198	180	361	303	266
382965	2	11 yr +/- 30m	3	222	194	177	318	260	255
382667	2	11 yr +/- 30m	3	201	172	155	278	229	227
382717	2	12 yr +/- 36m	3	210	187	169	315	250	233
325403	2	12 yr +/- 36m	3	224	200	181	327	271	269
381327	2	12 yr +/- 36m	3	226	193	176	311	252	255
381338	2	13.5 yr +/- 36m	3	.	.	.	.	.	319
325406	2	13.5 yr +/- 36m	3	.	.	.	347	298	.
325407	2	13.5 yr +/- 36m	3	220	.	.	315	.	258
325343	2	13.5 yr +/- 36m	3	220	.	.	319	262	255
382982	2	13.5 yr +/- 36m	3	265	218	196	346	291	291
382701	2	15 yr +/- 36m	1	307	277	252	412	363	359
382993	2	15 yr +/- 36m	1	311	266	241	418	389	375
383138	2	15 yr +/- 36m	1	250	215	202	346	294	287
382968	2	18 yr +/- 36m	1	309	258	237	443	367	350
381668	2	15 yr +/- 36m	2	.	.	.	361	332	319
382674	2	15 yr +/- 36m	2	287	245	224	400	345	.
383067	2	15 yr +/- 36m	2	298	249	221	413	363	351
381411	2	15 yr +/- 36m	2	.	.	.	359	.	.
325346	2	15 yr +/- 36m	2	290	254	228	426	384	342
325359	2	18 yr +/- 36m	2	295	252	226	408	336	324
381367A	2	18 yr +/- 36m	2	271	228	207	386	341	299
325405	2	18 yr +/- 36m	2	238	.	188	348	277	274
381663	2	18 yr +/- 36m	2	278	234	216	401	337	329
381351	2	17-25 yrs	1	316	.	.	425	.	.
382707	2	17-25 yrs	1	277	238	219	404	342	335
383035	2	17-25 yrs	1	325	280	266	.	.	.
381378	2	17-25 yrs	1	.	.	.	.	350	.
383098	2	17-25 yrs	1	.	257	248	.	380	368
325336	2	17-25 yrs	1	325	268	245	449	371	.

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
325383	2	17-25 yrs	1	332	275	261	472	408	394
325385	2	17-25 yrs	1	328	267	248	458	401	385
382699	2	17-25 yrs	1	322	282	262	464	393	389
382746	2	17-25 yrs	1	340	275	262	472	399	394
382926	2	17-25 yrs	1	305	263	245	428	366	354
382659	2	17-25 yrs	2	293	.	224	417	351	342
315532	2	17-25 yrs	2	323	254	229	442	348	337
325352	2	17-25 yrs	2	306	260	237	430	365	338
325356	2	17-25 yrs	2	271	231	215	371	325	.
325386	2	17-25 yrs	2	300	255	239	427	361	351
325389	2	17-25 yrs	2	302	.	.	408	344	.
325394	2	17-25 yrs	2	289	245	217	414	342	338
381369	2	17-25 yrs	2	287	.	216	.	.	317
381652	2	17-25 yrs	2	285	.	.	396	334	.
381661	2	17-25 yrs	2	299	242	227	408	327	317
381666	2	17-25 yrs	2	.	.	.	425	349	.
382706	2	17-25 yrs	2	321	.	231	420	357	339
382748	2	17-25 yrs	2	.	.	.	428	344	336
382951	2	17-25 yrs	2	289	257	236	401	345	343
382967	2	17-25 yrs	2	308	261	230	410	367	350
383045	2	17-25 yrs	2	295	240	225	.	340	.
383170	2	17-25 yrs	2	296	253	230	408	345	344
315531	2	17-25 yrs	2	320	268	248	453	377	362
325338	2	17-25 yrs	2	303	262	237	438	368	350
325367	2	17-25 yrs	2	.	.	.	441	380	369
325370	2	17-25 yrs	2	299	255	235	425	367	360
325371	2	17-25 yrs	2	324	.	246	439	354	344
325373	2	17-25 yrs	2	300	.	237	419	365	354
325379	2	17-25 yrs	2	299	250	234	424	353	339
325392	2	17-25 yrs	2	294	251	232	412	347	332
381328	2	17-25 yrs	2	304	263	238	.	.	.
381332	2	17-25 yrs	2	.	.	.	415	366	.
381353	2	17-25 yrs	2	.	.	.	.	317	.
382722	2	17-25 yrs	2	295	253	235	417	360	352
382732	2	17-25 yrs	2	280	246	232	399	347	334
382946	2	17-25 yrs	2	307	.	.	.	333	.
383019	2	17-25 yrs	2	318	270	254	.	.	384
383101	2	17-25 yrs	2	290	.	230	417	352	335

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
325348	2	20-30 yrs	1	315	277	262	463	393	386
325363	2	20-30 yrs	1	318	273	256	437	380	372
325399	2	20-30 yrs	1	.	.	257	462	.	.
325425	2	20-30 yrs	1	329	.	.	.	.	.
380272	2	20-30 yrs	1	339	.	.	.	.	.
380273	2	20-30 yrs	1	336	265	.	.	.	.
381330	2	20-30 yrs	1	.	.	.	453	393	.
381341	2	20-30 yrs	1	307	265	243	436	372	.
381377	2	20-30 yrs	1	.	.	.	442	361	358
381442	2	20-30 yrs	1	302	.	235	415	345	332
382900	2	20-30 yrs	1	385	282	261	468	397	389
325351	2	25-35 yrs	1	316	259	239	439	368	359
325353	2	25-35 yrs	1	.	.	.	467	417	396
325375	2	25-35 yrs	1	332	276	258	457	376	375
381326	2	25-35 yrs	1	300	265	246	412	349	338
381354	2	25-35 yrs	1	316	270	254	428	389	366
381360	2	25-35 yrs	1	.	.	.	.	372	360
381397	2	25-35 yrs	1	306	.	.	428	.	.
381688	2	25-35 yrs	1	323	269	249	461	376	368
382686	2	25-35 yrs	1	325	275	254	448	388	374
383009	2	25-35 yrs	1	333	286	265	466	386	381
383026	2	25-35 yrs	1	323	272	260	.	.	.
383046	2	25-35 yrs	1	.	.	.	455	.	.
383128	2	25-35 yrs	1	330	.	.	.	.	.
383129	2	25-35 yrs	1	315	.	.	.	.	.
324739	2	30-40 yrs	1	346	301	276	476	419	399
325335	2	30-40 yrs	1	343	289	273	481	402	.
325341	2	30-40 yrs	1	337	288	270	454	413	407
325349	2	30-40 yrs	1	312	280	259	454	378	367
325364	2	30-40 yrs	1	305	.	242	457	368	358
325376	2	30-40 yrs	1	342	290	272	467	394	.
325395	2	30-40 yrs	1	310	288	259	425	.	343
381159	2	30-40 yrs	1	.	.	.	456	369	357
381339	2	30-40 yrs	1	325	.	253	463	385	372
381342	2	30-40 yrs	1	297	.	246	450	382	362
381344	2	30-40 yrs	1	317	266	248	441	375	371
381357	2	30-40 yrs	1	308	.	250	455	400	381
381379	2	30-40 yrs	1	326	269	254	.	.	371

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
381388	2	30-40 yrs	1	321	.	264	442	390	370
381389	2	30-40 yrs	1	.	.	.	462	382	.
381390	2	30-40 yrs	1	.	.	.	460	394	385
381392	2	30-40 yrs	1	321	.	.	455	.	.
381400	2	30-40 yrs	1	326	269	253	439	390	388
381452	2	30-40 yrs	1	341	286	267	455	402	393
382662	2	30-40 yrs	1	329	287	273	459	407	392
382950	2	30-40 yrs	1	320	275	254	443	379	369
382969	2	30-40 yrs	1	321	265	240	445	375	358
383102	2	30-40 yrs	1	318	272	254	.	371	360
383119	2	30-40 yrs	1	334	275	253	431	363	.
325400	2	20-30 yrs	2	294	.	.	426	.	.
325417	2	20-30 yrs	2	.	.	.	457	367	.
381352	2	20-30 yrs	2	286	259	235	.	.	.
381401	2	20-30 yrs	2	278	240	222	400	332	320
381428	2	20-30 yrs	2	304	.	229	416	352	346
381453	2	20-30 yrs	2	321	.	.	.	.	.
382670	2	20-30 yrs	2	278	239	222	404	340	329
382911	2	20-30 yrs	2	324	.	.	.	.	.
382945	2	20-30 yrs	2	.	.	.	398	.	.
383023	2	20-30 yrs	2	304	250	233	420	356	347
383034	2	20-30 yrs	2	291	242	226	393	343	336
383150	2	20-30 yrs	2	.	248	231	.	.	.
325354	2	25-35 yrs	2	311	250	230	460	387	373
381348	2	25-35 yrs	2	294	.	.	410	341	330
381374	2	25-35 yrs	2	.	.	.	428	351	.
381398	2	25-35 yrs	2	293	249	.	398	.	.
381429	2	25-35 yrs	2	.	268	250	455	.	.
381435	2	25-35 yrs	2	306	270	252	442	380	370
381450	2	25-35 yrs	2	279	241	223	398	.	341
381657	2	25-35 yrs	2	316	262	239	434	374	357
382665	2	25-35 yrs	2	286	255	233	407	342	334
383032	2	25-35 yrs	2	.	.	240	420	.	.
383057	2	25-35 yrs	2	316	269	253	452	369	354
325339	2	30-40 yrs	2	318	266	249	437	374	369
325342	2	30-40 yrs	2	287	.	.	.	.	.
325357	2	30-40 yrs	2	305	269	246	438	370	.
325358	2	30-40 yrs	2	291	249	.	400	338	329

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
325382	2	30-40 yrs	2	302	272	247	425	360	.
325393	2	30-40 yrs	2	308	265	243	417	358	355
381343	2	30-40 yrs	2	280	239	218	395	345	325
381383	2	30-40 yrs	2	293	.	.	.	.	.
381669	2	30-40 yrs	2	315	247	.	427	367	359
382661	2	30-40 yrs	2	289	247	228	411	343	340
382980	2	30-40 yrs	2	.	233	214	387	335	329
383086	2	30-40 yrs	2	281	247	223	409	336	330
383121	2	30-40 yrs	2	.	239	217	382	320	.
383141	2	30-40 yrs	2	284	259	237	419	349	342
384958	2	30-40 yrs	2	.	250	.	.	355	.
380642	2	40+ yrs	1	304	.	.	.	.	.
315533	2	40+ yrs	1	325	272	256	458	385	367
325334	2	40+ yrs	1	.	284	267	470	385	382
325362	2	40+ yrs	1	321	277	253	448	382	373
325366	2	40+ yrs	1	306	260	246	434	380	368
325369	2	40+ yrs	1	316	276	257	441	371	365
325372	2	40+ yrs	1	311	267	250	439	357	347
325377	2	40+ yrs	1	343	284	262	480	411	400
325378	2	40+ yrs	1	306	262	243	429	353	345
325381	2	40+ yrs	1	324	283	261	433	.	.
325388	2	40+ yrs	1	318	272	252	446	388	.
325390	2	40+ yrs	1	324	273	254	432	375	362
325391	2	40+ yrs	1	339	.	.	451	372	353
325396	2	40+ yrs	1	320	.	.	436	392	.
325397	2	40+ yrs	1	.	.	.	431	359	.
381384	2	40+ yrs	1	.	.	261	454	384	376
381404	2	40+ yrs	1	.	272	254	433	363	356
381407	2	40+ yrs	1	306	.	.	426	369	.
381410	2	40+ yrs	1	319	.	248	438	369	.
381417	2	40+ yrs	1	314	267	248	433	.	363
381422	2	40+ yrs	1	348	286	266	.	421	.
381423	2	40+ yrs	1	.	281	267	465	401	.
381438	2	40+ yrs	1	318	279	.	458	395	364
381443	2	40+ yrs	1	319	.	254	.	.	372
381451	2	40+ yrs	1	335	280	257	468	.	.
381454	2	40+ yrs	1	306	272	252	430	372	364
381469	2	40+ yrs	1	.	.	.	407	349	342

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
381651	2	40+ yrs	1	323	264	250	460	379	370
381689	2	40+ yrs	1	320	269	247	.	.	.
382669	2	40+ yrs	1	315	286	269	459	402	390
382673	2	40+ yrs	1	308	258	244	433	366	364
382678	2	40+ yrs	1	310	260	246	427	367	360
382710	2	40+ yrs	1	323	267	245	453	394	385
382719	2	40+ yrs	1	316	267	248	465	383	367
382745	2	40+ yrs	1	301	266	254	439	384	380
382747	2	40+ yrs	1	311	274	253	453	372	352
382901	2	40+ yrs	1	317	270	250	453	387	372
382913	2	40+ yrs	1	312	.	252	.	.	350
382990	2	40+ yrs	1	332	.	271	448	398	388
382991	2	40+ yrs	1	315	270	252	443	382	367
383027	2	40+ yrs	1	307	.	.	436	374	.
383033	2	40+ yrs	1	.	.	248	445	349	.
383058	2	40+ yrs	1	286	248	229	392	340	331
383108	2	40+ yrs	1	316	278	258	.	.	373
383116	2	40+ yrs	1	344	279	258	483	402	390
383127	2	40+ yrs	1	321	259	242	447	376	369
383144	2	40+ yrs	1	312	268	250	458	393	.
383151	2	40+ yrs	1	342	287	265	482	408	400
383171	2	40+ yrs	1	318	279	258	437	380	373
381449	2	40+ yrs	1	305	274	247	437	367	.
383069	2	40+ yrs	1	.	.	.	432	376	356
325360	2	40+ yrs	1	335	298	275	480	406	386
325365	2	40+ yrs	1	338	283	273	478	410	393
325374	2	40+ yrs	2	300	244	228	425	.	.
325387	2	40+ yrs	2	301	238	222	.	357	341
381160	2	40+ yrs	2	291	242	.	396	336	.
381386	2	40+ yrs	2	.	.	.	.	338	335
381430	2	40+ yrs	2	298	239	221	417	328	.
381431	2	40+ yrs	2	285	249	231	406	352	.
381656	2	40+ yrs	2	301	256	.	424	344	342
382723	2	40+ yrs	2	276	239	220	393	326	312
383011	2	40+ yrs	2	292	.	.	406	332	.
383016	2	40+ yrs	2	294	254	238	420	343	.
383118	2	40+ yrs	2	293	.	232	421	357	347
383145	2	40+ yrs	2	288	250	231	400	347	340

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
387825	2	40+ yrs	2	285	.	225	385	321	.
381458	2	40+ yrs	2	305	256	.	.	372	.
325380	2	40+ yrs	2	304	253	235	419	363	357
269235	3	birth +/- 2m	3	68	61	53	79	66	63
271951	3	birth +/- 2m	3	.	68	.	88	75	70
314348	3	birth +/- 2m	3	69	65	57	81	69	66
311.2	3	birth +/- 2m	3	63	60	52	76	65	62
47b	3	birth +/- 2m	3	66	63	54	77	67	64
609BC57	3	birth +/- 2m	3	67	63	54	79	69	67
Bu8900561	3	birth +/- 2m	3	.	.	.	77	69	.
314347	3	birth +/- 2m	3	63	63	55	74	67	65
609BC53	3	3m +/- 3m	3	65	61	54	76	66	64
327132	3	3m +/- 3m	3	70	63	56	84	73	70
327133	3	6m +/- 3m	3	85	77	69	108	88	87
381259	3	6m +/- 3m	3	80	74	64	99	.	.
601.1	3	6m +/- 3m	3	81	72	62	98	82	77
269216	3	9m +/- 3m	3	86	.	.	.	.	.
269218	3	9m +/- 3m	3	88	.	.	115	95	89
271950	3	9m +/- 3m	3	77	70	63	96	81	77
308758	3	9m +/- 3m	3	.	71	.	.	.	.
308759	3	9m +/- 3m	3	85	74	66	104	89	84
334053	3	9m +/- 3m	3	99	88	79	.	.	.
325	3	9m +/- 3m	3	79	.	.	103	85	.
6012	3	9m +/- 3m	3	81	73	65	101	80	.
311.1	3	9m +/- 3m	3	88	.	72	.	.	.
271947	3	1 yr +/- 4m	3	93	.	.	.	99	.
381253	3	1 yr +/- 4m	3	83	74	66	104	87	.
381261	3	1 yr +/- 4m	3	98	.	77	.	97	94
608Bg	3	1 yr +/- 4m	3	91	81	71	116	.	.
h11179	3	1 yr +/- 4m	3	85	78	.	103	85	82
h1028	3	1 yr +/- 4m	3	89	78	69	115	.	89
314336	3	1 yr +/- 4m	3	97	87	75	120	103	99
St1950b	3	1 yr +/- 4m	3	85	76	.	107	.	84
327138	3	1.5 yr +/- 6m	3	.	65	67	.	90	.
269234	3	1.5 yr +/- 6m	3	.	.	.	117	.	.
314341	3	1.5 yr +/- 6m	3	95	.	.	.	104	98
269236	3	1.5 yr +/- 6m	3	97	.	.	.	.	.
271939	3	1.5 yr +/- 6m	3	86	.	.	106	.	90

