Age Estimation of a Skeleton: *Using the Methods of Pubic Symphysis Categorization, Cranial Suture Closure and Dentition*

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Abstract

When you pass away and eventually there is nothing left of you except for your bones, what will forensic anthropologists be able to tell the world about how you lived and who you were when you were alive? Was your story long, or was it cut short by outside forces? Forensic anthropologists can give skeletons a human identity. This tactic may also be used to aid in the process of helping law enforcement identify missing persons. Age estimation is one contributing factor to a biological profile. This essay examines various age estimation methodologies including evaluation of the pubic symphysis, cranial sutures and dental wear. However, each method of age estimation is subject to inaccuracy. Due to this, multiple methods must be used in order to narrow down a possible age group. These issues, along with possible solutions, will be discussed.

When you pass away and eventually there is nothing left of you except for your bones, what will forensic anthropologists be able to tell the world about how you lived, and who you were when you were alive? Was your story long, or was it cut short by outside forces? Forensic anthropologists can give skeletons a human identity. Age estimation is one contributing factor to a biological profile. Age estimation is a range of the youngest to oldest possible age of a person based on skeletal observations. These observations are made using multiple methods that categorize the condition of bone features into groups based on possible ages that closely match the condition of the skeleton. These methods include, but are not limited to, evaluation of the pubic symphysis, cranial sutures and dentition. However, each method of age estimation is subject to inaccuracy. Due to this, multiple methods must be used in order to narrow down a possible age group. These issues, along with possible solutions, will be discussed.

The human body changes over time. According to *The Human Bone Manual* by Folkens and White (2005), the early stages of fetal development stem cells differentiate into cartilage, which later converts into bone through the process of ossification. As children grow in height, epithelial plates in long bones allow for this increase in length. Eventually the bone tissues surrounding the epithelial plate begin to close as adolescents finish puberty and become fully developed adults. However, these markers do not have exact parameters for stages of development in children. It must also be considered that boys and girls develop at different rates. It becomes more difficult to determine the sex of a skeleton before secondary sex characteristics have developed. The variation between adult males and females become an added challenge as the standard for categorization between developmental stages may differ. This variation can best be seen in the pelvis, which will later be addressed in detail. The degree of joint closure may be evaluated in people of all ages, as the older an individual is, the higher the degree of closure becomes. Those over the age of fifty may be aged based on the wear and tear present on bones and joints. Unfortunately for forensic anthropologists, some individuals may age more gracefully than others. This makes the results of age estimation in the elderly highly ranged by twenty to thirty years.

Evaluation of the Pubic Symphysis

The first method of age estimation we will be discussing is the evaluation of the pubic symphysis. The pubic symphysis is a cartilaginous joint on the anterior side of the os coxae and joins the two bones together making the pelvis. Either side of the pubic symphysis where the joint connects to the bone wears away over time changing the shape and texture. This process of wear continues throughout a person's life with noticeable differences between those of different ages. In 1920, the Todd method of aging a skeleton using the pubic symphysis was developed. Todd noted four separate features of the pubic symphysis and recorded the condition of each feature based on the age of the individual (Folkens & White, 2005, pp. 374-377). He was then able to outline ten phases of degradation and created a standard of comparison between age groups. Generally, the pubic symphysis of younger individuals, starting at the age of 18, have rounded protrusions along the lateral surfaces, which become smoother with age (Folkens & White, 2005, p. 376). Todd notes,

> The young adult human pubic symphysis has a rugged surface traversed by horizontal ridges and intervening grooves. This surface loses relief with age and is bounded by a rim by age 35. Subsequent erosion and general deterioration of the surface are progressive changes after this age. (Folkens & White, 2005, p. 374)

The Todd method is highly accurate in estimating the age of skeletons under the age of 35 because the pelvis continues to develop up until the point of fusion between the pubic symphysis and the pubic ramus. The phases that the pubic symphysis goes though between the ages of late teens to mid-forties are so distinct that age estimation can be determined within a margin of error of five years. However, after the age of 50, the Todd method is unable to pinpoint a possible age within a few years and the margins between the possible age ranges become much wider. This room for inaccuracy arises because of the variation between skeletons can be affected by factors such as weight, daily activities and lifestyle, or degenerative diseases. Other concerns with Todd's method are the lack of variation in his population when the study was originally

conducted; the pubic symphysis that were used came from only Caucasian men. This means that Todd's method does not account for women or men of other ethnic populations. This is significant because the effects of childbearing on the pubic symphysis was not studied, nor were the variations that may be seen in other ancestral populations that do not show up in Caucasian men (Folkens & White, 2005, p. 374).

