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Sex Determination of Infant and Juvenile Skeletons: I. Morphognostic Features

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ABSTRACT Ancient cemeteries are often characterized by a considerable number of infants and young children. Sex differences in childhood mortality, however, could rarely be studied up to now, mainly because there were only few proven traits for sexual determination of immature skeletons. Based on a historic sample of sixty-one children of known sex and age from Spitalfields, London (37 boys, 24 girls), sexually distinctive traits in the mandible and ilium are presented for morphognostic diagnosis. Besides other features, boys typically show a more prominent chin, an anteriorly wider dental arcade, and a narrower and deeper sciatic notch than girls. Most of the traits presented in this study allow individuals between birth and five years of age to be successfully allocated to either sex in 70–90% of the cases.

Morphognostic determination of sex in ancient human skeletal remains is generally accepted as an efficient and sufficiently precise diagnostic method when adult individuals are involved. However, there is a lack of reliable methods for determining the sex of children's skeletons, although various hints concerning sex differences in the immature skeleton can be derived from anatomical and obstetrical investigations. As early as 1876, Fehling reported on sexually distinctive features of the fetal and neonate pelvis (see also Verneau, 1875). His observations on the differences in shape of the greater sciatic notch and the pubic angle were later supported by several investigators (Thomson, 1899; Villemin, 1937; Souri, 1959; Khomyakov et al., 1986). Sex-discriminant characters were also described for the immature sacrum (Happel, 1922). Weaver (1980) was the first to introduce a qualitative criterion (auricular surface elevation) for anthropological diagnosis of the sex of immature skeletons. Apart from pelvic features, no further hints of sexually distinctive structures that may serve as diagnostic criteria in children's skeletons have been reported in the literature (cf. Schutkowski, 1986, 1990 for review).

Moreover, only those traits are diagnostically suitable that can be applied to the isolated skeletal element. Such pelvic features as the pubic angle, which require more than one bone for an evaluation of shape, are rendered useless for anthropological purposes by postmortem disarticulation of the skeleton.

The vast majority of the literature on morphognostic sexual dimorphism of subadults refers to fetal and perinatal individuals. Reference data on skeletal sexual dimorphism are lacking for most immature age groups, particularly those which are generally represented in larger quantities in historic cemeteries. This study presents diagnostic criteria of sex derived from a sample of children of known sex and age, mostly between birth and five years.

MATERIALS AND METHODS

This investigation is based on children's skeletons from the "Coffin Plate Sample" of known sex and age. It is part of a historic skeletal series from Christ Church, Spi-

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TABLE 1. Distribution of age and sex for the immature skeletons of the Spitalfields "Coffin Plate Sample" investigated in this study

Age (years)	Boys	Girls	Total
0–0.5	9	7	16
0.5–1	6	4	10
2	6	5	11
3	8	3	11
4	1	3	4
5	4	0	4
6	1	0	1
8	1	0	1
11	1	2	3
Total	37	24	61

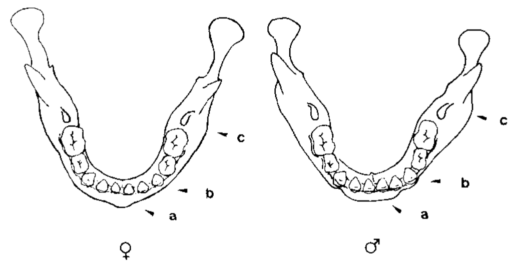

Fig. 1. Sex-typical appearances of morphognostic traits in the mandible of boys and girls of the Spitalfields "Coffin Plate Sample." a: Protrusion of the chin region; b: Shape of the anterior dental arcade; c: Eversion of the gonion region (see text).

talfields, London, stored at the Natural History Museum, London. The "Coffin Plate Sample" allowed individual identification from metal plates still attached to the coffins (Adams and Reeve, 1987; Molleson, 1990). Sixty-one individuals (24 girls, 37 boys) were suitable for examination. The distribution of age and sex, however, shows that individuals older than five years are clearly underrepresented (Table 1). The evaluation of sex-typical morphognostic traits therefore focused on children between birth and five years of age. Diagenetic loss of substance during the inhumation period did not allow an evaluation of the traits listed below in all individuals, so that the results are based on subsamples with slightly differing numbers of individuals (see Results).

Among those skeletal elements regularly preserved in the Spitalfields sample, sexually distinctive morphognostic features appeared most clearly in the mandible and the ilium. Other elements such as the pars basilaris of the occipital, the petrous temporal, or the long bones turned out not to be diagnostic of sex by morphognostic examination. Sex-typical appearances of different traits in girls and boys for the mandible and ilium can be described as follows:

Mandible (Fig. 1)

Protrusion of the chin region.

Girls. The chin region is not prominent and the mandible does not show distinct elevated rough structures at the side of the median sagittal line. The surface of the bone is rather smooth. Seen from the top, the mental protrusion appears faint and narrow and sometimes tapers.

Boys. The chin region is more prominent. To either side of the midsagittal plane, the mandible shows slightly elevated rough structures, which fade distally into shallow indentations. Seen from the top, the protrusion is generally wide and angular against the mandibular corpus.