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
271943	3	1.5 yr +/- 6m	3	87	.	.	112	91	.
308697	3	1.5 yr +/- 6m	3	101	87	77	125	107	105
308760	3	1.5 yr +/- 6m	3	103	91	83	132	108	.
308766	3	1.5 yr +/- 6m	3	88	77	68	.	89	.
381260	3	1.5 yr +/- 6m	3	97	86	76	125	103	101
381263	3	1.5 yr +/- 6m	3	107	90	80	135	112	.
3225	3	1.5 yr +/- 6m	3	.	77	68	105	90	.
2012	3	1.5 yr +/- 6m	3	88	.	.	.	.	.
3228	3	1.5 yr +/- 6m	3	105	93	83	133	110	106
47a	3	1.5 yr +/- 6m	3	89	79	70	.	.	90
6022	3	1.5 yr +/- 6m	3	90	.	.	110	.	.
603BC57	3	1.5 yr +/- 6m	3	102	93	81	.	.	.
h1013	3	1.5 yr +/- 6m	3	86	74	65	.	.	.
h1041	3	1.5 yr +/- 6m	3	88	80	72	109	.	.
228980	3	1.5 yr +/- 6m	3	100	.	.	.	.	.
308763	3	2 yr +/- 8m	3	89	.	.	.	.	.
413	3	2 yr +/- 8m	3	110	98	86	136	116	.
601.2g	3	2 yr +/- 8m	3	104	89	81	130	110	.
602.1	3	2 yr +/- 8m	3	104	90	80	.	.	.
h11165	3	2 yr +/- 8m	3	.	105	94	.	.	.
h11177	3	2 yr +/- 8m	3	92	.	.	112	.	.
308757	3	2 yr +/- 8m	3	.	.	.	.	.	.
271929	3	2 yr +/- 8m	3	99	89	78	130	107	.
314338	3	2 yr +/- 8m	3	.	.	82	146	120	118
381274	3	2 yr +/- 8m	3	128	100	90	169	134	.
327131	3	2 yr +/- 8m	3	.	93	82	136	113	105
3211	3	2.5 yr +/- 10m	3	105	93	.	.	.	.
308698	3	2.5 yr +/- 10m	3	113	95	85	143	119	.
308764	3	2.5 yr +/- 10m	3	103	.	.	130	.	102
308765	3	2.5 yr +/- 10m	3	109	97	85	144	.	.
417	3	3 yr +/- 12m	3	112	100	89	148	125	122
43	3	3 yr +/- 12m	3	122	.	.	161	136	130
3229	3	3 yr +/- 12m	3	119	100	90	158	.	.
603b	3	3 yr +/- 12m	3	.	.	.	100	.	.
271938	3	3 yr +/- 12m	3	.	.	.	.	.	.
271953	3	3 yr +/- 12m	3	.	.	.	118	.	.
308762	3	3 yr +/- 12m	3	111	.	88	147	120	114
327103	3	3.5 yr +/- 12m	3	137	115	105	190	157	152

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
327104	3	3.5 yr +/- 12m	3	146	129	118	204	174	167
381258	3	3.5 yr +/- 12m	3	137	123	.	185	.	.
3111	3	4 yr +/- 12m	3	157	133	119	.	.	.
271849	3	4 yr +/- 12m	3	142	118	105	196	.	.
421	3	4 yr +/- 12m	3	124	107	96	169	142	139
604	3	4 yr +/- 12m	3	120	103	93	158	134	.
609Bg3	3	4 yr +/- 12m	3	131	108	99	169	137	.
h11164	3	4 yr +/- 12m	3	.	.	112	.	.	.
h11172	3	4 yr +/- 12m	3	145	124	.	.	.	.
h1015	3	4 yr +/- 12m	3	.	.	.	.	150	145
239505	3	4 yr +/- 12m	3	.	113	102	.	.	.
308696	3	4 yr +/- 12m	3	136	113	104	185	154	149
314339	3	4 yr +/- 12m	3	130	112	104	176	143	140
326194	3	4.5 yr +/- 12m	3	144	125	113	199	170	165
429c	3	5 yr +/- 16m	3	140	119	109	187	158	155
447	3	5 yr +/- 16m	3	.	.	.	212	173	.
h109	3	5 yr +/- 16m	3	151	.	115	207	172	169
269279	3	5 yr +/- 16m	3	.	.	.	170	139	.
3232	3	5.5 yr +/- 20m	3	162	.	.	.	.	.
327105	3	6 yr +/- 24m	3	177	151	139	253	206	205
432	3	6 yr +/- 24m	3	160	.	.	218	183	.
6048	3	6 yr +/- 24m	3	154	.	.	205	.	.
h11198	3	6 yr +/- 24m	3	159	.	.	.	.	.
269213	3	6 yr +/- 24m	3	182	.	.	.	.	.
327098	3	6 yr +/- 24m	3	157	137	.	215	186	181
262959	3	6.5 yr +/- 24m	3	142	122	110	190	156	158
308666	3	6.5 yr +/- 24m	3	167	147	131	235	.	.
Gal601	3	7 yr +/- 24m	3	186	154	140	.	.	205
271882	3	7 yr +/- 24m	3	158	.	.	221	.	.
308665	3	7.5 yr +/- 24m	3	189	159	142	264	217	209
263079	3	8 yr +/- 24m	3	.	.	170	246	.	.
h1056	3	8 yr +/- 24m	3	183	.	138	254	.	.
269221	3	8 yr +/- 24m	3	206	165	.	280	234	.
308686	3	8 yr +/- 24m	3	193	169	152	264	215	220
308694	3	8 yr +/- 24m	3	188	161	145	252	210	210
314299	3	8 yr +/- 24m	3	180	150	136	245	200	.
269251	3	8 yr +/- 24m	3	179	.	133	252	212	209
h103	3	8.5 yr +/- 24m	3	192	161	.	.	.	.

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
308700	3	8.5 yr +/- 24m	3	222	184	171	.	.	.
262967	3	9 yr +/- 24m	3	222	.	.	322	262	259
262950	3	10 yr +/- 30m	3	195	172	.	280	.	.
314314	3	10 yr +/- 30m	3	220	178	164	330	272	259
327127	3	9 yr +/- 24m	3	184	155	137	263	215	210
308611	3	11 yr +/- 30m	3	281	225	206	394	337	296
308667	3	11 yr +/- 30m	3	.	.	.	335	286	262
327097	3	11 yr +/- 30m	3	227	.	.	336	.	.
308614	3	12 yr +/- 36m	3	303	239	216	395	325	316
308607	3	12 yr +/- 36m	3	259	203	190	360	308	286
308635	3	12 yr +/- 36m	3	279	225	203	407	331	291
327102	3	12 yr +/- 36m	3	233	201	184	355	291	.
308709	3	13.5 yr +/- 36m	3	.	220	201	406	351	309
308613	3	15 yr +/- 36m	1	306	255	233	410	364	354
327140	3	15 yr +/- 36m	1	.	.	234	.	.	345
262978	3	15 yr +/- 36m	2	263	.	.	.	324	304
271811	3	15 yr +/- 36m	2	.	.	.	385	330	310
308628	3	15 yr +/- 36m	2	286	219	203	365	312	.
269290	3	15 yr +/- 36m	2	199	.	.	295	.	.
308669	3	15 yr +/- 36m	2	199	169	154	291	259	229
327130	3	15 yr +/- 36m	2	274	230	216	382	324	.
381243	3	15 yr +/- 36m	2	281	233	208	406	334	318
381265	3	15 yr +/- 36m	2	277	.	.	.	319	.
308638	3	17-25 yrs	1	298	249	.	436	366	.
262947	3	17-25 yrs	1	281	.	.	410	359	338
262971	3	17-25 yrs	1	312	232	212	418	352	325
h11192	3	17-25 yrs	1	320	.	.	.	371	354
239259	3	17-25 yrs	1	304	258	244	425	361	355
314301	3	17-25 yrs	1	321	269	250	441	381	.
239216	3	17-25 yrs	1	294	.	242	413	353	334
271805	3	17-25 yrs	1	301	246	232	416	351	339
308606	3	17-25 yrs	1	.	.	218	404	330	.
314277	3	17-25 yrs	1	307	257	235	415	348	343
269227	3	17-25 yrs	2	291	.	215	411	336	.
271820	3	17-25 yrs	2	.	.	.	364	299	.
262911	3	17-25 yrs	2	280	.	.	392	320	.
271804	3	17-25 yrs	2	.	.	.	408	340	.
269281	3	17-25 yrs	2	.	228	.	389	323	318

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
269299	3	17-25 yrs	2	.	218	.	385	324	316
269214	3	17-25 yrs	2	282	237	226	407	342	335
314309	3	17-25 yrs	2	284	224	208	400	318	.
308651	3	17-25 yrs	2	282	232	220	397	341	329
262912	3	20-30 yrs	1	305	.	240	436	372	.
262924	3	20-30 yrs	1	286	239	.	389	323	.
269232	3	20-30 yrs	1	285	.	.	369	.	.
271808	3	20-30 yrs	1	308	257	.	442	377	357
271815	3	20-30 yrs	1	305	248	225	419	340	330
308601	3	20-30 yrs	1	289	240	225	406	325	316
308626	3	20-30 yrs	1	301	265	251	453	376	358
314293	3	20-30 yrs	1	305	256	240	428	359	344
262923	3	25-35 yrs	1	312	263	243	432	377	362
308610	3	25-35 yrs	1	296	245	228	423	360	347
308619	3	25-35 yrs	1	303	248	231	413	351	347
308627	3	25-35 yrs	1	318	266	246	450	369	367
308634	3	25-35 yrs	1	320	268	249	445	380	375
314285	3	25-35 yrs	1	278	236	218	396	328	326
314319	3	25-35 yrs	1	308	257	245	428	357	356
308617	3	30-40 yrs	1	285	.	224	.	341	337
308620	3	30-40 yrs	1	295	249	232	.	.	.
308623	3	30-40 yrs	1	317	269	256	.	.	.
308676	3	30-40 yrs	1	.	257	.	414	363	352
308677	3	30-40 yrs	1	296	254	233	421	357	345
314286	3	30-40 yrs	1	299	266	243	431	371	357
314289	3	30-40 yrs	1	321	.	.	428	365	360
314300	3	30-40 yrs	1	309	.	.	426	364	350
314322	3	30-40 yrs	1	312	258	245	436	368	354
608BC57	3	30-40 yrs	1	325	280	257	452	381	357
J8388	3	30-40 yrs	1	.	.	.	420	355	.
239202	3	20-30 yrs	2	310	253	229	436	356	.
262910	3	20-30 yrs	2	.	.	215	386	327	316
262916	3	20-30 yrs	2	268	.	198	395	311	.
271812	3	20-30 yrs	2	285	.	.	.	345	.
271853	3	20-30 yrs	2	.	.	.	407	341	.
308615	3	20-30 yrs	2	278	244	225	397	343	336
308624	3	20-30 yrs	2	292	239	225	403	353	341
308642	3	20-30 yrs	2	283	241	224	415	343	331

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
308672	3	20-30 yrs	2	297	243	229	.	.	343
308679	3	20-30 yrs	2	268	230	215	392	324	.
308685	3	20-30 yrs	2	276	223	210	391	340	330
314282	3	20-30 yrs	2	293	246	225	409	344	329
314295	3	20-30 yrs	2	279	.	216	394	330	.
239209	3	25-35 yrs	2	263	223	.	379	324	314
239215	3	25-35 yrs	2	275	239	223	388	334	323
262915	3	25-35 yrs	2	279	.	214	396	.	.
271809	3	25-35 yrs	2	278	230	210	404	329	320
271816	3	25-35 yrs	2	283	231	211	423	348	334
308612	3	25-35 yrs	2	290	253	233	418	343	330
308618	3	25-35 yrs	2	295	239	223	407	329	318
308621	3	25-35 yrs	2	279	231	218	387	332	321
308633	3	25-35 yrs	2	291	218	209	383	320	307
308707	3	25-35 yrs	2	299	244	227	409	345	348
308708	3	25-35 yrs	2	286	234	.	.	.	.
314287	3	25-35 yrs	2	267	222	205	392	310	304
314321	3	25-35 yrs	2	275	209	195	388	306	.
603QBq	3	25-35 yrs	2	.	.	.	421	350	344
271806	3	25-35 yrs	2	274	227	216	.	.	.
308608	3	25-35 yrs	2	279	231	217	384	320	309
239203	3	30-40 yrs	2	290	238	222	404	336	324
239293	3	30-40 yrs	2	268	218	199	378	308	299
262909	3	30-40 yrs	2	261	.	201	384	320	302
269207	3	30-40 yrs	2	276	.	205	374	321	.
308654	3	30-40 yrs	2	281	237	217	393	338	.
308674	3	30-40 yrs	2	274	236	221	394	345	333
308675	3	30-40 yrs	2	280	221	212	386	308	288
308681	3	30-40 yrs	2	303	247	222	422	348	333
314283	3	30-40 yrs	2	290	244	225	405	336	326
314284	3	30-40 yrs	2	273	231	217	395	328	315
314302	3	30-40 yrs	2	281	230	209	387	323	314
314303	3	30-40 yrs	2	290	235	213	404	336	321
314305	3	30-40 yrs	2	272	.	203	377	310	.
314308	3	30-40 yrs	2	.	249	230	409	337	333
239207	3	40+ yrs	1	275	238	.	395	335	327
239208	3	40+ yrs	1	302	257	239	427	366	357
269210	3	40+ yrs	1	327	.	248	475	374	365

Table A-3. Continued

Individual	Population	Dental Age	Sex	humeri	ulnae	radii	femora	tibiae	fibulae
271851	3	40+ yrs	1	.	.	.	.	366	355
308602	3	40+ yrs	1	301	259	241	427	364	.
308603	3	40+ yrs	1	312	262	241	422	349	338
308645	3	40+ yrs	1	328	264	250	445	376	366
308683	3	40+ yrs	1	294	.	.	.	.	.
314307	3	40+ yrs	1	331	280	262	450	387	371
h1010	3	40+ yrs	1	312	254	241	438	365	351
308609	3	40+ yrs	1	325	272	251	457	381	.
269223	3	40+ yrs	2	284	235	.	404	334	.
239204	3	40+ yrs	2	287	247	228	382	348	334
239251	3	40+ yrs	2	.	.	.	398	334	323
262921	3	40+ yrs	2	286	.	224	410	330	319
269211	3	40+ yrs	2	296	234	217	430	350	.
271810	3	40+ yrs	2	272	224	205	387	315	301
271860	3	40+ yrs	2	.	.	.	400	.	.
308604	3	40+ yrs	2	281	.	.	392	332	326
308622	3	40+ yrs	2	281	229	206	395	319	.
308629	3	40+ yrs	2	315	253	235	420	353	351
308649	3	40+ yrs	2	290	.	220	403	343	.
308691	3	40+ yrs	2	271	219	204	374	.	.
314294	3	40+ yrs	2	276	227	209	388	327	313
314317	3	40+ yrs	2	267	228	209	382	331	.
314318	3	40+ yrs	2	298	252	233	405	342	336
h1050	3	40+ yrs	2	297	.	.	406	351	.
314310	3	40+ yrs	2	269	.	.	388	323	308

APPENDIX B
DENTAL DATA

Appendix B represents the raw dental inventories of each individual from which post-cranial data was also recorded. In the interest of space, this section is separated into two tables: Table B-5 and B-6; adult and juvenile dental data respectively. Given the progressive and fluid nature of human development, many individuals have dental data represented in both Table B-5 and B-6.

For both adults and juveniles, dentition was often found at varied stages of crown calcification, root formation and eruption. Stage of crown and root formation (indicate in text by an "S" followed by the stage number) follow the pattern and code of Moorrees et al. (1963a, b) described in Table B-1.

Table B-1. Stages of crown and root formation

Code	Stage
1	Initial cusp formation
2	Fusion of cusps
3	Cusp outline complete
4	Crown 1/2 complete
5	Crown 3/4 complete
6	Crown complete
7	Initial root formation
8	Initial cleft formation (for multi-root dentition)
9	Root 1/4 complete
10	Root 1/2 complete
11	Root 3/4 complete
12	Root length complete
13	Apex 1/2 closed
14	Apex closed - tooth/root complete

Throughout the course of data collection addition code became necessary to more fully describe dental progression or when crown/root assessment was not possible. These additional codes are illustrated in Table B-2.

Table B-2. Additional code for dental assessment

Code	Description
X	Present
EAS	Erupting - at alveolar surface/plane
ER	Erupting - 1/2 of crown visible above alveolar plane
AFE	Almost fully erupted - 3/4 crown visible above alveolar plane
U	Unerupted - visible below alveolar plane
R	Tooth not present - socket resorbed
L	Loose dentition

Adult Dental Data

The adult complement of dentition is represented by 32 permanent teeth. For both clinical and practical purposes teeth are assigned a numeric (1-32) to designate tooth's identity and position as seen in Table B-3 (e.g. Buikstra and Ubelaker, 1994). The adult dental data collected for this project, found in Table B-5, displays the tooth number (1-32) across the horizontal axis with the individual catalogue number down the left, vertical axis.

