J Forensic Sci, Jan. 1977, Vol. 22, No. 1

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Age and Sex Determination of Subadult Skeletons

Forensic anthropologists who work in the medicolegal area are frequently requested to examine the partial or complete remains of individuals, with the goal generally being the identification of the individual in regard to age, sex, race, and stature. These data may then be used in an attempt to learn the identity of the individual or individuals. The condition of the material available for analysis varies tremendously. Complete skeletons with or without soft tissue should present the fewest problems. Those bodies which are less complete, consisting of parts of a skeleton only, present more problems in identification and in many instances may not be identifiable at all, although there are instances on record of individuals being identified on the basis of a few teeth and fragments of a mandible or maxilla.

In regard to the identification of skeletal material two categories can be identified and treated differently from one another: the first would include those individuals who were still growing and the second would include those individuals whose growth had ceased. This latter category includes individuals in the age range of approximately 20 years and beyond, while the former group would include fetuses and individuals up to the age of 20. Aging criteria for the older individuals are well presented by McKern and Stewart [*1*] and Kerley [*2*] and thus will not be presented here. Rather, my aim here is to review the current state of techniques applicable to age/sex determinations of subadult skeletons.

Krogman [*3*] suggests that most skeletal identification problems deal with adults rather than subadults, and while my experience does not entirely agree with this, it is obvious from the literature on skeletal identification techniques that a considerably greater amount of work has been done on age changes in adult individuals rather than in subadults.

This situation can be explained in part by the nature of the material that is available. The greatest strides in skeletal identification work have been made in skeletal collections where age and sex are known, such as the Todd and Terry Collections or the Korean War Dead Collections that were examined by McKern and Stewart [*1*]. These collections unfortunately, or in other respects fortunately, do not contain subadult individuals, at least in the quantities needed for analysis. Furthermore, there are not, in fact, any large collections of subadult skeletons of known age and sex. In large part because of this, forensic scientists have resorted to using growth data obtained in radiological studies of living children. Since these data were collected in all instances for reasons other than for forensic purposes they are not as valuable as they could be.

Data sources forensic scientists have overlooked are those skeletal collections that contain large numbers of subadult skeletons, such as archaeological collections available in museums and universities here in North America and elsewhere. It has been demonstrated by a number of investigators that infant and subadult mortality is relatively high in prim-

Received for publication 16 March 1976; accepted for publication 21 June 1976.
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itive populations, with one half of a total burial population generally in the subadult age range and one half of this subadult population in the age range from birth to 5 years. In populations such as that represented in the Indian Knoll site in Kentucky where 1234 burials were originally excavated, 647 or 52.4% are reported as being under 21 years of age, and sites of this size are not uncommon. To date, only four studies have examined skeletal age changes as observed in archaeological collections, and these have been restricted to American Indian skeletons and Eskimos. The studies include those by Stewart [*4*], Johnston [*5,6*], Sundick [*7*], and Merchant [*8*]; the former investigated Eskimo and Indian samples while the latter three studies used only American Indian samples.

With regard to the use of these skeletons for establishing standards for age determination in medicolegal cases, a problem arises in that sex and age of the skeletons are not known. In the case of sex determination of subadult skeletons some physical anthropologists maintain that sex can be determined in young skeletons, prior to the age of puberty and before the time that the three major segments of the innominate bone fuse together, by examination of the shape and size of the pelvis. Support for this idea has come from studies by Reynolds [*9*] and Boucher [*10*]. Reynolds examined radiologically 95 individuals, aged from birth up to 1 year, and took measurements and calculated pelvic indexes from the resulting X-rays. His data suggest that a sex difference does, in fact, exist in these individuals. Boucher examined macerated pelves from 96 American black and 33 American white fetuses, taking measurements of the sciatic notch and the subpubic angle, and found sex differences in both of these angles. In spite of the fact that both of these studies showed that sex differences exist in the pelves of fetuses and infants up to the age of 1 year, neither of these studies can be used to determine sex in these young individuals. This is because the angles used by both studies to show sex differences are determined by the cartilage that holds the bones together. These angles cannot be determined from the separate bones which comprise the juvenile pelvis.

