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Mandibular Ramus Height as an Indicator of Human Infant Age

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ABSTRACT: There were two goals to be achieved from the analysis of 53 skeletonized infants from the Southwest Collection at the National Museum of Natural History. The first objective was to determine whether this infant sample could be aged based on a mandibular measurement. The second was to determine which dimension of the mandible, if any, most accurately predicts infant age within a six-month range.

Seven osteometric measurements were applied to each mandible. Statistical analysis determined that the individuals in the Smithsonian's Southwest Collection that were under two-years-old could be accurately aged to within six months. Out of these seven measurements the most accurate age-at-death estimates were generated based on the maximum height of the mandibular ramus. This finding can potentially aid investigators in determining the age-at-death of infants.

KEYWORDS: forensic science, forensic anthropology, age-at-death, osteometrics

Determining the age of a human infant from skeletonized remains can be problematic. In both forensic and archeological settings the fragility of infant remains requires that an intensive and careful recovery be performed in order to ensure that a proper analysis can be accomplished. This type of recovery is best undertaken by someone trained in both archaeological methods and in the recognition of subadult remains. The delicate nature of infant remains and employing individuals who are not trained in osteology, and who may not recognize juvenile bones, may result in an inadequate recovery of the material (1). This, in turn, can hinder the determination of the age-at-death of the infant.

The current methods of infant aging, at least the ones based on dental eruption and long bone length, are limited due to the issues mentioned above. It is therefore important to develop a method of aging that can overcome the problems of eroded long bones, missing dentition, and easily overlooked skeletal components. Creating an aging method based on the analysis of the mandible may provide an accessible and accurate estimator of age.

Due to their dense nature, the body and the ascending ramus of the mandible are often preserved in the archeological record. The unique shape of the mandible makes it easily identifiable, whereas infant long bones may not be recognized without their epiphyseal components and may be overlooked. This makes the recovery of the mandible far more likely, even by individuals who are not intimately familiar with skeletal material.

Dental eruption and calcification are currently regarded as the most accurate determiners of juvenile age (2,3,4). In the infant the developing tooth crypts are filled with soft tissue. Consequently the deciduous teeth and the forming tooth buds are often released from their positions and lost when this tissue has decayed. This can result in the loss of valuable information. By looking at other aspects of the mandible, a lack of deciduous dentition will not result in the inability to arrive at an accurate age assessment.

The maturation and growth of the face will determine the appearance of an infant mandible. It is hypothesized (5) that this growth occurs at a predictable rate. It is known that as individuals grow out of the infant stage cultural activity begins to affect the development of the mandible. Much has been written about the mandible's ability to conform to pressures placed upon it by chewing and activity (6,7). This flexibility of the mandible does not affect individuals of a very young age. As an infant, mastication and cultural activity have not been persistent enough to produce any modifications of the jaw. Therefore, until chewing and activity are introduced, the growth of the mandible should be relatively similar among infants.

Methods

The 53 skeletal infants who were analyzed came from the Southwest Skeletal Collection housed at the National Museum of Natural History in Washington, DC. The infants in this sample represent prehistoric Native Americans that were recovered in what are now New Mexico and Arizona. The collection represents the remains of a number of tribes and locations throughout the Southwest. The tribes represented are the Amoxiumqua, Hawikah, Guisiwa, Yoquilo, Quarai, Tsankawi, and the Heshatauthia. The sites represented in this sample are Pueblo Bonito, Chaco Canyon, Casa Grande, Canyon del Murte, and Canyon Chelly. This sample was chosen for its accessibility and the lack of availability of a large collection of infants of documented identity.

It is recognized that the sample appears greatly varied. This has the potential for an increase in error. As Sundick (8) points out, it is a fact that populations mature at different rates depending on the genetics and the nutrition involved. However, results of growth studies based on specific populations run the risk of being too narrow in scope due to the limits caused by genetic similarity. Lampl and Johnston (9) point out that a major source of error that occurs in all age-at-death estimates is systemic error. This is caused by a local population being subject to the same circumstances, thereby causing population-wide advances or delays in growth. This reduces the wider applicability of any age-at-death method based on a single population.

The sample used for this study is, out of necessity, cross sectional through both time and geography. All the individuals repre-

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sented in this sample are of Southwestern Native origin. They share a relatively similar geographic location with like climate, environment, and resources. However, the environmental conditions and access to resources are not identical for every individual. It is believed that this is beneficial to the study. Having a sample that is from different tribes and different sites, yet still shares similar characteristics and environmental conditions, reduces the chances of having skewed data that may result when only one, possibly, "abnormal" group is analyzed. The sample is believed to be similar in enough respects to generate acceptable results.