Table B-3. Permanent dentition

Right	M3	M2	M1	P2	P1	C	I2	I1	I1	I2	C	P1	P2	M1	M2	M3	Left
Maxillae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Mandible	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	

Juvenile Dental Data

The juvenile complement of dentition is represented by 20 deciduous teeth. As seen in the permanent, adult dentition the deciduous teeth are assigned a numeric (51-7) to designate tooth identity and position following Table B-4 (e.g. Buikstra and Ubelaker, 1994). The juvenile dental data collected for this project, found in Table B-6, displays the tooth number (51-70) across the horizontal axis with the individual catalogue number down the left, vertical axis.

Table B-4. Juvenile dentition

Right	m2	m1	c	i2	i1	i1	i2	c	m1	m2	Left
Maxillae	51	52	53	54	55	56	57	58	59	60	
Mandible	70	69	68	67	66	65	64	63	62	61	

Table B-5. Adult dental data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17479	X	X		X				X	X	X	X	X		X	X	X	X	X	X										X		
225255																		X	X	X		X	X	X		X		X	X	X	X	X
279202	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X			X	X	X	X	X	X				X	X	X	X	
279204		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X		X	X		X	X					X	X	X
279211			US5																											US5/6		
332501	X	X	X								X			X			X	X	X												X	X
332502	X	X	X	X	X	X					X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
332503	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
332504	X	X	X	X	X				X		X	X	X	X	X	X	X	X	X			X					X	X	X	X	X	X
332505	X	X	X	X	X								X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X
332506	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X							X	X	X	X	X
332507	X	X		X		X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
332508	X	X			X	X	X	X		X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
332511		X	X	X	X					X	X	X	X	X					X	X	X	X				X	X	X	X	X	X	X
332512	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
332514	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X				X				X	X	X	X	X	X
332611	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
333467					X				X	X		X	X	X	X	X															
333468		X	X		X	X		X									X	X	X												X	X
333469	X		X		X	X	X			X	X			X	X	X	X	X	X				X								X	X
333470		X	X			X							X	X	X			X	X		X	X						X	X	X	X	X
333471	X	X	X	X	X	X					X	X			X				X											X	X	
333472			X																				X				X					
339031			X		X			X						X	X		X		X			X							X	X	X	X
339032																														X		
339033	X	X	X	X	X									X	X																	
339034	X	X			X	X					X	X	X		X	X		X	X	X	X	X	X	X	X	X	X			X	X	
339051		US7	X											X	US7			U	X				X							X	U	
339058	X	X																X	X	X		X					X	X	X			
339059	X	X	X							X	X		X	X	X																	
339060			X											X				X	X												X	
339061	X	X	X	X										X	X	X	X	X	X	X											X	ER
339062		X	X	X									X	X					X							X				X		
339114		X	X	X	X	X	X	X				X	X	X	X	X	X	X	X		X	X	X	X		X	X		X	X	X	X	X
339115																			X	X	X	X						X		X		
339116		X	X	X	X	X					X	X	X	X		X	X	X	X	X	X					X	X	X	X	X	X	X	X

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
339117	X	X														X			X	X						X	X	X	X			
339118	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X
339119	X		X		X				X				X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
339120			X	X	X						X		X	X		X			X					X		X		X	X			
339121								X						X					X	X	X								X	X	X	X
339123	X		X							X	X	X		X			X		X	X	X		X	X	X	X	X	X	X	X	
339124		X	X	X		X		X	X		X	X	X	X	X		X	X	X	X	X	X	X				X	X	X	X	X	
339125	X		X	X		X					X	X	X		X	X		X	X	X	X	X					X	X	X	X	X	
339749		EAS	X											X	U	US4		EAS	X			ER	AFE	X								
339750	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
339751	X	X	X	X	X	X					X	X		X	X	X	X	X				X	X	X		X	X	X	X	X	X	X
339754		U	X				EAS							X	U			US5								X				X		
342414	X	X	X			X								X	X	X															
342415	U	X	X	X										X	X	U																
342416		X	X	X	X	X	X			X	X	X		X	X		S11/12		X	X	X		X	X	X	X	X	X	X	X	X	X
342417		X		X	X	X					X	X	X									X						X			X
342482	X		X	X	X	X	X				X	X	X	X	X	X																
342504	X	X	X											X			X	X	X	X							X		X	X	X
342507	US4/5													X		US4/5								X			X					
342513			US5/6											U					U										U			
345300	X	X	X	X	X	X				X	X	X		X	X	X	X	X	X	X	X	X					X	X	X		X	X
345301	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
345302	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	AFE	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
345303	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
345304		X	X			X	X			X							X	X	X	X	X	X					X	X	X	X	X
345306	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X					X	X	X	X	X	
345307	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
345308				X		X							X						X		X	X	X				X	X	X	X	X	
345309	X			X	X	X					X	X		X	X	X		X	X		X	X				X	X	X	X	X		X
345310	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X			X	X				X		X	X	X	X
345311	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
345312		X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	
345313	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
345315	X	X															X	X	X	X	X	X	X				X					
345316	X	X	X			X				X				X	X	X	X	X	X		X	X				X				X	X	X
345330		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X							X	X	

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
345331		X	X		X	X								X	X			X	X													
345333		X	X	X		X					X	X	X	X	X	X	X	X	X		X	X				X	X	X	X	X	X
345334																			X	X	X	X	X				X	X	X	X		
345337		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
345339			US4											US4																		
345341																		X	X	X	X	X	X				X		X	X	X	
345343	X	X	X	X	X	X		X			X		X	X	X		X	X	X	X	X	X	X		X		X	X	X	X		X
345347	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X
345348	X	X															X	X	X	X									X	X	X	X
345349																			X		X	X	X			X	X	X		X	X	X
345351													X	X	X						X	X	X				X	X				
345355	X	X	X		X						X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
345357	ER	X	X	X	X	X	X		X	X	X		X	X	X	ER	ER	X	X	X	X	X	X			X	X			X	X	ER
345358																		US5													US5	
345359				X	X					X	X	X	X	X	X	X	ER	X	X											X	X	EAS
345360	X	X	X	X	X	X					X		X	X	X	X	X	X	X	X	X	X			X	X	X		X		X	X
345361		X	X	X		X		X	X			X	X	X	X		ER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
345365		US5	ER											EAS				U	EAS											EAS	U	
345366		X	X	X		X		X									X	X	X	X	X	X	X	X			X	X	X	X	X	
345368	U	X	X	X	X	X								X	X	U	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
345369	X															X	X	X	X	X	X	X				X	X	X	X	X	X	
345370				X		X	X			X	X	X	X	X			X		X	X	X	X	X				X	X		X	X	X
345373	X	X		X	X		X				X		X	X		X	X		X	X		X			X	X	X		X	X	X
345375			EAS											EAS				US4	U											U	US4	
345376			U											U					U											U	US4	
345377		X	X	X	X	X	X				X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
345378			X	X	X					X		X	X	X	X		X	X	X	X	X				X	X	X	X	X	X	X	X
345379					X	X				X		X	X	X		X	X	X		X			X		X			X	X		X	
345383		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X
345384		X									X	X	X				X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
345386			US5																US4/5											US4/5		
345388															X	X			X	X	X	X	X		X	X	X	X	X	X	X	
345390		X	X	X	X	X					X	X				X		X	X	X	X	X					X		X			
345391	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X			X				X		
345392	X			X		X										X	X	X	X	X	X	X	X		X	X	X	X	X	X		X
345394	X		X	X	X	X			X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
345395	X	X	X	X	X	X				X	X		X	X	X		X	X	X			X		X		X	X	X		X	X	X
345396																		X	X	X	X	X	X	X	X	X	X			X		
345397	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X				X		X	X	X	X	X	X
345400		X	X		X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X		X	X	X	X	X	X	X	
345701	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X		X	X	X	X	X	X
345702	X	X	X								X	X	X	X																X	X	X
345703	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
345707		X	X												X	X						X						X				
345708			EAS											EAS					US8											U		
345710	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X
345711	U		X	AFE										X	X	U	U	X	X	X	X	X				X	X	X		X	X	U
345715	X	X	X	X	X	X	X		X		X	X	X	X	X	X		X	X	X	X	X						X	X	X	X	
345719	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X				X		X	X	X	X
345721		X	X					X			X		X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
345724	X			X		X		X	X		X	X		X	X	X			X	X	X	X	X	X	X	X	X	X	X	X		
345725		X	X	ER	X	X	X			X			X	X	X			X	X	X		X	X	X		X	X	X	ER	X	X	
345726			ER											ER				US4	U										U	US4		
345727	X	X	X	X	X	X		X		X	X	X	X	X	X			X	X		X	X	X	X	X		X			X	X	
345728	X	X	X	X										X	X	ER													X	X	X	X
345729		U	X									ER		X	U			U	X				X	X	X	X				X		
345730		X	X	X									X	X	X				X	X	X	X	X				X	X	X	X	X	X
345731	X	X	X	X	X	X					X	X		X	X	X	X		X	X	X	X	X	X		X	X	X	X	X		X
345733																		X	X		X	X								X	X	X
345735	US8/9	X	X	X	X	X					X	X	X	X	X	U	U	AFE	X		X	X	X		X	X	X	X	X	X	X	US8
345736	U	X	X						X		X		X	X	X	U		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
345738	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X	X	X	X		
345739				X	X		X			X		X	X					X	X	X	X	X	X				X	X	X	X	X	
345742	X	X	X		X						X	X	X	X	X			X	X	X	X	X	X		X	X	X	X	X	X	X	
345743	X	X	X	X						X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X	X	X	
345744	X	X									X	X	X		X	X	X	X	X	X		X	X						X	X	X	X
345745		X	X		X	X		X			X	X		X	X			X	X			X	X				X	X	X	X	X	
345750	EAS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U	U	X	X	X		X	X	X	X		X	X	X	X	X	U
345751	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X			X					X	X	X	X	X	X
345752								R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	X				
345753																	US4/5		X		X	X	X		X	X	X			X	X	U
345754						X					X						X		X			X			X		X	X	X	X	X	

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
351197	X	X	X	X	X									X	X			X				X					X			X	X	
351198		X	X	X	X	X		X		X	X	X		X	X	EAS	EAS	X	X	X	X	X		X			X	X		X	X	EAS
351199																	X	X		X		X	X	X	X	X	X	X		X	X	X
351200	X	X	X	X	X	X					X	X	X	X	X		X	X	X	X	X	X				X	X		X	X	X	X
351201			X	X		X					X		X	X	X		X	X	X	X		X							X	X	X	
351202	X	X	X	X													X	X	X	X	X	X		X		X	X	X				
351203		X																									X	X	X	X	X	
351204																		X	X	X	X		X	X	X	X	X	X	X	X		
351205	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X		X						X	X	X	X	X	X
351207		X	X		X						X	X	X	X	X		X		X											X	X	
351208	R	R	R	R	R	X	R	R	R	R	X	R	R	R	X	R			X	X	X	X	X	X	X	X	X		X	X	X	X
351211	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X
351212	X	X	X	X	X	X					X	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
351213	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
351214	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	X	R	R	R	R	X	X	X	X	R	X	X	X	X	R	R	R
351215		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
351217	X	X	X	X	X	X		X	X		X		X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	
351218	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
351219												X	X	X	X	X		X	X	X	X	X			X	X	X	X				
351220		X	X	X	X						X		X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
351221	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
351224	X	X	X	X	X	X	X				X	X	X	X	X		X	X	X		X	X	X	X			X		X	X	X	X
351225	X	X	X	X	X	X	X				X	X	X	X	X		X	X	X	X	X		X				X			X	X	X
351226																	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
351228		US5	X					ER	ER	EAS				X	U			U	X				ER			ER				X	U	
351229			X											X					X				EAS	ER	ER	EAS				X		
351234				X	X							X				X	X	X	X	X		X	X				X	X	X	X	X	X
351236	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X							X	X	X	X
351237	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
351285	US4/5	X	X	X	X	X						X	X	X	X	U		X	X					X	X	X	X	X		X	X	
351286																																
351289	X	X	X	X	X	X	X				X	X	X		X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X
351299	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X											
351305	EAS	X	X		X	X			X	X	X		X	X	X	ER	ER	X	X			X					X	X	X	X	X	ER
351323			ER											X				US5	ER						ER					ER		
351325			EAS											ER					EAS											EAS	US4/5	

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
363525	ER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	LS11	ER	X	X	X	X	X	X	X			X	X	X	X	X	ER
363536			EAS											EAS					U											U		
363537			U											U					U											U		
363539	U	X	X	X								X	X	X	X	U																
363542		U	X											X	U			U	X											X	U	
363543			U											U					U											U		
363544			EAS											EAS					U											U		
363546		U	X											X	U			U	X			U	X	X	X	ER				X	U	
363562		X	X	X	X	X	X	X	X	X	X	X	X	X	X		ER	X	X	X	X	X	X		X	X	X	X	X	X	X	ER
363563	U		X		X	X	X	X	X		X	X		X		U	U	X	X	X	X	X	X	X	X	X	X	X		X	X	U
363564		EAS	X			U					U	EAS		X				U	X		U	ER	X	X	X	AFE	ER	U		X	EAS	
363565	US6	ER	X			ER	X	X	X	X	AFE			X	ER	U		X	X		AFE	AFE	X	X	X	X	AFE	AFE		X	X	U
363566			U											U					U											U		
363568	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
363571	EAS	X	X	X	X	X	X			X	X	X	X	X	X	U	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	EAS
363572		AFE	X		X	AFE	X	X	X	X	ER	X		X	X			X	X	ERA	X	AFE	X	X	X	X	AFE	AFE	XA	X	X	
363577		X	X	X	X		X		X	X		X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
363581	ER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ER	ER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ER
363587	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
363601														U					U											US4		
363602			U											U					U											U		
363603	AFE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	AFE	AFE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	AFE
365907	U	X	X	X	X	AFE	X	X		X	ER		X	X	X		U	X	X	X	X	X			X	X			X	X	X	U
377752		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
377822			U											U					U											U		
377823			US6/7											U					U											U		
377824			ER											ER																		
377912		AFE	X	X	X								X	X	X			X	X	X	X							X	X	X	X	
377918	U	X	X	X	X	X	X				X	X	X	X	X	U	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
377923	X	X	X			X	X	X	X	X	X	X	X	X	X	X																
378342	U	X	X											X	X	U	X			EAS										X		
378369	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
378379		US5												ER	US6			U	ER												U	
378380	U	X	X	X						X	X	X	X	X	X	U	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
378381		U	X						X					X	U			U				ER								X	U	
378382		U	X															U	X											X	U	

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
378383		US6/7	X											X	U				X					EAS	EAS						X	
378384																		US4	EAS													
378394			X			U					U	U		X	U												U				U	
378434			US5																													
378489	U	X	X								X			X	X	U																
378492			U											U					U											U		
378494			U											U					U											U		
378496			U											U					U											U		
378650																	U		X	X	X									X	X	U
378694	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X
378695	X	X	X	X	X	X		X	X				X	X	X	X	X	X	X									X	X	X	X	X	X
378696	LS10	X	X	X	X	X	X			X	X	X	X	X	X	LS8																	
379173	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ERS1(	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
379697				EAS										X			U									X	AFE					
379713			X	XX	X			X					X	X			X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
379716			U											U					U											U		
381091	X	X	X										X	X	X	X		X	X											X		
381105	US5/(	X	X	AFE	X						X	X		X	X	U	US5	X	X	AFE	X	X	X	X	X	X	X	X	X	X	X	US5
381108	U	LS10	X											X		U	U		X													U
345759x			X					ER	U					X				U	X					X	X	ER				X	U	
315531				X	X					X		X	X	X	X																	
315532	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
315533	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
324739			X	X	X	X			X	X	X		X	X	X	R					X	X	X	X	X	X	X		X	X	X	X
325335	X		X	X	X		X	X	X	X	X	X	X	R	X	R		X	X	X	X	X	X	X		X	X	X	X		X	X
325336	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X			X	X	X			X	X	X	X	X	X
325338	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325339	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
325341	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325342		X	X	X	X	X	X			R	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	
325343	U	X	X	X	X	X	X		X	X	X	X	X	X	X	U	U	X	X	X	X	X	X	X	X		X	X	X	X	X	U
325344																	U					EAS	X		X		EAS					
325346	U	X	X	X	X	X		X	X	X		X		X			U	X	X	X	X	X	X	X	X	X	X	X		X		U
325348	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X			X		X	X	X	X	X
325349	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
325351	X	X	X	X	X		X		X		X	X	X	X	X		X	X	X	X	X				X	X	X	X	X	X	X	X