Suchey and Brooks later expanded on Todd's method of pubic symphysis identification in order to account for both men and women (Folkens & White, 2005, p. 379). The Suchey-Brooks method is refined to include only six phases with two different standards—one for men and one for women, noted as follows:

> In difference from many other techniques the SB method does not involve trait scoring, but instead uses a pattern-based approach . . . classification of pubic bones into the different phases is done via an overall comparison with the 12 male and 12 female reference bones selected by Suchey and Brooks. For each male and female phase, there are two reference bones representing typical early and advanced patterns within each phase. (Warmlander & Sholts, 2010, p. 132)

Though the Suchey-Brooks method, like the Todd method, does not include changes resulting from pregnancy and childbirth.

In 1979, Suchey and Kelley conducted a study that evaluated the pubic symphysis of women who had given birth. Their new method accounted for damage that may occur to the joint during pregnancy and childbirth. This might later be identified in an unknown skeleton. The study found that there were a notable number of parturition cases that showed pitting along the pubic symphysis. However, this pitting later disappeared with the degradation of the joint and there was no correlation found between the number of children the women had and the markings left behind. In rare cases, pitting of the pubic symphysis was also observed in men. In relation to aging a skeleton, the variation that is seen on the pubic symphysis of women who have conceived children will wear down over time. Later research may be done to find a

standard of measurement for how many years it has been since a woman has had a child based on the diminution of pits (Folkens & White, 2005, p. 380).

Degree of Cranial Suture Closure

Before discussing the method of evaluation of cranial suture closure, we must first describe how cranial sutures are created and their evolutionary means for existing. When a baby is born, the cranium is not fully formed and is divided into sections of bone by fontanelles. Fontanelles are composed of dense, fibrous connective tissue creating a thin protective layer over the brain. A scholar notes,

> The bones of the skull are also growing, but they fail to keep pace. At birth, the cranial bones are connected by areas fibrous connective tissue . . . . The connections are quite flexible, so the skull can be distorted without damage. Such distortion normally takes place during delivery, and the changes in the head shape ease the passage of the infant through the birth canal. (Bartholomew, Martini, & Nath, 2014, pp. 224-226)

Over time, bone grows over the fontanelles. Each section of bone meets and forms a cranial suture creating a zig zagging pattern across the skull. By the age of two, all sutures are fully formed. These sutures continue to grow closer together throughout a person's life until finally the suture lines are no longer visible.

Meindl and Lovejoy refined a method of cranial suture evaluation that measures the amount of closure between cranial sutures using a scale from zero to three (Folkens & White, 2005, p. 369-371). The amount of closure can then be used to determine the age of the individual. The older a person is, the more closure between sutures will be observed. A score of zero means that the suture was open, a score of one would be given to a suture with minimal closer, a score of two would be given to a site with significant closure, and a score of three would be given to a completely obliterated suture showing complete fusion between cranial bones (Folkens & White, 2005, p. 371).

A study was done by Baccino et al. (2008) using a similar method of identification of front sphenoidal cranial sutures in order to establish the age of the individual at the time of death. The study was done using a method based on that of Meindl and Lovejoy's method. This method instead uses a scale of one to four for evaluation. The cadavers studied were found to range in ages 18 to 91 in males, and ages 18 to 93 in females. At stage one, the suture is open or irregular in closure pattern. At stage two the suture is primarily closed, at less than 50% closure. In stage three, there is significant closure of more than 50 %, and finally, stage four sees a complete closure of the suture. The results of the study showed a correlation between the average age of the subjects increased as the degree of suture closer increased. However, as the average age of each group evaluated increased, so did the standard deviation of years. This means that the range of possible of age becomes less specific in individuals of higher predicted age showing more front sphenoidal suture closure.

The results were highly accurate, though the age range for each group was divided based on which of the four stages of suture closure was seen on the skull and the age ranges used for each stage were high. For example, cadavers with a cranial suture closure at stage four were said to likely be between the ages of 24 and 93. In turn, this makes the statistical data unspecific and the method unreliable when applied to an unidentified skeleton in order to estimate age at death. The older the individual is, the wider the possible age ranges. This occurs as the case with many methods of age estimation reliant on erosion of bone after the age of 60 the age becomes much more difficult to pinpoint. A possible solution to this issue may be to look at the closure of multiple cranial suture patterns, rather than just the front sphenoidal suture. Each suture closes at a different rate and measuring multiple patterns may provide anthropologists with multiple ranges of possible age. These can then be cross-referenced and used to find a more specific age range (Baccino et al., 2008, pp. 275-289).