Each individual from the Southwest Collection was chosen based on the criteria that at least one currently recognized accurate method of aging could be applied. It was important that two independent methods of assessing age be available to reduce the amount of error in the study. In most cases, both long bone length and dental age estimates could be made. The most accurate age-at-death assessments were determined by dental analysis. Due to the limitations of the sample not all of the individuals could be aged by this method. When age estimates had to be based solely on diaphyseal length, the individual case had to have at least two, intact, identifiable long bones.

The diapyseal length and dental age charts presented in Ubelaker (4) were used to assign an age to each skeletal specimen. After each individual specimen was analyzed according to accepted standards, it was placed into one of four categories: Near Birth (NB) to 6 months, 6 months to 1 year, 1 year to 1.5 years, and 1.5 to 2 years. On the rare occasions where the age estimates fell between two categories, the individual was placed in the lower of the two categories. For example, an individual who was determined to be exactly 12 months old was placed in the 6 month to 1 year category. It was decided that a consistent adherence to this policy would not skew the data in any significant way. It must be noted that this occurred only twice; one individual was placed in category one, and the other was placed in category three. A breakdown of the sample determined there to be 15 individuals in the NB to 0.5 year category, 14 individuals in both the 0.5 to 1 year and the 1 to 1.5 year categories, and 10 individuals in the 1.5 to 2 year category. After the category determinations were made, a series of seven measurements was applied to each mandible. Each measurement was recorded to the nearest millimeter. The seven measurements and the landmarks associated with them are as follows [taken from Buikstra and Ubetaker (10)]:

"Length of the Body: The distance between the tuberculum mentale to the angle. Instrument: Sliding calipers.

Full Length of Half the Mandible: The distance between the tuberculum mentale and the articular condyle. Instrument: Sliding calipers.

Height of the Mandibular Body: The direct distance from the alveolar process to the inferior border of the mandible perpendicular to the base at the level of the mental foramen. Instrument: Sliding calipers.

Minimum Ramus Breadth: The least breadth of the mandibular ramus measured perpendicular to the height of the ramus. Instrument: Sliding calipers.

Maximum Ramus Breadth: The distance between the most anterior point of the ramus and a line connecting the most posterior point on the condyle and the gonial angle. Instrument: Sliding calipers.

Maximum Ramus Height: The direct distance from the highest point on the mandibular condyle to gonion, a point along the rounded posteroinferior corner of the mandible between the ascending ramus and the body. Instrument: Sliding calipers or mandibulometer.

Gonial Angle: The angle formed by the inferior border of the corpus and the posterior border of the ramus. Instrument: mandibulometer."

Statistics

The ANOVA Tests

The ANOVA test simultaneously takes into account all four of the group means and tests the hypothesis that all are estimates of the same population mean. In this study the null hypotheses for the ANOVA tests state that in each category the variation of measurements is due to chance. It is the variance between the sample means that is of interest. If the variance of means between age categories is found to be significant, it can be stated that all four categories are distinct and that the means of each are not equal.

Each of the seven mandibular measurements taken were used as dependent variables and tested against the independent variable of age category. Ramus height (HTR), maximum width (MWT), length of half the mandible (LGH), minimum ramus breadth (MNBR), height of the body (HTB), length of the body (LGB), and gonial angle (GAN) were found to be significantly influenced by the age category. Additionally ANOVA tests were performed on two other ratio variables to determine if they were significantly influenced by age category. The first of these variables was a ratio of ramus height to body height (HTR/HTB). The second was a ratio of ramus height to body length (HTR/LGB). These variables were considered because of their relationships during the growth phase of the mandible. Only the second of these two was found to be significant.

The variable ramus height had an F-value of 60.17 and a $Pr > F$ of 0.0001, which allowed the null hypothesis to be rejected. Maximum width of the ramus had an F-value of 32.93 and a $Pr >$ of 0.0001, so again the null could be rejected. Length of half the body had an F-value of 44.72 and a $Pr > F$ of 0.0001, so the null could be rejected. Minimum ramus breadth had an F-value of 41.16 and a $Pr > F$ of 0.0001, so the null could be rejected. Height of the mandibular body had an F-value of 19.16 and a $Pr > F$ of 0.0001, so the null could be rejected. The length of the body had an F-value of 30.66 and a $Pr > F$ of 0.0001, so the null was rejected. Gonial angle had an F-value of 11.81 and a $Pr > F$ of 0.0001. If the ratio of HTR/LGB had an F-value of 12.49 and a $Pr > F$ of 0.0001, so the null could be rejected. If the ratio of HTR/HTB had an F-value of 0.99 and a $Pr > F$ of 0.4042, the null hypothesis could not be rejected.