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
325352	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325353	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325354			X	X	X	X					X			X	X		X	X	X												X	X
325356	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325357	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
325358	R	R	X		X	X	X	X	X	X	X	X	X	R	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
325359		X	X	X	X	X	X			X	X	X	X	X	X	ER		X		X	X	X	X	X	X	X	X	X	X	X	X	
325360	X	R	R	X		X					X	X	X	X	X	X	R	X	X		X	X	X		X	X	X	X	X	X	X	R
325362	R	R	R	X	X	X	X	X	X	X	X	X	X	X	R	R	X	X	R	X	X	X	X	X	X	X	X	X	X	R	X	X
325363	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325364		X	X	X	X	X	X	R	R		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
325365	X	X	R	R	R	X	X	R	R				X	R	X	X	Xc	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325366	R	R	X	X	X			X	X	X	X	R	R	X	X	X	X	X	R	X	X	X	X	X	X	X	X	X	X	X	X	X
325367	X	X	X	X	X	X				X	X			X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X
325369	X	X	X	X	X	X	X	X	X		X	R		R	X	X	R	R	X	X	X	X				X	X	X	X	X	R	X
325370	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325371	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X			X	X
325372	R	R	R	X	X	X	X			X				X	X	X	X	R	R	X	X	X	X	X	X	X	X	X	X	R	X	X
325373		X	X	X	X	X	X	X	X	X	X	X	X	X	X		ER		X	X	X	X			X	X	X	X	X	X	X	ER
325374	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
325375		X	X	X	X	X	X	X		X			X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
325376	X	X	X	X	X	X	X	X	R	R	R	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
325377	R	X	X	X	X	X	X	X	X	X	X	X	X	X	X	R	R	X	X	X	X	X	X		X	X	X	X	X	X	X	R
325379	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X
325380						X					X																					
325381		X	R			X	X	X	X		X		R	X	X	R	X	X	X	X	X			X			X	X		X	X	X
325382	R	R	R		X	X	X	R	R		X	X	X	R	R	R	R	R	R	R	X						X	X	X	X	X	X
325383	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
325385	R	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X
325386	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325387						X											R	R	X	X	X	X	R	R	R	R	R	R	R	R	R	R
325388	R	R	R	X		X	R	X	R	R	R	R	R	R	R	R	X	R	R	R	X	X	X	X	X	X	X	X	R	R	X	X
325389		X	X						X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X			X	X	
325390		X	X	X	X	X	X	X		X	X	X		X	X		X	X	X		X	X	X		X	X				X	X	X
325391		X	X	X	X						X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X		X
325392	R	X	X	X	X	X				X		X	X	X	X	R	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
325393		R	X		X	X	X	X	X	X	X	X	X	X	R	X		X	X	X	X	X	X	X		X	X	X	X	X	X	
325394	X	X	X	X	X	X	X				X	X	X	X	X		X	X	X	X	X				X	X	X	X	X	X	X	X
325395	X	X	X	X	X	X			X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325396	X	X	X	X	X	X	X	R	R	X	X	X	X	R	R	R	R	R	X	X	X	X	X		X	X	X		X	R	R	R
325397	R	X	X	X	X	X					X	X	R	R	R	R	X	X	X	X		X	X		X	X		X	R	R	R	X
325399	X	X	X	X	X	X	X	X		X		X		X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
325400			X											X														X				
325401		EAS	X				X	X	X	X	U			X	EAS			EAS	X			U	X	X	X	X	EAS			X	EAS	
325402		U	X		U	U											US4	U	X												LS8	
325403	U	X	X	X	X	X	X	X	X	X	X		ERS1(	X	X	U		X	X		X	X	X	X	X	X	X	X		X	X	
325405		X	X		X	X	X	X			X	X	X	X	X	U	U	X	X	X	X		X		X	X			X	X	X	U
325406		X	X	X	X	X					X		X	X	X			X	X	X		X	X	X	X	X	X	X	X		X	US6
325407	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U	U	X	X					X	X	X		X		X	X	U
325413																			US4											U		
325417			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X		X	X	X	X	X	X
325425		X	X	X	X	X						X	X	X	X		X	X	X	X			X	X		X	X	X	X	X	X
380272	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
380273	X	X	X			X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
380642	X			X	X	X				X	X	X	R	R	R	R																
381159			X	X	X							X	X	X	X		X	X	X	X										X	X	X
381160	R		R	R	R								R	R	R	R														U		
381181																			U											U		
381213																						U			X	X	U			X	U	
381326	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	
381327		X	X	X	X	X		X	X	X	X	X	X	X	X	U	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
381328	X	X	X	X	X	X	X			X	X	X	X	X	X			X	X	X	X	X		X	X		X	X	X	X	X	X
381330		X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
381332	X	X	X					X						X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X
381335																														U		
381338	U	S12/1	X			X		LS13			X	X	X	X	X		U		X	X	X	X	X	X	X	X	X	X	X	X	X	U
381339	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Xc	X	X	X	X		X	X	X	X	X	X	X	X
381340														U																U		
381341	X	X	X	X	X	X	X	X	X		X	X		R	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381342	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381343	X	X	X		X	X			X	X		X		X	X		X	X	X	X	X	X	X	X			X	X	X	X	X	X
381344	X	X	X	X	X	X	R				X	X	X	R	X	R	X	X	X				X	X	X	X	X	X	X	X	R	R

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
381348	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X		X	X		X	X	X	X	X	X		X	X	X	X
381349			AFE				EASS	LS7	LS7	LS7				LS9/10					AFE					LS10	LS10					X		
381351	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X
381352	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381353		X	Xc		X	X	X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381354	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
381357	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381360		X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X
381366		U	EAS											EAS	US5			U	EAS											EAS	U	
381368																			U											U		
381369	X	X	X		X	X					X		X	X	X	X		X	X						X			X	X	X		X
381374	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381377		X	X	X	X	X	X	X			X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	
381378	L	X	L	L		X	X	X	X	X	X	X	L	L	L		L	L									X	X		L	X	L
381379	X	X	X		X	X		X	X	X	X	X	X	X	X		X		X	X	X	X	X			X		X		X	X	
381380		LS9	LS9		US6/7	US7								LS9	LS6				U					U	U					LS9/1	LS6	
381383			X	X	X	X				X	X	X	X	X	X		X	X	X	X	X	X	X			X	X	X	X	X	X	X
381384		X	X	X	X	X					X	X	X	X	X		X	X	X	X	X					X	X	X	X	X	X	X
381386						X							X	X	X	X		X	X	X	X	X	X			X	X	X	X	X	X	X
381387			U											U					U											U		
381388		X		X	X	X	X	X	X	X	X	X	R	R	X		X	X	X		X	X	X	X	X		X	X	X	X	X	X
381389	R	X	X	X	X	X						X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X
381390	X	X	R			X	X	X	X	X	X	X	X	X	X	X	X	X	Xc	X	X	X	X	X	X	X	X	X	X	X	X	X
381392			X	X	X	X		R	R	X	X	X	X	X	X		X	X	X	X	X	X	X			X	X	X	X	X	X	X
381394			X			LS9		LS9	LS9		LS9			X					XS10				U			U						
381397	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381398	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381400	R	X	X	X	X	X	X		X			X	X	X	X	R	X	X	X			X				X		X	X	X	X	X
381401	X	X	X	X	X	X						X	X	X	X		X	X	X	X	X	X	X			X	X	X	X	X	X	X
381404	R	R	R	X	R	R	R	R	R	R	X	R	R	R	R	R	R	R	R		R	X			X		X	R	X	R	R	R
381406																														LS4		
381407		X	X	X	X		X	X	X	X	X	X	X	X	X		R	R	R	X	X	X	X	X	X	X	X	X	X	X		
381408			US4/5																U											U		
381410	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381411																	U		X	X	X	X	X	X	X	X	X	X	X	X	X	
381417	X	R	R					X			Xc	X	X	R	R	R	X	X	X	X	X		R	R	R	R			R	R	R	R

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
381418		XS5	X																					EAS	EAS							
381419																			LS8													
381422	R	R	R	X	R	R	R	R	R	R	R	R	R	R	R	R	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381423	R	R	R	R	R	R	R	R	R	R	X	X	X				R	R	R	R	X	X	X	X	X	X	X	X	X	X	X	R
381424			XS4																XS4													
381425																			EAS											EAS		
381428		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	R	R	X	X	X	X	X	X	X	X		X	R	R	X
381429	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X				X	X	X	X	X
381430	X	R	X		X												X	X	X							X	X			X	X	X
381431			X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X					X					X
381434			U											U					U					U	U				U		
381435	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381436																																
381438	R	R	R	X	X	X		X	X	R	X		R	R	R	R	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
381439														U					U													
381440		LS6	LS10											LS10	LS6			LS6	L10										X	LS6		
381442		X	X	X	X	X		X		X	X	X	X		X	X	X	X	X	X	X	X	X	X		X		X		X	X	X
381443	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R	R		R	R	R	R	R
381444			U											U					U											U		
381445			ER											ER	U				LS9											LS9		
381449	R	R	R	R	R	R	R	R	R	R	X	X	X	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
381450	X	X	X	X	X	X	X	R	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	R	X	X
381451	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	X	R	R		X	X	X	R	R	X	X	X	X	R	R	R
381452	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X
381453	X	X	X	X	X	X	X	X	X		X	X	X							X	X	X	X	X	X	X	X	X	X	X	X	X
381454	R	R	R	X	R	R	X	R	R		X	R	R	R	R	R			X	X	X	X	X	X	X	X	X	X	X	X	X	
381455		U	X				U		ERS1(	U				X	US7				XS11				LS11	LS11	LS11	LS11			LS11		
381458	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	X	R	R	X	R	R	R	R	R	R	R	X	R	R	R	R
381462			EAS											U				U	U											US7		
381465		U	X			U		X	X	X				X	U			U	X				X	X	X	X				X	U	
381466																			US3/4											US3/4		
381469	R	R	R	R	R	X							R	R	R	R	X	R	R	R	X	X	X	X	X	X	X	X	X	X	R	R
381651		X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381652	X	X	X	X		X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381656			R	R	X	X	X				X	X	X	R	R		X	X	X	X	X	X	X			X	X	X	X	X	X	X
381657	X	X	X	X	X	X	X	X	X	X	X	X	R	X	X	X		X	X	X	X		X	X	X	X	X		X	X	X	X

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
381658		U	X											X	U			U	X						X					X	U	
381659			U											U					U											U		
381661	X	X	X		X		X		X	X		X	X	X	X	X	X	X	X	X										X		X
381663		X	X		X	X	X			X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X		X	X	
381664			U											U					U											U		
381666		X	X		X	X								X	X	X	X	X	X	X	X	X	X	X				X	X	X		
381668	U	X	X	X	X		X			X	X	X	X	X		U		X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
381669		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
381680		U	X											X	U				X											X		
381686		U	X					ER	EAS					X	EAS			U	X				X	X	X	AFE				X	U	
381687			U											U				US4	U											U	US4	
381688	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
381689	R	R	R	X	R	R		R	R	X	R	X			R	R	R	R	R	X	X	X	X	X	X	X		X	X	R	R	R
381719					US6			LS6			LS6								U											U	US4/5	
382659	U	X	X	X	X	X					X	X		X	X	X		X	X	X	X							X				X
382661	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382662	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382665	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	R			X	X	X	X	X	X	X	X	R	X	X
382666			X						X	X				X	U			U	X					ER	ER					X	U	
382667	U	X	X		X	AFE	X	X	X	X	AFE	XS11		X	X	U	U	X	X		X	X	X		X	X	X	X	ER	X	X	U
382668			U											LS7					U							US6/7				U		
382669	X	X	X	X	X		X	X		X	X	X	X	X	R	R	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382670	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382671			U											U					U											U		
382673																		X	X	X	X	X	X	X			X	X				
382674	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
382675			U											U				U	U											U	U	
382678	R	R	X	R	R	X	X		R	R		R	R	R	X	R	R	R	R	R				R		R	R	R	R	R	R	
382685			U											U					US6											U		
382686	R	R	R	X	X	X	X	X	X	X		X	X	X	X	X		X	R	X	X	X	X	X	X	X	X		X	X	X	
382689		U	X				X	X	X	X				X	U			U	X				X	X	X	X				X	U	
382696		U	X											X	LS6			U	X											X	U	
382698			EAS											EAS					ER											ER		
382699	X		X			X								X	X	X		X	X										X	X	X	X
382701		X	X	X	X	X	X		X			X	X	X	X	X	U	X	X	X	X		X		X	X	X	X	X	X		U
382705		U	X											X	U				X						ER					X		

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
382706	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382707	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382708		U	ER															US4	EAS											EAS	U	
382709		U	X		ER			X	X	ER		ER		X	U			U	X				ER	X						X	U	
382710	X	X	X	X	X	X			X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	R
382716			LS6											LS6					LS6											U		
382717		LS11	X		LS11	X	X	X		X	X	X		X	X		US4	X	X		X	X	X	X	X	X	X	X		X	LS11	
382718														U																		
382719	X	X										X	X	X	X		X	X	X	X	X	X	X			X	X	X	X	X	X	R
382721			EAS											EAS				U	ER											ER	U	
382722	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
382723	X	R	R	X	X	R	X	X	X	X	X	X	X	R	X	X	R	R	R	X	X	X	R	R	R	X	X	X	X	R	R	R
382726		LS7	L					X	X					X	U			U	X				X	X						X	U	
382727			U											U					U											U		
382728		U	X		U	LS9		LS11	LS11					X	U			X				U	X		X	X				LS12		
382729																		US4													U	U	
382732	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382743			U											U																		
382744	U	X	X	EAS	X		X	X	X	X	EAS	X	EAS	X	X	U		X	X		U	ER	X	X	X	X	ER	EAS		X	X	
382745	R	R	R	X	X	X	R				X	X	X	X	R	R	X	X	R	R	X	X			R	X	X	X	X	X	X	X
382746	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382747		X	X	X	R	R	R	R	R	R	R	R	R	R	R	R																
382748	ER	X	X		X	X	X	X	X	X	X	X	X	X	X	X	ER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382749		U	X				X	X						X	EAS			U	X				X	X		X			X	US6	
382751			X											X				U	X						EAS				XS10	U	
382754		US5	AFE											X	U			U	X				X	X	X				X	U	
382756														U																		
382757	U	X	X	U	AFE	X	X	X	X	X	X	X	AFE	X	X	U	U	X	X		ER	X	X	X		X	X	AFE		X	X	U
382867																			XS11				U							XS11		
382870			US5																													
382892																			U											U		
382900	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X				X	X
382901	X	X	X	X	X	X			X	X		X		X	X	R	X	X	X	X	X	X	X	X		X	X	X	X	X		X
382911	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X					X					X	X
382913	R	R	R	X	X	X	X	X	X			X	X	X	X	R	R	R	X			X			R			X	X	X	X	
382926		X	X		X	X	X	X		X	X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
382927																														U		
382929			L			L	L	L	X	X	X			X				EAS	X				L	L	L	L	S10/11			X		
382930			US4											US4					US4													
382936																														U		
382937																														U		
382945	X	X	X	X		X					X		X	X	X	X																
382946	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X		X	X
382950	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	R	R
382951		X	X	X	X	X	X	X	X		X	X	X	X		ER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
382960			US4											U					U											U		
382965		X	X	AFE	AFE	LS12	X	X	X	X	AFE	X	X	X	X	U	U	X	X	ER	AFE	ER	X	X	X	X	AFE	AFE	AFE	X	X	U
382967	X	X	X	X	X	X	X		X		X	X		X	X	X		X	X	X			X	X	X	X	X	X	X	X	X	X
382968	EAS	X	X	X	X	X	X	X	X		X	X	X	X	X	EAS	U	X	X	X	X	X	X	X	X			X		X	X	U
382969	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382980	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	R	R	R	X	X	X	X	X	X	X	X	X	X	X	X
382982		X	X	X		X		L						L				X	X		L	L		X		X	X	X	X	X	X	
382984														US5/6					U											U		
382988																			U											U		
382990	R	X	X	X					X	X	X	X	X	R	R	R	R	R	X	R	R	X	X		X	X	X	X	R	R	R	R
382991		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	R		X		X	X	X	X	X	X	X	R	X	X
382993		X	X	X	X			X			X	X	X	X	X		U	X	X	X	X	X	X		X				X	X	X	U
382996			LS11						LS10										LS11					LS11	LS11							
383009	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
383011	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
383016	R	R	R	R	X	X	X	X		X	X	X	R	R	R	R	X	X	X	X	X	X	X			X	X	X	X	X	X	X
383019	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
383023		X	X	X		X		X	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	
383026			X	X	X	X	X				X	X	X	X			X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
383027			X	X	X	X					X	X		X																		
383032	X	X	X	X	X									X	X	X																
383033	X	X	R	R	R	X	R	R	R	R	X	X	R	R	R	R																
383034	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
383035	X	X	X	X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
383043			U											U					U											U		
383045		X															U		X													
383046		X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
383057		X	X	X	X	X		X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
383058		R	R	R						R	X	R	R	R	X	X	X	R	R	R	X	X	X	R	R	X	X	X	X	X	X	X
383066			US5																													
383067		X	X	X	X	X	X	X	X	X		X	X	X	X	U	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
383069	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	X	X	X			X	X	X	R	R	R	R
383086		X	R	X	X	X	X	X		X	X	X	X	X	X	X	R	X	R	X	X	X	X	X	X	X	X	X	X	X	X	R
383091			U											U					U											U		
383096			U											U																U		
383098		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X
383101		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
383102	R	R	X	X	X	X	X			X	X	X	X	X	R	R	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
383107		U	X					EAS	LS9						U			U					U			U				U	
383108	X	X	X	X	X	X	X		X	X	X		X	X	X	X	R	X	X	X	X	X	X	X	X		X	X		X	X	X
383113			X					US9	US9					X					X				EAS		X	RS9/10				X		
383116	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	R	X	X
383118	X	R	X	X	X	X	X	X		X	X	X	X	R	R	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X
383119	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
383121	X	X			X						X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	R
383127	R	R	X	X	X	X	X		X	X	X	X	R	R	X	X	X	R	X	X	X		X		X	X	X	X	X	X	X	X
383128	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
383129		X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	R	X	X
383138	U		X	X	X			X	X	X		X	AFE	X	X	U	U	X	X	X	X	X	X	X	X	X	X		X	X	X	U
383139																			U													
383141	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X		X	X	X	X	X	X	X	X	X	X	X	X
383142			U											U					U											U		
383143			U											U				U	U											U	U	
383144	X	R	R	R	R			X	R	R	R	R	R	R	R	R	X	R	R	X	X	X	X		X	X	X	X	X	R	R	X
383145	R	X	X	X	X	X	R	R	X	X	X	X	R	R	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
383150			X		X							X	X	X			X	X	X			X					X	X	X	X		X
383151	X	X	X		X	X	X			X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
383170		X	X	X	X	X	X	X				X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
383171		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	R	X
383175			U																											U		
384819		U	X							EAS				X	U			U	X				EAS	AFE	AFE	ER				X	U	
384958	X	X	X	X	X		X		X	X	X	X		X	X	X																
385946																			U											U		

