THE ESTIMATION OF AGE AND SEX OF PRE-ADOLESCENT CHILDREN FROM BONES AND TEETH

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The diagnosis of age of living children

In a previous paper (Gleiser and Hunt, '55), the authors presented data on the calcification and eruption of the permanent mandibular first molar. Dental calcification has the great advantage of being conveniently ascertainable from radiographs of a child's jaws at any age. Although tests of the equivalence of radiographic stages with extracted teeth have not yet been carried out, potentially the teeth themselves could be used for these assessments, especially those from skeletal material.

One of the problems which sometimes arises in the identification of a living child is the diagnosis of his chronological age from the calcification of his bones or teeth. On the basis of the dentition, three related estimates of dental age are now available. One estimate can be made from the numbers of teeth visible in the oral cavity (Cattell, '28; Robinow, Richards and Anderson, '42; Nanda, '54). A second, more limited estimate, can be based on our schedule of calcification of the permanent mandibular first molar (Gleiser and Hunt, '55). A third kind of estimate is based on the schedule of calcification of the dentition as a whole, as depicted in the table of

Schour and Massler ('41). The first two estimates take account of the sex of the child: whereas the third table presents dental maturation as though no sex difference occurred in its timing.

Schedules of eruption of the teeth in man are an important part of this kind of assessment. For the clinical emergence of the deciduous teeth, convenient data can be found in Robinow, Richards and Anderson ('42), and in Meredith ('46). For the permanent dentition exclusive of the third molars, the charts of Hurme ('48) can be recommended. These standards are especially useful for American Whites.

For non-Whites, no such adequate standards are yet available, although it is known that their permanent teeth show some tendencies toward early emergence (Steggerda and Hill, '42; Hurme, '46; Garn and Moorrees, '51). Even less is known of specific racial patterns of dental calcification, although the findings of Saito ('36) on the calcification of the roots of the permanent mandibular first molar in Japanese children seem to resemble our data on American White children from Boston, Massachusetts.

Bone age in children may be estimated by many methods. The presence or absence of osseous centers in several body regions may be noted and compared with standards such as those in Sontag and Reynolds ('45), Flecker ('42), Pyle and Sontag ('43), or Harding ('52). In the intact body, exhaustive studies of osseous centers may require a prohibitive number of radiographs. Less precise, but often more practicable methods of regional assessment may be employed. For the hand, suitable standards include those of Todd ('37), Flory ('36), and Greulich and Pyle ('50).

A laboratory where identification is routinely carried out should have publications such as the foregoing on hand.

The sexing of immature skeletal remains

The determination of sex from the skeletal remains of children is notoriously difficult and uncertain, but is of interest
both in medico-legal applications and in the study of skeletons from archaeological sites. Improved diagnoses can be based on the fact that the sex difference in dental maturation is far less than that occurring in the skeleton. By whatever criteria are feasible, concurrent estimates of dental age and bone age are made for the remains. These estimates make it possible not only to sex the skeleton, but also to improve the diagnosis of its age at death.

A preliminary test of this method was made, somewhat unrealistically, on radiographs of living children. Problems of applying these techniques to skeletal remains will be considered later in this paper.

The radiographic test is based on a lateral jaw film and a standard developmental film of the hand. On the dental radiograph, the developmental stage of the permanent mandibular first molar is recorded. For a tooth with "two-thirds of the root completed," for example, the mean age for boys of our Boston series would be 84.3 months (7.0 years). For girls, the estimate would be 80.7 months (6.7 years). An assessment of bone age should be made from the atlas of Greulich and Pyle (1950) on male standards, and another from female standards. In the foregoing case, if the "male bone age" were 7 years, the equivalent "female bone age" would be about 5.6 years.

For this imaginary child, the dental and osseous ages by male standards agree closely; while by female standards they diverge by more than a year. Its sex would therefore be diagnosed as male, and its age as 7 years.

Efficiency of the method

The preceding techniques were applied to data on living children in order to determine their efficiency in estimating both sex and age. First, linear equations were calculated by the use of least squares (Arkin and Colton, '39) to represent
sex differences in both dental and osseous maturation. Hurme (‘48) has published means for the clinical emergence of all permanent teeth except the third molars, and the equation computed from his means fits the sex difference in the calcification of the permanent mandibular first molar as well. Where $y$ equals the age of girls, and $x$ that of boys, the equation is: $y = 0.95x$.

An equally simple equation for the preadolescent sex difference in skeletal maturation of the hand was calculated by using two copies of the Greulich-Pyle atlas. The male standards at or below 12 years 6 months were read from one atlas according to the female standards in the other, and the following equation of sex difference obtained: $y = 0.80x$.

In other words, with increasing age, boys and girls diverge much more rapidly in skeletal maturation than in the development of the permanent teeth.

In an earlier paper (Gleiser and Hunt, ’54), the calcification of the permanent mandibular first molar was studied from longitudinal data on Boston White children. Doctor S. I. Pyle has also derived the skeletal age of the hand from radiographs of these children, using the Greulich-Pyle standards. This series of children are among the group who have been investigated by members of the staff of the Harvard School of Public Health and the Forsyth Dental Infirmary for Children, under the supervision of Professor Harold C. Stuart.