Tukey's Studentized Range Test

Because most of the variables looked at yielded significant results, a comparison was made to determine which generates a more accurate age estimate. Tukey's studentized range test was used to evaluate the aging accuracy of each variable. This test is designed to determine if groups are statistically separable from one another. The results of this test showed that only the variable HTR could statistically separate each of the four age groups. MWT, LGH, MNBR, and LGB could not statistically separate individuals found in group two from individuals in group three. Neither the HTB nor the HTR/LGB ratio could statistically separate group three from group four and group two from group three. GAN could not statistically separate group one from group two and group two from group three.

Descriptive Statistics

The results generated in this study were arranged in a table that is similar to the one found in Ubelaker (4) for age assessment based on long bone length. The means, standard deviations, and the minimum-maximum ranges of the four sample generated age categories are presented in it. Table 1 shows the descriptive statistics for all the variables and ratios analyzed in this study. These findings indicate that the sample of infants from the Smithsonian's Southwest collection could be accurately aged, within six-month intervals, based on the mean height of the ascending ramus of the mandible. Maximum ramus height can clearly distinguish between category one individuals and category four individuals. This table, however, indicates that there is a great deal of overlap between age category two and age category three (see Table 1 and Fig. 1). The wide range between the maximum and minimum values in age category two presents some problems. This wide range could cause a category three individual to be classified into category two. The fact that 34 mm is the maximum ramus height for both category two and category three may indicate an outlier is present.

The age categories that were created for this study are arbitrary dimensions of a continuous process of growth. Every individual grows at a relatively different rate. Overlap between the maximum values of one age category and the minimum values of the next category is to be expected. However, the overlap between age category two and age category three is extreme. Therefore, caution should be taken when an individual is found to have a ramus height of 29 to 34 mm.

Results

Fifty-three specimens were used to compile data for this study. Seven dimensions of the mandible were measured on each specimen. The measurements for each mandibular dimension were analyzed using an ANOVA test in order to ascertain if an individual could be placed into an age category based on a particular mandibular dimension. The four age categories used in this study are: near birth to six months (NB to 0.5 year), six months to one year (0.5 to 1.0 year), one year to one and a half years (1.0 to 1.5 year) and one and a half years to two years old (1.5 to 2.0 year). The ANOVA tests for maximum ramus height (HTR), maximum ramus breadth (MWT), length of half the mandible (LGH), minimum ramus breadth (MNBR), height of the body (HTB), length of the body (LGB), and gonial angle (GAN) all produced significant results.

After the results of ANOVA tests were found, a series of Tukey's Studentized Range tests were performed using each mandibular dimension as the dependent variable. These tests were used to compare each age category to the other three based on the measurements of one of the mandibular dimensions. This test determines if there is a significant difference between each age category. The Tukey Studentized Range tests found that the only mandibular dimension, which could statistically differentiate between each age category, was maximum ramus height (HTR). Descriptive statistics were then run in order to determine the mean, the standard deviation, and the range of each mandibular dimension.

TABLE 1—*Descriptive statistics for maximum height of the mandibular ramus in millimeters. Agecat. 1 = 0.0 to 0.5 years old, Agecat. 2 = 0.5 to 1.0 years old, Agecat. 3 = 1.0 to 1.5 years old, Agecat. 4 = 1.5 to 2.0 years old. N = sample size.*

The SAS System
Analysis Variable: HTR

N	Mean	Std Dev	Minimum	Maximum
Agecat = 1				
15	20.7333333	3.1952345	17.0000000	27.0000000
Agecat = 2				
14	28.0000000	3.4641016	21.0000000	34.0000000
Agecat = 3				
13	31.5384615	1.6132464	29.0000000	34.0000000
Agecat = 4				
9	35.4444444	2.4551533	32.0000000	39.0000000

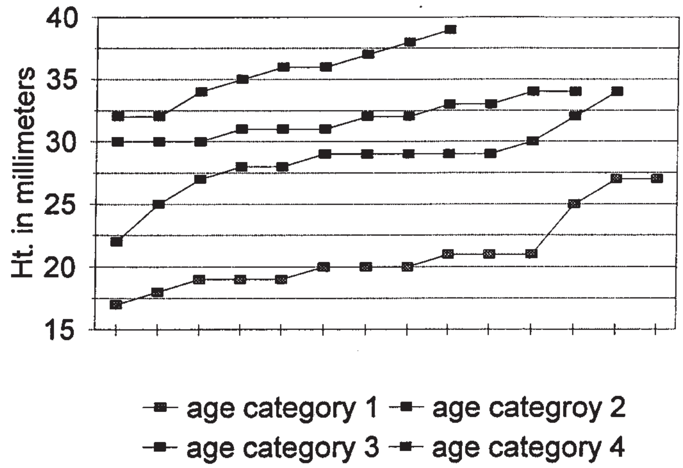

FIG. 1—*Distribution of maximum ramus height by age category. Age category 1 = 0.0 to 0.5 years old, age category 2 = 0.5 to 1.0 years old, age category 3 = 1.0 to 1.5 years old, age category 4 = 1.5 to 2.0 years old.*