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
385947			U											U				U	U											U	U	
385948		U	X		EAS	U	X	X			U		U	X	U			EAS	X		EAS	ER					ER	EAS		X	U	
385951			U											U				U	U											U	U	
387825	R	R	R	R		X	X	X	X	X	R	X	R	R	R	R																
325378	X	X	R	X	X	X	X	X	X	X	X	X	X	R	X	X	R	X	X	X	X	X	X	X	X		X	X	X	R	X	R
381367JS9/1		X	X	X	X	X			X	X	X	X	X	X	X	ER	AFE	X	X			X	X			X	X		X	X	X	AFE
4.13			US6																U											U		
4.17			US6											U					U											U		
4.21			U											US7					U											U		
4.3			U											U					U											U		
4.32		US4																U	X							US6			LS9	U		
4.47			AFE			U	U												LS7/8				U	LS7						U		
31.11																			US6											U		
32.11														U																		
32.25																								US4						US5		
32.28			LS4/5											LS4/5					U											U		
32.29			LS5											US5					U											U		
32.32											US4														U							
239202			X			X								X		X	X	X	X											X	X	X
239203			X			X					X						X		X	X	X	X	X	X	X	X	X					X
239204		X	X	X	X	X	X	X		X		X		X	X		X	X	X	X	X				X		X				X	X
239207		X	X	X	X	X		X			X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	
239208	X	X			X	X	X				X							X	X	X		X	X	X			X			X	X	X
239209		X		X	X	X				X		X							X		X		X		X	X			X		X
239215	X			X		X							X	X	X																	
239216		X	X									X	X	X	X	X																
239251				X	X	X		X																				X	X	X		
239259																	X	X	X		X							X		X	X	X
239293					X	X												X	X	X		X										
239505			LS7/8																U											U		
262909	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X			X	X	
262910		X		X	X	X					X	X	X		X	X	X	X	X										X		X	
262911	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X				X		
262912	X	X	X	X	X	X	X	X	X		X							X		X	X	X	X			X	X	X	X		X	
262915	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X
262916	X	X	X				X	X	X	X	X	X	X	X	X	X						X	X	X	X	X	X	X	X	X	X	X

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
262921					X							X	X	X	X	X						X	X		X	X	X					
262923		X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X		X	X	X	
262924	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
262947	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X
262950			U	U		U					U			U																		
262959																		U							ER							
262967		LS9					X	X	X	X					LS9			U	X				X	X	X	X	U			X		
262971		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
262978			X								X	X	X	X	X	XS8	X	X	X	X		X	X	X	X	X	X	X	X	X		
263079																		U		LS7												
269207	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
269210		X	X		X	X		X		X	X	X	X	X				X	X	X	X	X		X	X		X	X	X	X	X	X
269211																			X	X		X	X	X		X		X	X		X	
269214	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
269221																			X				X	X	X	X				X		
269223	X				X	X			X	X	X		X	X		X	X	X	X	X	X					X	X			X	X	
269227	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	AFE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	AFE
269232	X	X	X	X	X	X	X	X	X		X	X	X	X			X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
269234																			LS11													
269251																		U	X					X	X					X	U	
269279			U						U	ER				U					U						U							
269281	X	X		X	X	X	X				X	X	XA	X	X		X	X	X	X	X	X	X	X	X	X	X			X		
269290		X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X			X	X	X	X	X	X	
269299	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X										X	X	X	X	X	X	X
271804		X	X	X	X		X						X	X	X	X	X	X	X	X	X	X					X	X	X	X	X	X
271805	X	X	X	X	X				X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	
271806								X										X											X	X		
271808	X	X	X	X		X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X		X	X	
271809	X	X	X	X		X		X			X	X	X	X		X	X		X	X	X	X	X		X	X	X	X	X	X		X
271810				X		X		X	X	X	X			X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
271811		X	X	X	X	X	X			X	X	X	X	X	X	X																
271812	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X		X
271815	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
271816	X	X	X	X	X	X		X		X	X	X	X	X				X	X		X		X	X	X		X	X	X	X	X	X
271820	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X		X	X	X	X	X	
271849			US7					U	U					US7																U	US6	

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
271851	X	X	X	X	X		X	X	X		X	X	X				X	X	X	X		X	X			X					X	X
271853		X	X	X	X	X				X			X	X	X			X	X	X	X	X	X	X	X							
271860					X							X	X	X							X						X	X	X	X	X	
271882			X						ER	U				X				US6	X					X	X	X						
271929			U																													
271938														US6					U											U		
271943																			U											U		
271953																			U													
308601		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
308602		X			X						X	X	X	X	X		X			X	X	X	X	X	X	X	X	X	X	X	X	X
308603			X	X	X			X				X					X				X	X	X			X	X					X
308604	X		X			X		X									R	R	R	X		X				X		X	X	R	R	R
308606	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X
308607		ERS1(	X	ER		U	X	X		X		ER	ER	X	ERS10								X	X	X	X	ER	X		X	AFE	U
308608			X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X
308609				X			X	X					X		X					X	X	X		X	X	X						
308610	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																
308611			X	U	AFE	ER	X	X	X	X	X			X	EAS			AFE	X	ER	ER	X	X	X	X	X	X	ER	ER	X	AFE	
308612	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
308613	EAS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	EAS	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U
308614	US5/(	X	X	X	X	X	X	X	X	X	X	X	X	X	X	US5/6																
308615	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
308617		X	X			X	X	X	X			X	X	X											X	X	X		X	X	X	
308618	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X
308619	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
308620	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X
308621		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X
308622			X			X	X	X	X			X										X				X		X				
308623	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X				X	X		X		X	X	X	X	X	X	X
308624		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
308626	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
308627	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
308628		X	X	X	X	X	X		X		X	X	X	X	X	US6/7	U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	EAS
308629						X	X	X	X	X		X					X			X	X	X					X	X				
308633		X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		
308634	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X	X	X	X	X	X	X	X		X	X	X	X	X		

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
308635	US5/6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	US5/6	US4/5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	US4/5
308638		X	X		X						X	X	X	X	X		X	X	X											X	X	X
308642	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
308645	X	X	X	X	X	X	X	X	X	X	X	X				X	X			X	X	X	X				X	X	X			
308649											X												X	X	X	X	X	X	X			
308651	X	X	X	X	X	X	X				X	X	X	X	X		X		X	X	X	X	X		X	X	X	X	X	X	X	X
308654				X	X	X	X	X	X	X	X	X		X		X		X	X	X	X	X				X	X	X				
308665				US10								US11	US10	X	US8																	
308666														XS11					X						ER				X			
308667																	US4/5	EAS	X	U	AFE	AFE	X	X		X	AFE	X	EAS	X	EAS	U
308669																		X	X	X	X	X	X			X	X	X	X	X	X	
308672									X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
308674		X	X	X	X	X	X	X	X	X	X	X	X				X		X	X		X	X					X		X	X	
308675			X	X	X				X		X	X	X	X					X	X	X	X	X				X	X	X	X	X	
308676		X	X	X	X	X	X	X		X		X	X	X	X	X		X	X	X			X			X		X	X	X	X	
308677	X		X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
308679	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X
308681			X														X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
308683			X	X	X	X		X	X	X			X	X			X		X	X	X	X				X	X	X	X		X	
308685	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X			X	X	X	X	X	X	X	
308686		U	X				X	X	X	X				X					XS12				X	X	X	X						
308691		X	X	X	X	X	X				X	X	X	X	X			X	X	X	X		X			X	X	X	X	X	X	
308694			X							ER				X				U	X										X			
308696			U											U					U										U			
308698			U											U					U										U			
308700			X	LS10								LS10	LS11	X	US8			U	X				X	X	X	X			X	U		
308707		X	X	X	X	X					X	X	X	X				X	X		X									X		
308708			X		X	X								X	X																	
308709																	US6/7	X	X	X	X	X			X	X	X	X	X	X	X	U
308757																			U				U	U	U	U						
308762								U	U					LS6					US8										US8			
308764																													U			
308765			LS6											LS6					U								LS5/6		LS6			
308766									U																							
314277	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																
314282	X	X	X	X	X	X	X	X	X	X	X		X		X	X			X	X	X	X	X	X	X	X	X	X	X		X	

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
314283	X		X	X	X		X	X			X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
314284		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X			X	X	X	X			X
314285	X		X		X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
314286	X			X	X	X	X	X	X	X	X						X			X	X	X	X	X		X	X	X	X		X	X
314287	X	X	X	X		X					X			X	X	X	X	X	X			X					X			X	X	X
314289					X	X	X	X	X	X	X	X	X	X	X	X				X		X	X	X	X	X	X	X	X	X		
314293	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
314294			X	X	X	X	X	X	X	X		X			X		X				X	X	X	X	X	X	X	X				
314295	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
314299		U	X				ER	ER	ER	ER				X	U				X				ER	ER	ER	ER				X		
314300				X		X	X	X	X	X	X	X					X	X	X	X			X					X	X		X		
314301	X	X	X	X	X	X	X		X	X	X	X	X	X	X			X	X	X	X	X			X		X	X	X	X	X	X
314302	X			X	X	X				X	X	X		X			X			X	X	X				X	X	X	X			
314303					X							X									X	X	X			X	X	X	X		X	X
314305			X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X		X	X	
314307																			X											X		
314308	X	X	X	X	X	X		X	X		X	X		X	X			X	X	X		X	X	X				X	X	X		
314309		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
314310																						X							X			
314314			X		U	U	X	X	X	X	U			X	EAS			U	X		X	ER		X	X	X	ER	ER		X	U	US3/4
314317	X	X	X	X	X	X	X	X	X	X	X	X	X				X				X	X	X	X		X	X		X			
314318	X			X		X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X			X	X	X			X	X
314319	X	X	X										X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X
314321		X	X	X	X	X	X	X	X	X	X	X		X	X					X	X	X	X		X	X	X	X	X			
314322		X	X	X		X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
314336																							U	U	U	U						
314338														U					US5													
314339			US8											US8					U											U		
326194		U	U											U	U			US4	U											U	US4	
327097		US9	X	U														U	X								ER			X	U	
327098																								U	U							
327102	LS6/7	AFE	X											X				X	X	X	X	X	X	X	X					X		US6/7
327103			U											U					U											U		
327104			U											U																		
327105			ER		U						U			ER					ERS10					U	U							
327127		U	X								U			X				U	X			U		X			ER			X	U	US3/4

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
327130																	EAS		X						X				X	X	X	ER
327140	US5/6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	U	LS8	X	X	X	X	X	X	X	X	X	X		L	L	LS8
334053																														U		
381243																									L	L	L	L	L	L	L	LS10
381258			US6/7			US5													U											U		
381265	FES1	X	X			X							X	X				X				X	X				X			X	X	XS10
381274																			U											U		
20.12																			U											U		
31.1a																			US4											US4		
4.29c					US4/5									U																		
4.7a																			U													
60.1Bg																														US5/6		
60.22																			US5													
60.2a																			U											U		
60.3b			US7											U																		
60.3BC57			LS5																US4/5													
60.4														U	U			U	U											U	U	
60.48		US6													U									U	U						U	
60.3-QBq	R	X	X	R	R	R	R	R	R	R	R	R	R	X	X	R																
60.8-BC57	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
60.8-Bg			LS4											LS4																		
60.9-Bg3			U											U				US4	U													
Gal 60-1		U	X				EAS			EAS				X	U																	
h1.1/192	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
h1.1-164			EAS											EAS					U											U		
h1.1-165																			U											U		
h1.1-172			LS7											LS7					LS7													
h1.1-177																			U											U		
h1.1-198		U	LS9											LS9	U				ER					U	U					EAS		
h10-10	R	R	X	X	X	X	X	X	R	X	X	X	X	R	X																	
h10-50																	X	X	X	X	X		X	X	X	X	X	X	R	X	X	
h10-13																			US4													
h10-15														EASS7					U											LS7/8		
h10-28			U																													
h10-3		U	X							AFE				X	US7			U	X				X	X		X				X	U	
h10-41																														US4		

Table B-5. Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
h10-56		U	X											X	U			U	X											X	U	
h10-9			LS8											LS8					LS8						U	U						
J8 38.8	R	R	R	R		X						X	R	X	X	R	R	R	R	R	X	X	X	X	X	X	X	X	X	X	X	
St 1950B																														U		

Table B-6. Juvenile dental data

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
279211	X	X							X	X	X	X							X	X
339051	X	X	X						X	X	X	X							X	X
339749	X									X	X									
339754	X	X		X					X	X	X	X						X	X	X
342513	X	X	X						X	X	X	X							X	X
345339	X	X	X			X		X	X	X										
345358	X	X							X	X	X	X							X	X
345365	X	X		X	X	X			X	X	X	X	X	X	X	X	X		X	X
345375	X	X			X	X			X	X	X	X		X					X	X
345376	X	X					X	X	X	X	X	X		X				X	X	X
345386		X	X	X	X						X	X			X	X	X		X	X
345708	X	X	X	X	X		X				X	X							X	X
345726	X	X	X	X	X		X		X	X	X	X	X	X		X	X	X	X	X
345729	X	X	X					X		X	X	X							X	X
345753												X								X
351228	X	X	X	X					X	X	X	X	X					X	X	X
351229	X	X	X		X	X		X	X	X	X	X	X					X	X	X
351286	X	X	X	X		X	X	X	X	X		X		X			X	X	X	X
351323	X	X							X	X	X	X							X	X
351325	X	X							X	X	X	X							X	X
351347	X	X	X	X	X				X	X	X	X	X						X	X
363536	X	X	X	X	X	X	X	X	X	X	X	X	X				X		X	X
363537	X	X					X		X	X	X	X	X					X	X	X
363542	X	X	X						X	X	X	X							X	X
363543	X	X			X	X			X	X	X	X						X	X	X
363544	X	X	X	X	X	X			X	X	X	X							X	X
363546	X	X	X						X	X	X	X							X	X
363564	X	X								X	X									X
363565	X										X									X
363566	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
363572	X									X										
363601	US8/9	X	X	X			X	X	X	US8/9	U	X		X	X	X			X	U
363602	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
377822	X	X						X	X	X	X	X							X	X
377823	X	X	X	X	X	X	X	X	X	X	X	X	X						X	X
377824	X	X	X					X	X	X										

Table B-6. Continued

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
377826			US5	U		U		U			US5	U	U	U			U	U	U	
377827		XS8/9																		
378342																				X
378379		X			X				X	X	X	X							X	X
378381		X							X	X	X	X								
378382	X	X	X	X					X	X	X	X							X	X
378383	X	X	X	X		X	X		X	X	X								X	X
378384											X	X							X	
378385			US5/6															US5/6	US4/5	US4
378386											ER	X							X	ER
378394	X	X								X	X	X								X
378434	EAS	X		X					X	EAS	U	X	X	X					X	U
378492	X	X							X	X	X	X						X	X	X
378494	X	X	X	X			X	X	X	X	X	X	X				X	X	X	X
378496	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X
378660											US6									US6
379697											X									X
379716	X	X									X	X							X	X
345759x	X	X	X	X			X	X	X	X	X	X	X					X	X	X
325344										LS9	X									X
325401	X	X	X						X	X	X	X							X	X
325402											X	X								
325403											X									
325413						US5/6						US5						US5			
381181											X	X							X	X
381213																				X
381325								EAS				EASS9	EAS	ER				EAS	EAS	
381334															X	X	X	X	X	
381335						EAS			U	U			EAS	ER	X			ER	EAS	
381340	LS12	LS14	LS13				L	LS13	LS14	LS12	LS12	LS14		L	L	L	L		LS15	X
381349	X	X	LS6						L	L	X	X						X	X	X
381361				EAS	ER									U			U			
381364												US6							US6	
381366	X	X	X						X	X	X	X	X		X	X		X	X	X
381368											U	ERS9					ER		EAS	U
381369																				