Using the two least-squares formulae, the dental and bone ages for the inappropriately sex of each child were calculated at the chronological ages of 2, 5 and 8 years. The sex of the child was then diagnosed as the one in which the bone and dental ages agreed most closely. The results of this attempt to sex these children are presented in table 1.

Table 1 indicates that even at the age of two years, this method of sexing is worth the effort. Its efficiency improves with age, as might be expected from the increasing absolute divergence of skeletal and dental maturation in the two sexes.
The diagnosis of chronological age

If the sex of a child is unknown, the equation of the sex difference in ossification of the hand shows how inaccurate a diagnosis of age may be from this region alone. On the average, the age of a girl diagnosed by male standards of ossification will be about 20% younger than her true chronological age.

When sex has been ascertained from osseous and dental maturation, it is of some interest to find out how accurate the

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diagnosis of chronological age will be. The ages of those “diagnosed as male” were estimated using male standards, and those “diagnosed as female” by female ones. Table 2 presents the means and standard deviations of bone and dental ages at the true chronological ages of 2, 5 and 8 years. By comparison, equivalent data are presented for the entire group according to their true sexes.

Table 2 indicates that when the sex of a child is diagnosed from osseous and dental calcification, his chronological age can be estimated about as accurately as though his true sex were known. In general, the calcification of the permanent mandibular first molar is slightly more efficient as a predictor of chronological age than is the ossification of the hand.

Systematic errors, however, may be expected in applying many of the current developmental standards to unknown children. The Boston children in the present series, for example, tend to mature late by the standards of Greulich and Pyle, which were based on a sample of children from Cleveland, Ohio. Even greater delays in maturation can be expected in children growing up in adversity: whether because of diseases, climatic stress, or poor nutrition. An example of such late maturation was found by Weiner and Thambipillai (’52) in radiographs of the hand in a group of West African Negro children.

Possible improvements in the method

As mentioned previously, the foregoing evaluation of age and sex of children was done on radiographs of the living, and therefore be regarded as a somewhat unrealistic test of its efficiency on skeletal material. In transferring it to immature skeletons, a number of modifications in the technique would probably be desirable.

From the permanent mandibular first molar alone, dental age can be estimated up to 8 or 9 years. If standards were perfected for either or both of the permanent second molars, the dental age could be determined up to 14 or 15 years. Den-
tal calcification is now being studied in several ongoing investigations of human physical growth in the United States, so that these standards should soon be available. Standards for several additional classes of teeth might also improve the precision of estimation of dental age.

Although comparisons of osseous and dental maturation appear to be the method of choice in sexing younger children, in the adolescent, a much more accurate diagnosis of sex can probably be made by Washburn's techniques (see Washburn, '48, '49; and Hanna and Washburn, '53), especially when fusion has begun in the acetabulum.

In making assessments of dental age from skeletal remains, the problem of preservation is generally not critical, and radiographs or studies of the teeth themselves should not ordinarily be difficult. In diagnosing bone age, however, the skeleton of the hand is by no means ideal material. These bones are small and easily destroyed, and the comparison of these fragments with standards in a radiographic atlas may be virtually impossible.

More suitable parts of the skeleton for determining bone age should resemble the hand in that a clear sex difference occurs in their rates of maturation. These regions should also include large epiphyses, since these major centers are relatively apt to be preserved in exposed or buried skeletons. The most suitable single region may well be the knee, and a radiographic atlas of this region has just been published by Pyle and Hoerr ('55). In further tests of this method on immature skeletal material of known age and sex, the dentition and knee would almost certainly be one of the best combinations of sites.

SUMMARY

The determination of sex from the skeletal remains of preadolescent children is notoriously difficult. A possible improvement of such diagnoses is based on the fact that the sex difference in dental maturation is slight, so that for equivalent stages of development of the permanent teeth, the
average age of a girl is about 95% of that of a boy. For the maturation of the bones of the hand, at a given stage, a girl will be about 80% as old as a boy.

On the basis of these equations, concurrent estimates of bone and dental age by male standards should agree closely if the remains are those of a boy, but should be more divergent if female standards are applied. The opposite is usually true if the remains belong to a girl. If bone and dental ages are assessed for the remains by the standards of both sexes, the sex for which the standards agree best is considered to be the correct one.

Somewhat unrealistic tests of this method were completed on dental and skeletal (hand) radiographs of living children from a longitudinal growth study at the Harvard School of Public Health. At two years of age, 73% of 33 children were assigned to the correct sex. At 5 years, 76% were correctly diagnosed. Eighty-one per cent of 27 children in this group were accurately sexed at 8 years of age.

In an unknown immature skeleton, a lateral radiograph of the jaws and an examination of osseous development make the determination of its age at death somewhat more accurate. In fact, this age can be estimated about as precisely as though its true sex were known.

In applying this method to skeletal materials, it would usually be impracticable to estimate bone age from the bones of the hand. A radiographic atlas of the knee by Pyle and Hoerr ('55), however, may make the method more widely useful if applied to the teeth and knee alone.

LITERATURE CITED


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AGE AND SEX OF CHILDREN