Discussion

Conclusions

This study was designed with two goals in mind. The first was to test a sample of subadults to determine whether an infant age indicator based on a mandibular dimension is possible. The second was to find which mandibular dimension, if any, most accurately predicts infant age within a six-month range.

The first goal was accomplished. It was discovered that the infant skeletal remains of the Smithsonian's Southwest collection could be placed into one of four six-month age categories. This placement could be made based on the measurement of certain dimensions of the mandible. This goal had to be realized before any attempt could be made at reaching the other.

The second objective was also met. It was found that, while many of the mandibular dimensions were significantly influenced by age, only one could accurately place an individual into one of the four prescribed age categories. This dimension is the maximum height of the ramus. This means that by measuring the height of the ramus each infant from the Southwest Collection could be definitively aged to within six months.

Sources of Error

There are two potential sources of error introduced when performing any type of analysis that requires measurements. These are interobserver error and intraobserver error. The first of these refers to the ability of two or more researchers to obtain the same measurement from the same bone. The second pertains to how accurate a single observer measures a particular specimen.

A simple comparison of measurements was made in order to determine if interobserver error played any significant role in the data collection portion of this thesis. During the time the author was collecting data at the National Museum of Natural History, another student of physical anthropology was also doing research with osteometric data. This individual was kind enough to remeasure ten of the specimens the author had previously measured.

The second observer was given a description and a diagram of each measurement that was to be taken. This set of measurements was then compared with the original. If any of the measurements showed more than 2-mm difference, a third measurement would have been required. This contingency proved unnecessary. There was never more than a 2-mm difference between the measurements of the two observers. Based on this evidence, two assumptions can be made. The first is that the data in this study are recorded accurately, and, second, the measurements and methods of this study are easily understood and replicable.

Even though the measurements used for this study are considered standards, a test was still performed to determine how well the researcher followed these standards. The data collection process, in part, consisted of seven measurements of the mandible. The standard landmarks and procedures used for taking each measurement can be found in Buikstra and Ubelaker (10). It would seem that having diagrams and explicit instructions as to how each measurement is to be taken reduces intraobserver error.

The collection of data from this sample took place over a period of four days. On the second day the first ten specimens that were measured on the first day were remeasured. Again, it was found that no second measurement differed by more than 2-mm from the one originally recorded. In this way it was determined that intraobserver error played no role in the data collection from this sample.

Walker and colleagues (11) introduce the topic of age and sex biases in the preservation of human remains. Differential preservation of infant remains caused by incomplete calcification can have a significant effect on the mortality profile of a sample. The possibility exists that the infant remains analyzed in this study do not represent the actual number of infants in the population. Besides the incomplete calcification, mistakes made during the recovery process can also contribute to the underrepresentation of infant skeletal material (1). Because the author did not recover the sample used, the bias that may be introduced due to these factors was unavoidable.

Steyn and Heneberg (12) claim that a serious problem encountered when dealing with an infant skeletal sample, or any skeletal sample for that matter, is that the sample consists of individuals who died. This means that the sample does not necessarily reflect the normal healthy infants or individuals of a population. Wood et al. (13) discuss this when they write about the osteological paradox. This is considered a problem of "selective mortality." They state that "This bias cannot be avoided . . . it is simply built into the very structure of the data" (p. 344).

Konigsberg and Frankenberg (14) maintain that in any anthropological case where age is estimated, rather than known, there will be bias. According to these authors the uncertainty of actual chronological age will cast doubt on a researcher's results. This caveat was considered during the design of this study. It is felt that the methods used to determine the ages of the specimens, dental characteristics, and long bone length in this sample adequately controlled the amount of bias.

Lampl and Johnston (9) note two primary sources of error that occur when dealing with juvenile skeletal material; the first is simply random error. This refers to the variability in maturation between individuals of the same chronological age. Systemic error is the second source of bias. This occurs when a shared environment alters the maturation process of a local population. This reduces the applicability of standards based on the sample (15).

The sample used in this study is relatively small. The reliability of the results is therefore somewhat suspect. An increase in the sample size, possibly by the addition of data from modern Native Americans of the Southwest, would help alleviate this problem. The sample, however, is large enough to produce reasonably reliable statistical results.

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