Table B-6. Continued

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
381370	LS8/9	L	L	L	L	L	L	L	L	LS8/9	LS8	L	L	L	L	L	L	L	LS15	U
381380	X	X							X	X	X	X							X	X
381387	X	X	X			X			X	X	X	X	X	X	X	X		X	X	X
381394	X	L								X	X	X							X	
381408		X	ERS9	X	X		X	ERS9	X	U	U	X	ERS9			X	AFE	ERS9	X	U
381409			U	U	EAS															
381416																	U		U	
381418	X	X	X		X			X	X	X	L	X	X						L	L
381419	LS5	LS7/8	LS7	LS10			LS10	U	EAS		LS5		LS7		LS10	LS10	LS10	LS7		LS6
381424				LS10	LS6	LS6														
381425	X	X	X						X	X	X	X	X				X	X	X	X
381434		X							X	EAS	EAS	X							X	
381436	US6	EAS	LS7	LS10	LS9			LS6			LS6	U	U				LS10	LS7	LS8	LS6
381439	U	ERS10	LS9	X	X			XS9	ERS10	U	U	ER	LS9	X	X	X		LS9	LS9	LS6
381440	L	L	XS7	LS7	LS9	LS9	LS7	XS7	L	L	X	X	LS6	LS9	LS10	LS10		L	X	X
381444	EAS	X	LS10	X	X		X	LS10	X	AFE	EAS	X		X		X	X	X	X	EAS
381445	L	X	XS7	X	X	X	X	X	X	X	X	X	X				X	L	L	L
381446	LS5	LS5		LS6	LS7	LS6		LS6	LS5	LS5	LS5/6	LS6	EAS	U	L		LS6		U	U
381447		LS5			LS5	LS5						LS4/5	LS6		LS5					
381448												LS4/5								
381455	X	X							X	X	X	X							X	X
381460	US5	LS7	US6			US5		US6			U	U	U						U	LS5
381462	L	X	X	L	L	L	L	X	X	X	X	X	X		X	X		X	L	X
381465	X	X	X					X	X	X	X	X	X					X	X	X
381466	LS5/6	US6	U				LS9/10	U	EAS		US4/5	U	U	LS9	LS9/10			U	U	U
381467	LS5/6	LS6	LS5		LS9	LS9		LS5	LS6/7	LS5/6	LS5	LS6/7	LS5/6			LS9/10	LS9	LS5/6	LS6	LS5
381468		LS5			LS6	US6						LS4/5								
381658	X	X	X	X				X	X	X	X	X				X		X	X	X
381659	X	X						X	X	X	X	X				X			X	X
381664	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X		X	X
381680	X	X	X					X	X	X	X	X		X		X	X			
381686	X	X	X	X				X	X	X	X	X							X	X
381687	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
381719	X	X				L					X	X	X	X	X		X	X	X	X
382666	X	X	X	X	X			X	X	X	X	X	X					X	X	X
382668	X	X				X			X	LS11	X	X	X						X	X

Table B-6. Continued

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
382671	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X
382675	X	X	X	X			X	X	X	X	X	X	X		X	X	X	X	X	X
382685	X	X	X	X	L	X	X	L	X	X	X	X	X	X	X		X	X	X	X
382689	X	X	X						X	X	X	X							X	X
382695	U	LS6	U		LS9	LS9				LS6	U	U	U	U			U	U	U	US4
382696	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X	X
382697	LS5		US6					US6		LS5	LS6		US5/6						LS6	
382698	X	X	X						X	X	X	X	X	X	X		X		X	X
382700	EAS	X		X		LS11/12	X		LS11		EAS	X	AFE					AFE	X	ER
382705	X	X						X	X	X	X	X	X	X				X	X	X
382708	X	X	X	X	X	X		X	X	X	X	X	X					X	X	X
382709	X									X	X	X	X						X	X
382716	XS9/10	X	X	X		X	X	XS10	XS10	XS9/10	LS11	LS10					L	X	X	
382718	EAS	X	LS9/10		X	LS10		LS9/10	X	EAS	ER	X	ER	X	X		LS10/11	ER	X	EAS
382721	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
382726	X	X							X	X	X	X	X					X	X	X
382727	X	X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X
382728	X	L							X	X	X	X							X	X
382729	X	X				X		X	X	X	X	X	X	X	X	X	X	X	X	X
382730		US5	U															U		U
382733					LS6/7															
382743	ER	X	LS10		LS12	LS12			X	AFE	AFE	X	X	X	L	L	L		X	AFE
382744											X									X
382746								X												
382749	X	X	X	X	X				X	X	X	X	X						X	X
382751	X	X							X	X	X	X							X	X
382754	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
382756	LS9	LS11	LS11		L	X		X	X	ER	X	X	LS11	X					LS11	ER
382757											X									X
382867											X	X						X	X	X
382870	U	X		X	X	X	XX	ER	X	U	U	ER	EAS	X	X	X	X	EAS	ER	U
382892	U			LS11						US8	EAS			LS11		LS12	LS11		LS10	LS8
382893		LS11	LS10			LS12	LS11	LS10			LS9	LS11	LS10		LS11					
382899	LS9	LS11	LS10		LS11			U		US5	LS9									
382902	U	LS8/9	U							LS5										
382927	LS6	LS8	LS9	LS10	LS10	LS10	LS10	LS9	LS8	LS6	LS7	LS9	LS9	LS10	L	X	LS10	LS9	LS8	U

Table B-6. Continued

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
382928	ER	X							X	ER		X	X						LS8	LS10
382929	X									X	X	X	X						X	X
382930		LS9	LS9	L	LS10	LS10			LS9	U	U	LS9	LS9	LS10	LS10			LS9	LS8/9	LS7
382936	LS10	L				L	L	L	X	LS10	LS11	X	LS9		L	L	L	L	X	LS11
382937																			EAS	U
382957		LS4		LS5	LS5/6		LS5		LS4										US5	
382960	LS6		LS9	LS10				LS9	ERS9	ER	U	EAS				LS10	LS10	LS9	LS9	US6
382963			LS4	LS5													LS5	LS4		
382966				LS5	LS5		LS5		LS4					LS5						
382970		LS8/9		LS10	LS10	LS10			LS8/9			LS8/9		LS10	LS10	U	U	U	LS8/9	
382984	U	L	LS10	L	L	L	L	LS10	X	US7/8	L	L	LS10	X	U	L	L	LS10	L	
382987												LS4	LS4	LS5	LS5					
382988	US6	LS8/9	US7	LS9				US7	LS8/9	LS6	U		U				LS9	LS7	LS8/9	U
382989												LS4		LS5						
382992						LS5	LS4/5													
382996	X								X	X	L	L							X	
383017	ER	L	L	L			L	L	L		LS10	X	L	L			L		X	ER
383024			U		U		LS7	LS5	LS6	LS5	U	LS6					LS7		LS6	
383028						LS6		LS4/5			U									
383031	LS5/6		LS6		LS9						LS5/6	US6/7	U	LS9	LS9	LS9	LS9	LS6	US6/7	US6
383042	LS4	LS5		LS7	LS7	LS7														
383043	X	X	X			X	X	X	X	X	X	X				X	X	X	X	X
383059					LS6															
383064	US7	LS8	L	LS9	LS9	LS9	LS9	L	LS8	LS6	LS6	LS7	L	LS9	LS9	LS9	LS9		EAS	U
383066	LS8	LS11		LS11							U									
383081	LS6	LS8	LS7	LS9	LS9	LS9	LS9		LS8	LS6	LS6	LS8	LS9		LS10	LS10	LS9	LS9		
383083		LS5		LS6	LS7	LS7	LS6		LS5			LS4/5		LS6		LS6	LS6		LS5	
383084					LS6															
383091	X	X							X	X	X	X			L			L	X	LS10/11
383096	X	X						L	X	X	LS10	LS11					L		LS11	X
383099		LS5	LS4	LS5	LS5/6	LS5/6	LS5	LS4	LS5				LS4	LS5		LS6	LS5	LS4		
383105							LS6			LS4/5		LS6								
383107	X	X							X	X	X	X							X	X
383109							LS5								LS6					
383110					LS7	LS7	LS5		LS5			LS5		LS5	LS5	LS5			LS5	
383111		LS4/5	LS5	LS5	LS6		LS5													

Table B-6. Continued

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
383113	X	X	L				X	X	X	X	X	X	X					X	X	X
383114		LS4		LS5										LS5						
383115					LS6	LS6						LS5		LS6	LS7			LS6	LS5	
383134				LS6	LS6	LS6									LS6	LS6	LS5/6		LS4	
383139	X	X			L		L	L	L	L	X	X	X			L	L		L	L
383140								LS5		LS4		LS6								
383142	X	X							X	X	X	X							X	X
383143	X	X	L	L	L	L	L	L	X	X	X	X	L	L	L	L	L	L	X	X
383168						LS6			LS5			LS4								
383175	U	X	ER	LS11	X	X	X	ER	X		LS7	X	ER			X	X	ER	X	U
384819	X	X	X						X		X	X	X					X	X	X
385946								ERS9			U	EAS							EAS	U
385947	X	X							X	X	X	X							X	X
385948	X										X									X
385951	X	X							X	X	X	X	X	X	X	X			X	X
4.13	AFE	X							X	ER	ER	X				X			X	ER
4.17	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4.21	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4.3	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X
4.32	X	X	X					X	X	X	X	X								
4.47	X	X						X	X	X	X	X	X	X	X			LS14	X	X
31.11											X	X							X	X
32.11	LS10										LS10	L	L							
32.25																			AFE	U
32.28			LS9	LS10	LS10	LS10	LS10	LS9	X	U	U	ER	LS9	LS10	LS10	LS10	LS10		ER	U
32.29	X	X			LS14	LS14	LS13		X	X	X	X							X	X
32.32	X	X	X						X	X	X	X							X	X
32.5											US6								U	U
228980												X							X	
239505	X	X							X			X							X	
262950		X							X											
262959	X	X	X	X	X				X	X		X	X						X	X
262967		X							X		X	X							X	X
263079												X								
269213											X	X	X						X	X
269216																			U	US5

Table B-6. Continued

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
269221											X	X							X	X
269234	U		ER					ER			U	ER	U					U	ER	U
269235					LS6	LS6			L5/6			LS4/5								
269236											U								X	U
269251	X	X							X	X	X	X							X	X
269279	X	X								X	X	X							X	X
271849	X	X	X		X	X			X	X	X	X	X	X		X		X	X	X
271882	X	X		X	X						X	X	X					X	X	X
271929	AFE	X			X															
271938	X	X							X	X	X	X							X	X
271939	US6																			
271943												X							X	
271947																				U
271950											U	U	X	X	X	X	ER	U	US6	U
271951		LS5			LS6		LS6		LS5			LS5	LS5/6							
271953																			X	X
308611									X											
308665	X	X							X	X										
308666		X			X	X	X	X	X	X	X	X	X				X	X	X	X
308686	X	X	X					X	X	X	X	X	X					X	X	X
308694	X	X							X	X	X	X							X	X
308696	X	X				X	X	X	X	X	X	X	X	X	X		X	X	X	X
308697									X			X			X	X	X	X	X	U
308698	X	X		X				X	X	X	X								X	X
308700	X								X	X	X	X	X					X	X	X
308757											X	X	X					X	X	X
308758											US6							US6		U
308759																		ER	US8	U
308760	U	X		X	X				X	U	U	X	ER	X		X		ER	X	U
308762	XS11	X			X	X			X	X	X	X							X	X
308763											U	EAS	ER						ER	
308764												X	X					X	X	
308765	XS10/11	X							X	X	X	XS12							XS12	
308766										U										
314299	X	X	X					X	X	X	X	X	X					X	X	X
314314	X								X	X		X							X	

Table B-6. Continued

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
314336						X					US6									US6
314338		X							X	ER	ER	X		X					X	ER
314339	X	X			X				X	X	X	X							X	X
326194	X	X	X						X	X	X	X	X				X	X	X	X
327097		L							L			L							L	
327098										X	X	X								
327103	X	X	X					X	X	X	X	X							X	X
327104	X	X									X	X							X	X
327105	X		X							X	X	X								
327127	X	X							X	X	X	X							X	X
327131											X									
327132											US6	U	U	U	U			U	US8	US6
327133		U	X		X	X		U			LS5	LS6	U	X			X	U	LS6	LS5
327138											U	ER	X					U	ER	US7/8
334053											US6	U						U	U	US6
381253	L	L	L	L		L	L	L	L	L	X	X			X	X	X			X
381258	X	X						X	X	X	X	X	X	X	X	X	X	X	X	X
381259	US5/6	US6	US6		LS9					US5/6	US5/6					LS10		LS6	U	US5/6
381260	LS6/7	L	L		L		L	L	L	LS6/7	LS6/7	L		L	L	LS10	L	LS6	L	LS6/7
381263		X										X	ER	X			X		X	ERS9
381274											X	X							X	X
20.12	US6										U		ER							U
31.1a			EAS					EAS				EAS	U					EAS	US6	U
4.29c		X	X	X	X	X	X	X	X	X	X	X	X	X	X					
4.7a		X				X	X		X		U	ER	EAS					EAS		
4.7b			LS4/5	LS5	LS5	LS5	LS5	LS4/5												
60.12												US6/7	U	AFE	ER		AFE	U	US7	US5
60.1a			US5/6					US5			US6	US6	U	U	U		US6	U	U	US5
60.1Bg		X				LS12	LS11	LS11	LS11			X							LS11	LS10
60.22			LS9									LS9	LS9							
60.2a			LS10	LS11			LS11	LS10			X	X	LS10	LS11	LS12	X	LS11	LS10	X	X
60.3b	X	X				X			X	X										
60.3BC57	LS7	LS10	LS9	LS10				LS9		LS7		X			LS11					US7
60.4	X	X						X	X	X	X	X							X	X
60.48	X	X			X	X			X	X		X		X		X	X	X	X	X
60.8-Bg	LS7	LS9			LS11				LS9											

Table B-6. Continued

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
60.9-BC53	LS4					LS7														
60.9-BC57												LS5			LS6	LS6				
60.9-Bg3	X	X	X	X	X		X	X	X	X	X	X	X		X	X		X	X	X
Bu8-900561																	U			
Gal60-1	X	X	X						X	X										
h1.1-164	X	X	X		X		X		X	X	X	X	X	X	X	X		X	X	X
h1.1-165	X	X	X	X			X	X	X	X	X	X	X			X	X	X	X	
h1.1-172		LS12							LS12			LS14								
h1.1-177	X	X									X	X							X	X
h1.1-179											US6	EAS	U							US6
h1.1-198	X	X	X		X	X	X	X	X	X	X	X						X	X	X
h10-13											EAS		EAS							
h10-15	L	X	L		L				X	X	X	X							X	X
h10-28	U	ER	U								U	ER	U						EAS	U
h10-3	X	X	X						X		X	X	X					X	X	X
h10-41	U	AFE						U	ER	U	U	ER	U					U	ER	U
h10-56	X	X							X	X	X	X							X	X
h10-9	X	X							L	L	L								X	X
St1950B	US7		US9									EAS	U	EAS				U	U	US7

APPENDIX C
DESCRIPTIVE STATISTICS

Table C-1. Descriptive statistics - Native Alaskan juveniles

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
1	4	humeri	82.250	4	15.152	18.422	33.000	70.000	103.000
		radii	79.000	3	12.767	16.161	25.000	68.000	93.000
		ulnae	67.250	4	10.626	15.801	23.000	59.000	82.000
		femora	101.000	4	23.051	22.822	50.000	82.000	132.000
		tibiae	88.333	3	16.042	18.160	32.000	73.000	105.000
		fibulae	86.000	2	24.042	27.955	34.000	69.000	103.000
2	8	humeri	108.800	5	16.037	14.740	40.000	96.000	136.000
		radii	87.250	4	5.188	5.946	11.000	81.000	92.000
		ulnae	78.750	4	5.852	7.432	13.000	72.000	85.000
		femora	133.333	6	13.53	10.148	40.000	118.000	158.000
		tibiae	116.500	4	29.85	25.622	63.000	98.000	161.000
		fibulae	103.500	4	5.972	5.770	14.000	97.000	111.000
3	8	humeri	127.571	7	14.444	11.322	46.000	109.000	155.000
		radii	101.167	6	9.725	9.612	26.000	91.000	117.000
		ulnae	90.000	7	8.851	9.834	24.000	82.000	106.000
		femora	165.750	8	20.317	12.258	67.000	134.000	201.000
		tibiae	128.571	7	12.367	9.619	35.000	114.000	149.000
		fibulae	133.500	4	12.234	9.164	28.000	122.000	150.000
4	13	humeri	144.000	11	9.497	6.595	27.000	132.000	159.000
		radii	116.100	10	7.781	6.702	21.000	105.000	126.000
		ulnae	103.222	9	7.190	6.954	21.000	94.000	115.000
		femora	190.727	11	14.806	7.763	47.000	172.000	219.000
		tibiae	151.923	13	11.056	7.278	36.000	135.000	171.000
		fibulae	150.444	9	12.249	8.142	37.000	137.000	174.000
5	7	humeri	157.667	6	17.739	11.251	48.000	135.000	183.000
		radii	127.250	4	14.614	11.485	35.000	112.000	147.000
		ulnae	121.667	3	9.018	7.412	18.000	113.000	131.000
		femora	221.200	5	28.438	12.856	76.000	187.000	263.000
		tibiae	169.400	5	30.088	17.762	75.000	139.000	214.000
		fibulae	173.250	4	24.144	13.936	58.000	143.000	201.000
6	7	humeri	195.167	6	14.648	7.505	39.000	177.000	216.000
		radii	153.750	4	5.909	3.843	14.000	148.000	162.000
		ulnae	137.200	5	6.221	4.534	17.000	130.000	147.000
		femora	268.167	6	34.528	12.875	82.000	235.000	317.000
		tibiae	204.000	7	23.259	11.402	69.000	183.000	252.000
		fibulae	193.250	4	7.365	3.811	17.000	185.000	202.000
7	8	humeri	215.600	5	23.818	11.047	63.000	180.000	342.000
		radii	174.333	3	18.717	10.736	35.000	153.000	188.000
		ulnae	150.000	6	16.661	11.108	37.000	134.000	171.000