Evaluation of Dentition

Age estimation can also be determined using dentition. In children the developmental stages, teeth can be closely observed using x-rays as a living child grows then be compared with the dental records of unidentified children to

determine an age estimation at death. Provided, this method would need to be used in conjunction with other methods in order to draw the conclusion that the unidentified body is that of a child. Then, dentition would later be used to narrow down the age range. As stated by Lee et al. (2011), "Dental development is a useful indicator of maturation because of its high reliability, a low coefficient of variation, and resistance to environmental effects" (pp. 41-46). The younger the child is, the more distinctive the developmental stage is. Children younger than two years can be identified with a standard deviation of several months, while those around age 15 can be identified with a standard deviation of 3 years (Folkens & White, 2005, p. 366).

The four distinctive stages of tooth formation used by forensic dentists for age analysis in adolescents have been outlined by Folkens and White (2005):

> First, most deciduous teeth emerge during the second year of life. The two permanent incisors and the first permanent molar usually emerge between six and eight years. Most permanent canines, premolars and second molars emerge between 10 and 12 years. Finally, the third molar emerges around 18 years. (pp. 365-366)

However, variation between standards of exact formation and eruption of teeth vary between ancestral groups, sometimes by a matter of months. This is a critical difference in children under the age of two as full teeth have not yet erupted form the gums, but formation of teeth in the mandible has begun. This issue may be solved though the formation of standard measurements for comparison between children of the same ancestry. A similar problem arises when comparing males and females, as girls are ahead of boys in growth and development. This factor is accounted for as dentition in men and women are always compared separately, even within ancestral groups.

In some cases, wisdom teeth may be used to identify an individual as being in their late teens or early twenties, if their wisdom teeth are developing or erupting from the gums. Though this is often unreliable, as humans are evolving and they're losing their wisdom teeth, progressively becoming obsolete. This results in variation with some people having between zero to four wisdom teeth.

Other attributing factors may also affect the ability to use of dentition in ageing a skeleton, such as the lack of teeth present, poor nutritional health while the individual was alive, poor dental hygiene and heavy smoking. In some cases, skulls of unidentified people are found missing teeth, as teeth may fall out of the head after death due to movement of the body attributed to scavengers or perpetrators attempting to hide or dispose of a body.

There are other ways to complete an age estimation using dentition with a lack of teeth as well. Teeth are held into both the maxilla and the mandible by an immovable joint called dental cementum. Over time, annulation occurs, resulting in a scoring of lines in the cementum. These lines coincide with seasonal changes; a pair of light and dark lines represents a calendar year. These pairs of lines can then be counted to determine the age a skeleton, along with providing the season during which the individual died. This method of aging works similarly to counting rings on a tree stump to figure out the age of the tree, with each ring representing a year the tree has lived. Counting line pairs within dental cementum works best with individuals between the ages of 21-45 with a standard deviation of only 2.8 years, deeming this method of age determination highly accurate. The only issue with using this method of identification is that there is no standard magnification used for the technique when looking under a microscope which may change the results of an identification and make the method difficult to recreate. This factor tests the validity of the study meaning more research would need to be done in the future in order to create a standard for the method with replicable results subject to peer review (Grosskopf & McGlynn, 2011, pp. 275-289).

Conclusion

The methods of age estimation most commonly used by forensic anthropologists are the pubic symphysis, cranial sutures, and dentition. These methods are continually developed in order to create a more accurate and concise picture of what age an individual was at their time of death. Todd's method of comparison between the 10 phases of pubic symphysis modification over time is an accurate representation of Caucasian men however, the method has been adjusted by Suchey to account for women and people of other

ancestry groups. The method of measuring closure of cranial sutures has been unreliable in the past, because the lack of specificity among age ranges even with multiple suture evaluation. However, anthropologists continue to use the method because the cranium is almost always present during evaluation unless purposely removed and not found with the body. Evaluation of teeth remains one of the most promising ways of identifying exact age in children based on the stages of development of the front teeth and molars. This shows distinct differences in development leading to the conclusion of a more exact age, within a few months to the span of a year. Adult dental cementum allows forensic anthropologists to count the years of an adult's life much like you would count rings in a tree stump to identify age. An age estimation of a skeleton is just one portion of a biological profile that helps give an identity to a victim, providing insight into the gnawing question, *who was this bag of bones?*

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