Hunt and Gleiser [*11*], using the fact that there appears to be a closer correlation in dental age than skeletal age between males and females throughout the growing period, suggested an interesting method for determination of sex in unknown skeletons. Basically, what they suggested is that for each unknown skeleton a dental age and a skeletal age should be determined separately with standards for both males and females. If the resultant dental age and skeletal age from male standards were closer to one another than those found for female standards, then the unknown skeleton would be male. If both the dental age and skeletal age were more similar to female standards, then the unknown skeleton would be a female. They tested this hypothesis using, as they describe, an unrealistic sample consisting of carpal X-rays and dental X-rays from 49 living males and 45 living females. Not too surprisingly they came up with reasonable results, determining the sex correctly in 73% of 2 year olds, 76% of 5 year olds, and 81% of 8 year olds. They suggest that this study is unrealistic because of the difficulties involved in determining a carpal age in skeletons. Based on my analysis of approximately 300 subadult skeletons, I fully agree that it is impossible to determine a carpal age from skeletal remains. However, I believe the idea has merit, as I was able to ascertain the sex of individuals from the age of approximately 12 years onwards by looking at the difference between skeletal age and dental age. Males in all instances were less mature skeletally than females of the same dental age. Sex of each of these individuals was confirmed by pelvic morphology, as the three elements comprising the innominate bone had begun to fuse by this time. With additional work I believe a technique can be developed to ascertain the sex of subadult skeletons.

With regard to the age of subadult skeletons, investigators in the past have used either a dental age or a skeletal age, but it was not until relatively recently that a study was done to show which of these measures gave a more reliable estimate of chronological age. Lewis and Garn [*12*] investigated this question by using a sample of children from the Fels Research Institute longitudinal growth study and found that dental development correlates better with chronological age than does skeletal development. Tooth formation, furthermore, proved to be a more reliable criterion in the assessment of chronological age than was tooth eruption. Tooth formation also has the advantage that it can be studied over a relatively longer period of time than tooth eruption.

In view of this study it seems that we should place greater emphasis on tooth formation as a means of estimating chronological age than on such criteria as tooth eruption or skeletal development. The standard most commonly used is the one developed by Schour and Massler [*13*], and while it has been pointed out by many investigators that the sample used by them was too small, the standard has the advantage that it is relatively easy to use. The problem with it is that the range given for the age of maturation and development of individual teeth is too narrow.

Other dental standards that could be used include those by Moorrees et al [*14*], Garn et al [*15*], Nolla [*16*], Demirjian et al [*17*], and Anderson et al [*18*]. The standards of Nolla and Demirjian et al differ from the others in that a complete dentition is required to determine a maturity rating. Demirjian et al are also the only investigators who tested to see whether a different age would be assigned if fewer teeth were used and found that the age determined might be off by as much as 5 weeks at 8 years of age when six teeth are used instead of seven.

Now that I have shown that standards are currently available to assign dental ages to unknown individuals, a number of cautions should be mentioned. First, it is quite well known that populations mature at different rates, some populations showing tooth formation and eruption at earlier ages than others, and other populations showing later maturation than the standards. These differences in maturation rate are due in part to genetics and in part to nutrition. Second, it is also known that some populations show different sequences of tooth formation and eruption than others. For instance, in white populations it is generally found that central incisors, both upper and lower, erupt before the lateral incisors. In American Indian populations this is generally not true; all four lower incisors tend to erupt before any of the upper incisors. Third, it is also known that there is a great deal of variation between individuals in the same population, some children being early maturers, others being late maturers. A fourth point which should be mentioned, but which is not that important in most forensic cases, is that a secular trend has occurred in most maturational events, which means that the standards developed on today's populations may not be applicable to populations from the past.

In view of these four points just mentioned, it should be seen that it is difficult, if not impossible, to give a specific estimate of age such as "the individual at the time of death was 5 years old." What we should be doing, and is not always done, is to express age estimates in ranges of years. Two-year ranges would not be unreasonable for the first 5 years of life, while 4-year ranges might not be considered out of line for the next 10 years when sex differences, population differences, and individual differences, particularly in the age of puberty, are taken into account.

Now that we have seen that we can assign a dental age to skeletons using various dental standards, the next question becomes one of what to do if the dentition is missing or is too broken to use for an age assessment. Until relatively recently the best that could be done was to estimate skeletal age on the basis of the appearance or fusion of the epiphyses. Then Johnston [*6*] published an article indicating the lengths of the six major long bones from the Indian Knoll Archaic Indian skeletal collection for ages up to 5.5 years. This data has been used by some investigators in assigning ages. In 1967 I reexamined the Indian Knoll skeletal collection and studied a total of 128 individuals in the age range from birth to approximately 20 years. In this study, rather than just the lengths of long bones being measured, epiphyses were studied also; these measurements are reported in Ref 7. This past summer I examined 78 Arikara Indian skeletons from South Dakota. In 43 of 44 skeletons in the age range from birth to approximately 10 years, in which I was able to obtain a dental age and a skeletal age based on the Indian

Knoll standards, the two ages agreed with one another. In the last individual the skeletal age was younger than the dental age. This is significant because it shows that these data are useful in aging other Indian skeletons that are totally unrelated biologically or temporally. The problem to test now is to see how applicable the Indian standards are to white and black skeletons. This is something that I intend to test in the near future, and I hope that other investigators look at this problem also.

Acknowledgment

This study was supported in part by a WMU Faculty Research Fellowship during the summer of 1975.

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