Table C-1. Continued

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
7	8	femora	305.250	8	30.705	10.059	92.000	254.000	346.000
		tibiae	246.571	7	29.871	12.115	95.000	199.000	294.000
		fibulae	231.667	6	21.86	9.436	61.000	198.000	259.000
8	14	humeri	227.692	13	16.378	7.193	64.000	199.000	263.000
		radii	183.300	10	17.764	9.691	51.000	166.000	217.000
		ulnae	163.333	12	10.165	6.224	33.000	146.000	179.000
		femora	329.250	12	21.566	6.550	73.000	292.000	365.000
		tibiae	256.364	11	17.351	6.768	63.000	233.000	296.000
		fibulae	246.000	9	22.327	9.076	79.000	215.000	294.000

Table C-2. Descriptive Statistics - Native Alaskan males

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
9	6	humeri	303.250	4	16.215	5.347	37.000	286.000	323.000
		radii	230.800	5	16.709	7.240	42.000	205.000	247.000
		ulnae	204.600	5	13.686	6.689	36.000	185.000	221.000
		femora	407.800	5	16.903	4.145	43.000	383.000	426.000
		tibiae	319.333	3	17.156	5.372	34.000	301.000	335.000
		fibulae	315.000	2	14.142	4.490	20.000	305.000	325.000
10	11	humeri	304.000	10	13.904	4.574	44.000	284.000	328.000
		radii	240.250	8	14.310	5.956	41.000	210.000	251.000
		ulnae	221.000	8	7.445	3.369	21.000	210.000	231.000
		femora	415.545	11	22.020	5.299	75.000	376.000	451.000
		tibiae	335.250	8	27.049	8.068	77.000	295.000	370.000
		fibulae	335.500	6	11.167	3.328	33.000	317.000	350.000
11	24	humeri	306.591	22	21.073	6.873	104.000	274.000	378.000
		radii	246.684	19	12.074	4.895	38.000	230.000	268.000
		ulnae	227.091	22	10.954	4.824	40.000	210.000	250.000
		femora	422.783	23	17.850	4.222	82.000	393.000	475.000
		tibiae	338.952	21	19.795	5.840	78.000	298.000	376.000
		fibulae	327.150	20	16.787	5.131	57.000	290.000	347.000
12	31	humeri	304.929	28	16.161	5.300	65.000	273.000	338.000
		radii	250.850	20	12.787	5.097	52.000	228.000	280.000
		ulnae	228.269	26	12.344	5.407	55.000	201.000	256.000
		femora	421.857	28	20.301	4.812	87.000	380.000	467.000
		tibiae	342.680	25	21.748	6.346	74.000	311.000	385.000
		fibulae	334.100	20	20.789	6.223	70.000	305.000	375.000

Table C-3. Descriptive Statistics - Native Alaskan females

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
9	9	humeri	270.857	7	15.678	5.788	53.000	243.000	296.000

Table C-3. Continued

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
9	9	radii	212.600	5	17.729	8.339	48.000	188.000	236.000
		ulnae	190.200	5	17.484	9.193	45.000	167.000	212.000
		femora	386.778	9	14.078	3.640	46.000	362.000	408.000
		tibiae	307.222	9	9.782	3.184	29.000	292.000	321.000
		fibulae	279.750	8	16.577	5.926	51.000	258.000	309.000
10	18	humeri	283.071	14	10.788	3.811	40.000	260.000	300.000
		radii	224.500	14	10.811	4.816	33.000	206.000	239.000
		ulnae	206.385	13	10.744	5.206	31.000	194.000	225.000
		femora	385.563	16	23.016	5.969	90.000	337.000	427.000
		tibiae	312.200	15	15.844	5.075	69.000	274.000	343.000
		fibulae	303.077	13	20.023	6.606	68.000	268.000	336.000
11	44	humeri	289.590	39	15.736	5.434	77.000	247.000	324.000
		radii	227.727	33	14.041	6.166	70.000	187.000	257.000
		ulnae	208.143	35	13.931	6.693	73.000	163.000	236.000
		femora	398.409	44	22.084	5.543	107.000	332.000	439.000
		tibiae	316.897	39	20.542	6.482	100.000	260.000	360.000
		fibulae	310.576	33	19.682	6.337	94.000	251.000	345.000
12	30	humeri	283.036	28	13.031	4.604	54.000	252.000	306.000
		radii	229.048	21	13.075	5.708	47.000	212.000	259.000
		ulnae	206.700	20	11.743	5.681	47.000	187.000	234.000
		femora	398.214	28	17.608	4.422	77.000	353.000	430.000
		tibiae	318.179	28	16.755	5.266	73.000	281.000	354.000
		fibulae	313.250	16	14.434	4.608	51.000	287.000	338.000

Table C-4. Descriptive statistics - South Dakota Arikara juveniles

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
1.1	40	humeri	66.138	29	4.189	6.334	17.000	56.000	73.000
		radii	63.069	29	3.605	5.716	15.000	55.000	70.000
		ulnae	55.308	26	3.069	5.550	13.000	48.000	61.000
		femora	76.765	34	5.466	7.121	28.000	62.000	90.000
		tibiae	67.077	26	4.251	6.338	19.000	56.000	75.000
		fibulae	63.600	15	4.595	7.225	21.000	52.000	73.000
1.2	37	humeri	83.214	28	11.305	13.585	43.000	64.000	107.000
		radii	73.474	19	10.052	13.681	35.000	61.000	96.000
		ulnae	65.458	24	9.156	13.987	33.000	52.000	85.000
		femora	97.808	26	17.875	18.276	61.000	68.000	129.000
		tibiae	84.640	25	14.877	17.577	51.000	60.000	111.000
		fibulae	77.818	11	12.344	15.862	33.000	64.000	97.000
2	19	humeri	109.733	15	10.361	9.442	41.000	93.000	134.000
		radii	99.714	14	6.911	6.931	27.000	89.000	116.000
		ulnae	87.875	16	6.965	7.926	29.000	75.000	104.000

Table C-4. Continued

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
2	19	femora	141.727	11	13.857	9.777	49.000	124.000	173.000
		tibiae	116.167	12	13.155	11.324	46.000	98.000	144.000
		fibulae	113.111	9	8.923	7.888	27.000	103.000	130.000
3	12	humeri	126.000	10	5.617	4.458	19.000	116.000	135.000
		radii	110.500	6	3.271	2.960	8.000	107.000	115.000
		ulnae	98.714	7	3.638	3.686	9.000	94.000	103.000
		femora	164.875	8	7.492	4.544	18.000	158.000	176.000
		tibiae	137.200	5	7.190	5.241	18.000	131.000	149.000
		fibulae	143.000	4	16.145	11.290	36.000	128.000	164.000
4	15	humeri	150.444	9	8.589	5.709	24.000	137.000	161.000
		radii	127.222	9	8.212	6.455	23.000	116.000	139.000
		ulnae	114.333	12	7.475	6.538	21.000	104.000	125.000
		femora	199.000	11	17.070	8.578	59.000	177.000	236.000
		tibiae	168.455	11	14.788	8.778	44.000	146.000	190.000
		fibulae	162.429	7	16.328	10.053	44.000	143.000	187.000
5	18	humeri	170.867	15	13.700	8.018	40.000	145.000	185.000
		radii	143.571	14	9.255	6.446	31.000	127.000	158.000
		ulnae	132.429	14	9.304	7.026	28.000	115.000	143.000
		femora	241.000	14	12.926	5.363	51.000	210.000	261.000
		tibiae	193.188	16	16.971	8.785	57.000	155.000	212.000
		fibulae	189.938	16	17.230	9.071	57.000	153.000	210.000
6	10	humeri	198.500	8	11.551	5.819	32.000	184.000	216.000
		radii	165.333	6	10.764	6.511	30.000	150.000	180.000
		ulnae	149.857	7	9.582	6.394	28.000	137.000	165.000
		femora	273.900	10	15.286	5.581	42.000	257.000	299.000
		tibiae	230.800	5	14.789	6.407	37.000	214.000	251.000
		fibulae	215.750	4	6.898	3.197	16.000	207.000	223.000
7	8	humeri	217.000	6	19.339	8.912	46.000	199.000	245.000
		radii	187.833	6	10.685	5.688	26.000	172.000	198.000
		ulnae	169.000	5	10.416	6.164	25.000	155.000	180.000
		femora	305.750	8	32.810	10.731	86.000	275.000	361.000
		tibiae	257.125	8	26.894	10.459	74.000	229.000	303.000
		fibulae	247.143	7	15.247	6.169	39.000	227.000	266.000
8	8	humeri	227.500	6	19.181	8.431	55.000	210.000	265.000
		radii	199.500	4	13.429	6.731	31.000	187.000	218.000
		ulnae	180.500	4	11.446	6.341	27.000	169.000	196.000
		femora	325.714	7	15.041	4.618	36.000	311.000	347.000
		tibiae	270.667	6	20.057	7.410	48.000	250.000	298.000
		fibulae	268.571	7	28.260	10.522	86.000	233.000	319.000

Table C-5. Descriptive statistics - South Dakota Arikara males

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
9	4	humeri	294.250	4	29.545	10.041	61.000	250.000	311.000
		radii	254.000	4	27.142	10.686	62.000	215.000	277.000
		ulnae	233.000	4	21.618	9.278	50.000	202.000	252.000
		femora	404.750	4	41.404	10.229	97.000	346.000	443.000
		tibiae	353.250	4	41.121	11.641	95.000	294.000	389.000
		fibulae	342.750	4	38.578	11.255	88.000	287.000	375.000
10	11	humeri	318.889	9	18.510	5.804	63.000	277.000	340.000
		radii	267.222	9	13.599	5.089	44.000	238.000	282.000
		ulnae	250.667	9	14.491	5.781	47.000	219.000	266.000
		femora	446.500	8	24.946	5.587	68.000	404.000	472.000
		tibiae	378.889	9	23.358	6.156	66.000	342.000	408.000
		fibulae	374.143	7	22.741	6.078	59.000	335.000	394.000
11	49	humeri	323.725	40	15.908	4.914	88.000	297.000	385.000
		radii	276.214	28	10.093	3.654	42.000	259.000	301.000
		ulnae	255.853	34	10.361	4.049	41.000	235.000	276.000
		femora	450.175	40	15.619	3.469	69.000	412.000	481.000
		tibiae	383.784	37	17.095	4.454	74.000	345.000	419.000
		fibulae	371.424	33	17.234	4.640	75.000	332.000	407.000
12	53	humeri	318.867	45	12.892	4.043	62.000	286.000	348.000
		radii	273.103	39	9.888	3.621	50.000	248.000	298.000
		ulnae	254.364	44	9.236	3.631	46.000	229.000	275.000
		femora	446.383	47	18.972	4.250	91.000	392.000	483.000
		tibiae	380.622	45	18.038	4.739	81.000	340.000	421.000
		fibulae	368.816	38	15.971	4.330	69.000	331.000	400.000

Table C-6. Descriptive statistics - South Dakota Arikara females

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
9	9	humeri	279.571	7	20.598	7.368	60.000	238.000	298.000
		radii	243.667	6	10.443	4.286	26.000	228.000	254.000
		ulnae	215.714	7	14.127	6.549	40.000	188.000	228.000
		femora	389.111	9	27.260	7.006	78.000	348.000	426.000
		tibiae	339.375	8	30.580	9.011	107.000	277.000	384.000
		fibulae	319.714	7	26.139	8.176	77.000	274.000	351.000
10	33	humeri	299.893	28	13.022	4.342	53.000	271.000	324.000
		radii	253.474	19	9.800	3.866	36.000	231.000	270.000
		ulnae	232.560	25	9.256	3.980	36.000	215.000	254.000
		femora	418.667	27	16.864	4.028	82.000	371.000	453.000
		tibiae	351.000	30	15.091	4.299	63.000	317.000	380.000
		fibulae	344.458	24	14.903	4.326	67.000	317.000	384.000
11	38	humeri	297.724	29	14.205	4.771	46.000	278.000	324.000
		radii	252.741	27	11.551	4.570	39.000	233.000	272.000

Table C-6. Continued

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
11	38	ulnae	233.600	25	11.644	4.985	39.000	214.000	253.000
		femora	418.226	31	21.197	5.068	78.000	382.000	460.000
		tibiae	353.231	26	16.585	4.695	67.000	320.000	387.000
		fibulae	343.571	21	15.753	4.585	53.000	320.000	373.000
12	15	humeri	293.786	14	8.350	2.842	29.000	276.000	305.000
		radii	247.273	11	7.086	2.866	18.000	238.000	256.000
		ulnae	228.300	10	6.147	2.693	18.000	220.000	238.000
		femora	409.333	12	13.513	3.301	40.000	385.000	425.000
		tibiae	344.000	14	14.961	4.349	51.000	321.000	372.000
		fibulae	339.143	7	13.825	4.077	45.000	312.000	357.000

Table C-7. Descriptive statistics. Ancestral Puebloan juveniles.

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
1.1	10	humeri	66.375	8	2.615	3.94	7.000	63.000	70.000
		radii	63.000	9	2.398	3.806	8.000	60.000	68.000
		ulnae	54.375	8	1.598	2.939	5.000	52.000	57.000
		femora	79.100	10	4.228	5.345	14.000	74.000	88.000
		tibiae	68.600	10	3.204	4.671	10.000	65.000	75.000
		fibulae	65.667	9	2.872	4.374	8.000	62.000	70.000
1.2	20	humeri	86.842	19	6.414	7.386	22.000	77.000	99.000
		radii	76.643	14	5.486	7.158	18.000	70.000	88.000
		ulnae	69.077	13	5.454	7.895	17.000	62.000	79.000
		femora	106.357	14	7.469	7.023	24.000	96.000	120.000
		tibiae	89.250	12	4.545	8.454	23.000	80.000	103.000
		fibulae	86.200	10	6.973	8.089	22.000	77.000	99.000
2	31	humeri	97.292	24	9.937	10.213	42.000	86.000	128.000
		radii	87.158	19	9.805	11.25	40.000	65.000	105.000
		ulnae	78.150	20	7.836	10.026	29.000	65.000	94.000
		femora	126.000	18	16.284	12.924	64.000	405.000	169.000
		tibiae	106.500	16	12.215	11.469	45.000	89.000	134.000
		fibulae	101.625	8	9.211	9.064	28.000	90.000	118.000
3	11	humeri	111.750	8	6.431	5.755	19.000	103.000	122.000
		radii	97.000	5	3.082	3.178	7.000	93.000	100.000
		ulnae	87.000	5	2.302	2.634	5.000	85.000	90.000
		femora	138.778	9	19.601	14.124	61.000	100.000	161.000
		tibiae	125.000	4	7.789	6.231	17.000	119.000	136.000
		fibulae	117.000	4	11.944	10.209	28.000	102.000	130.000
4	19	humeri	138.571	14	10.128	7.309	37.000	120.000	157.000

Table C-7. Continued

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
4	19	radii	117.286	14	8.730	7.444	30.000	103.000	133.000
		ulnae	106.714	14	7.966	7.464	26.000	93.000	119.000
		femora	186.214	14	16.282	8.744	54.000	158.000	212.000
		tibiae	154.077	13	14.609	9.481	40.000	134.000	174.000
		fibulae	153.444	9	11.425	7.446	30.000	139.000	169.000
5	11	humeri	164.000	11	13.038	7.950	44.000	142.000	186.000
		radii	142.200	5	12.988	9.134	32.000	122.000	154.000
		ulnae	130.000	4	13.928	10.714	30.000	110.000	140.000
		femora	219.571	7	20.28	9.236	63.000	190.000	253.000
		tibiae	182.750	4	20.549	11.244	50.000	156.000	206.000
		fibulae	187.250	4	22.544	12.040	47.000	158.000	205.000
6	12	humeri	194.364	11	15.552	8.001	43.000	179.000	222.000
		radii	163.000	8	10.268	6.299	34.000	150.000	184.000
		ulnae	147.111	9	14.391	9.783	38.000	133.000	171.000
		femora	264.200	10	22.837	8.644	77.000	245.000	322.000
		tibiae	220.625	8	19.198	8.702	62.000	200.000	262.000
		fibulae	219.000	6	19.807	9.023	50.000	209.000	259.000
7	5	humeri	230.750	4	36.207	15.691	86.000	195.000	281.000
		radii	191.667	3	29.023	15.142	53.000	172.000	225.000
		ulnae	185.000	2	29.698	16.053	42.000	164.000	206.000
		femora	335.000	5	40.410	12.063	114.000	280.000	394.000
		tibiae	298.333	3	34.210	11.467	65.000	272.000	337.000
		fibulae	272.333	3	20.551	7.546	37.000	259.000	296.000
8	5	humeri	268.500	4	29.727	11.071	70.000	233.000	303.000
		radii	217.600	5	15.868	7.292	38.000	201.000	239.000
		ulnae	198.800	5	12.398	6.236	32.000	184.000	216.000
		femora	384.600	5	25.245	6.564	52.000	355.000	407.000
		tibiae	321.200	5	22.830	7.108	60.000	291.000	351.000
		fibulae	300.500	4	14.295	4.757	30.000	286.000	316.000

Table C-8. Descriptive statistics - Ancestral Puebloan males

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
9	2	humeri	306.000	1			0.000	306.000	306.000
		radii	255.000	1			0.000	255.000	255.000
		ulnae	233.500	2	0.707	0.303	1.000	233.000	234.000
		femora	410.000	1			0.000	410.000	410.000
		tibiae	364.000	1			0.000	364.000	364.000

Table C-8. Continued

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
9	2	fibulae	349.500	2	6.364	1.821	9.000	345.000	354.000
10	10	humeri	304.222	9	12.706	4.177	40.000	281.000	321.000
		radii	251.833	6	12.608	5.007	37.000	232.000	269.000
		ulnae	233.286	7	13.913	5.964	38.000	212.000	250.000
		femora	419.778	9	12.101	2.883	37.000	404.000	441.000
		tibiae	357.200	10	13.983	3.914	51.000	330.000	381.000
		fibulae	341.143	7	10.699	3.136	30.000	325.000	355.000
11	26	humeri	303.250	24	12.712	4.192	47.000	278.000	325.000
		radii	256.050	20	11.409	4.456	44.000	236.000	280.000
		ulnae	238.474	19	11.389	4.776	39.000	218.000	257.000
		femora	424.217	23	20.392	4.807	84.000	369.000	453.000
		tibiae	359.087	23	17.347	4.831	58.000	323.000	381.000
		fibulae	349.850	20	14.151	4.045	59.000	316.000	375.000
12	11	humeri	310.700	10	17.976	5.786	56.000	275.000	331.000
		radii	260.750	8	12.476	4.785	42.000	238.000	280.000
		ulnae	246.625	8	7.763	3.148	23.000	239.000	262.000
		femora	437.333	9	23.092	5.28	80.000	395.000	475.000
		tibiae	366.300	10	15.217	4.154	52.000	335.000	387.000
		fibulae	353.750	8	14.916	4.217	44.000	327.000	371.000

Table C-9. Descriptive statistics - Ancestral Puebloan females

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
9	8	humeri	254.143	7	38.325	15.08	87.000	199.000	286.000
		radii	212.750	4	29.781	13.998	64.000	169.000	233.000
		ulnae	195.250	4	28.016	14.349	62.000	154.000	216.000
		femora	354.000	6	49.031	13.85	115.000	291.000	406.000
		tibiae	314.571	7	25.520	8.113	75.000	259.000	334.000
		fibulae	290.250	4	41.234	14.206	89.000	229.000	318.000
10	9	humeri	283.800	5	4.266	1.503	11.000	280.000	291.000
		radii	227.800	5	7.294	3.202	19.000	218.000	237.000
		ulnae	217.250	4	7.632	3.513	18.000	208.000	226.000
		femora	394.778	9	14.593	3.696	47.000	364.000	411.000
		tibiae	327.000	9	14.186	4.338	43.000	299.000	342.000
		fibulae	324.500	4	9.037	2.785	19.000	316.000	335.000
11	43	humeri	281.564	39	11.066	3.930	49.000	261.000	310.000
		radii	234.424	33	10.627	4.533	44.000	209.000	253.000
		ulnae	216.000	38	9.656	4.470	38.000	195.000	233.000
		femora	397.846	39	14.414	3.623	62.000	374.000	436.000
		tibiae	331.821	39	13.751	4.144	50.000	306.000	356.000
		fibulae	322.867	30	14.335	4.440	60.000	288.000	348.000
12	17	humeri	284.667	15	13.151	4.620	48.000	267.000	315.000

Table C-9. Continued

DA category	N	Element	Mean	n	Std Dev	COV	Range	Min	Max
12	17	radii	234.800	10	11.942	5.086	34.000	219.000	253.000
		ulnae	217.273	11	11.490	5.288	31.000	204.000	235.000
		femora	397.882	17	14.326	3.601	56.000	374.000	430.000
		tibiae	335.467	15	11.951	3.563	38.000	315.000	353.000
		fibulae	323.444	9	15.436	4.772	50.000	301.000	351.000

APPENDIX D
POSTCRANIAL MEASUREMENTS

Appendix D depicts the maximum long bone measurements of the humeri, ulnae, radii, femora, tibiae and fibulae of all individuals. “Maximum length” is defined as the greatest distance from the proximal most point to the distal most point for each element. Measurements were recorded to the nearest millimeter using an osteometric board.

All illustrative figures present the anterior view of the right post-cranial element. In each image the juvenile element is on the left, adult element on the right.

Figure D-1. Juvenile and adult humeri measurement

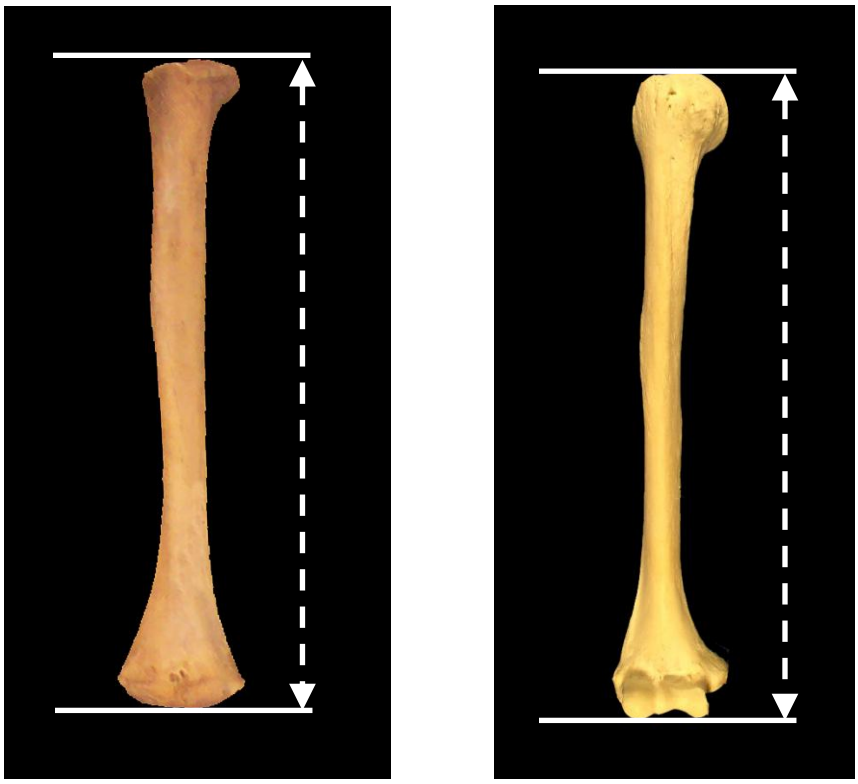


Figure D-2. Juvenile and adult ulnae measurement

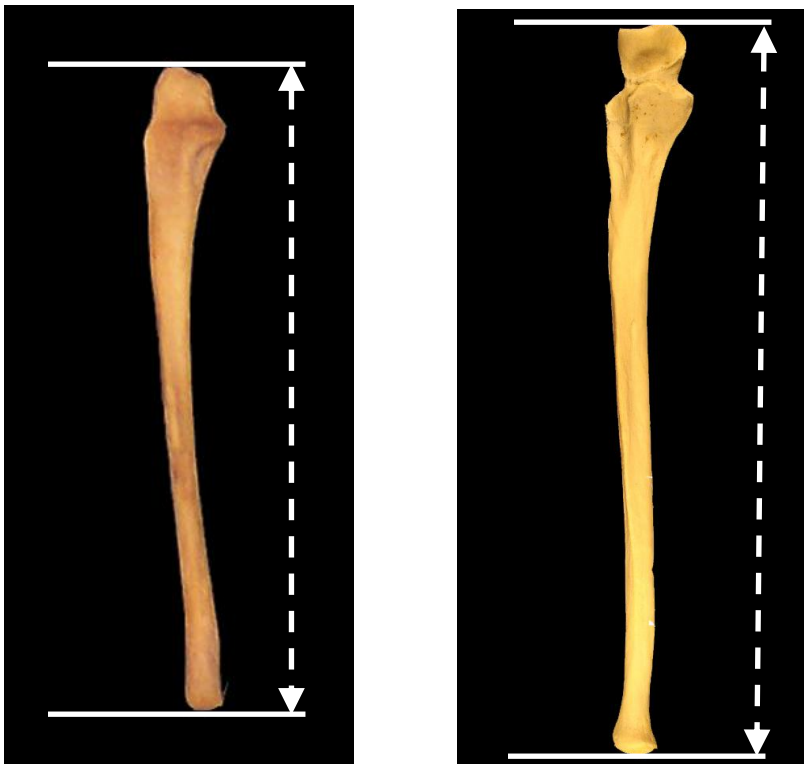


Figure D-3. Juvenile and adult radii measurement

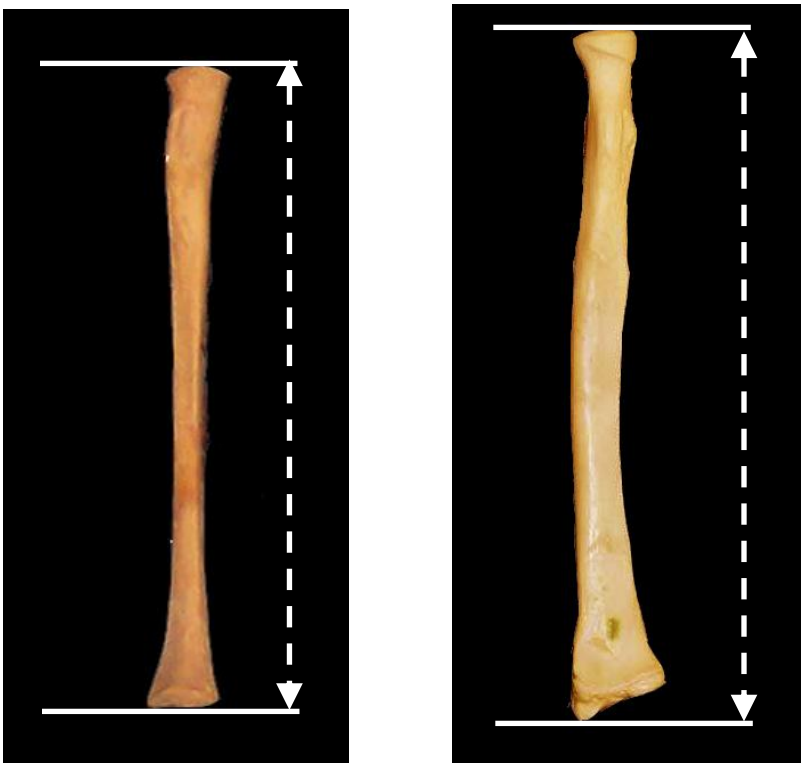


Figure D-4. Juvenile and adult femora measurement

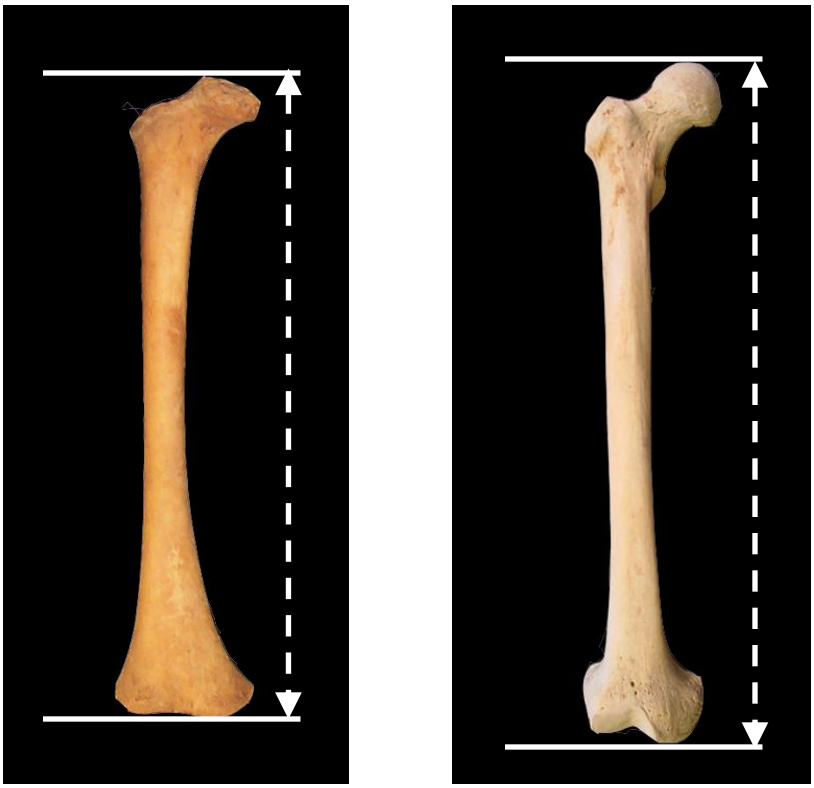


Figure D-5. Juvenile and adult tibiae measurement

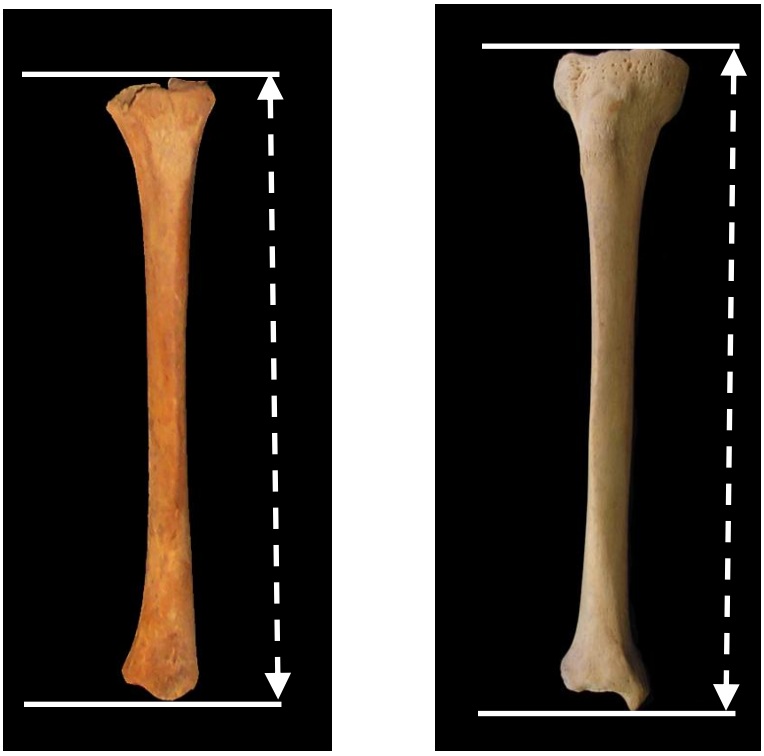
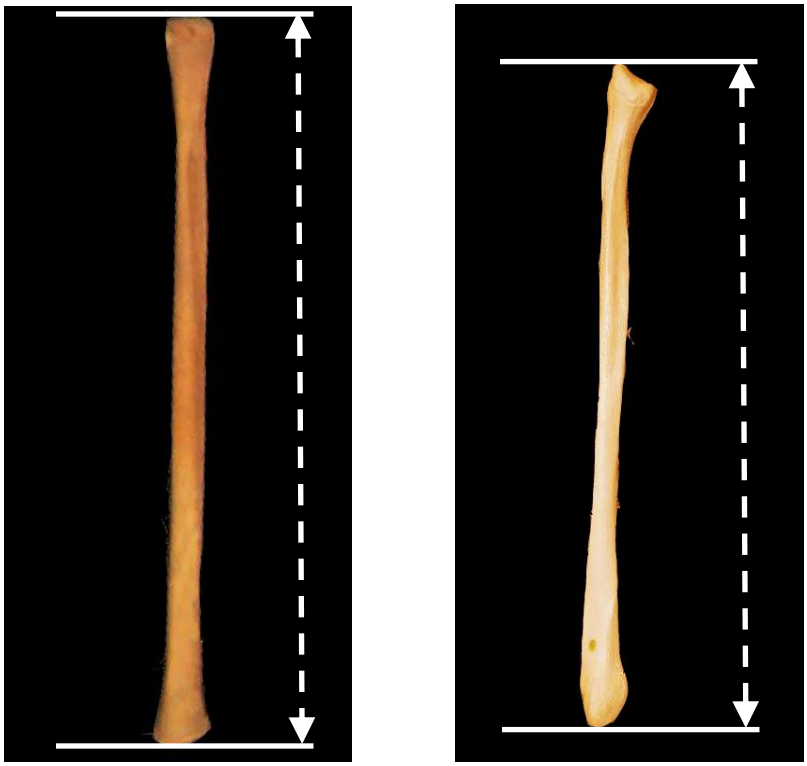


Figure D-6. Juvenile and adult fibulae measurement



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BIOGRAPHICAL SKETCH

Erin B. Waxenbaum received her bachelor of arts and master of arts in anthropology from Brandeis University in May 2002. From 2003-2007, she pursued a doctorate in anthropology specializing in skeletal biology, growth and development, and forensic anthropology at the University of Florida. During this period, she taught for the Department of Anthropology and Honors College and was involved in casework at the C.A. Pound Human Identification lab, University of Florida. This work resulted with a Ph.D. project entitled "Ontogenetic variation in three Native North American populations: eco-geographic effects on human growth and development" (Dr. Anthony B. Falsetti, chair).