Shape of the anterior dental arcade.

Girls. The alveoli of the front teeth conform to a rounded contour. The canines normally do not protrude in the dental arch, which gives it a roughly parabolic shape.

Boys. The dental arcade is wider anteriorly. The alveoli of the canines protrude slightly against the adjacent molars, so that the dental arch usually appears U-shaped rather than parabolic.

Eversion of the gonion region.

Girls. The outer surfaces of the horizontal rami of the mandible are aligned with the gonion region.

Boys. Viewed from the frontal aspect of the mandible, the gonion areas are everted, protruding slightly beyond the general surface of the mandible's horizontal rami.

Ilium (Fig. 2A–C)

Angle of the greater sciatic notch (Fig. 2A).

Orientation: The bone is viewed from the ventral aspect and positioned in a way that

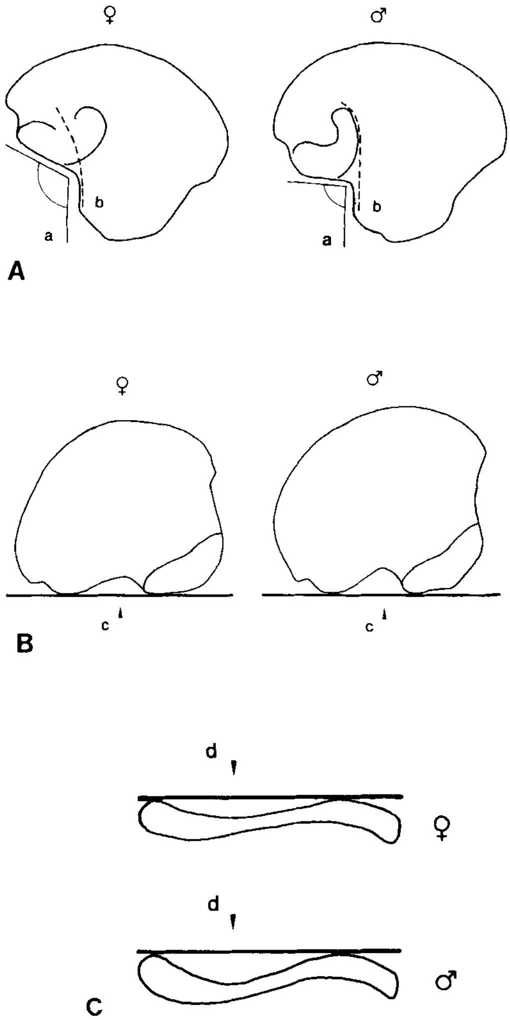

Fig. 2. A: Sex-typical appearances of morphognostic traits in the ilium of boys and girls of the Spitalfields "Coffin Plate Sample." Ventral aspect of the bone. a: Angle of the greater sciatic notch; b: Arch criterion (dashed line) (see text). B: Sex-typical appearances of morphognostic traits in the ilium of boys and girls of the Spitalfields "Coffin Plate Sample." Dorsal aspect of the bone. c: Depth of the greater sciatic notch (see text). The black bar represents an imaginary reference line to help evaluate this trait. C: Sex-typical appearance of iliac crest of boys and girls according to the Spitalfields "Coffin Plate Sample." Top view of the iliac crest. d: Curvature of the iliac crest (see text). The black bar represents an imaginary reference line at the dorsal surface of the bone to help evaluate this trait.

the anterior side of the greater sciatic notch is aligned vertically.

Girls. The notch describes an angle of >90°/>>90°.

Boys. The greater sciatic notch is narrower and describes an angle of ~90°.

Depth of the greater sciatic notch (Fig. 2B).

This trait directly corresponds to the relative width of the angle of the greater sciatic notch.

Orientation: Viewed from the dorsal aspect, the spina iliaca posterior inferior and the dorsal rim of the acetabular region point downwards in a line.

Girls. The notch between the spina iliaca posterior inferior and the acetabulum joint portion is usually shallow.

Boys. The notch between the spina iliaca posterior inferior and the acetabulum joint portion is usually deep.

"Arch" criterion (Fig. 2A).

Orientation: as for "angle of the greater sciatic notch."

Girls. The "arch" formed by drawing a cranial extension from the vertical side of the greater sciatic notch crosses the auricular surface.

Boys. The cranial extension of the vertical side of the greater sciatic notch leads into the lateral rim of the auricular surface.

Curvature of the iliac crest (Fig. 2C).

Orientation: The ilium is viewed from the top and the dorsal surface is aligned horizontally.

Girls. Viewed from the top, the crest shows a faint S-shape.

Boys. The curvature of the iliac crest is more pronounced, exhibiting a marked S-shape when viewed from the top.

The significance of differences between girls and boys for the investigated traits was tested by means of the χ^2-test for 2×2 contingency tables (Sachs, 1972). χ^2-approximation was considered appropriate since a calculation of the expected frequencies revealed values >5. Yates's correction was applied for small cell sample size.

RESULTS

The evaluation of morphognostic sexual differences in the *mandible* was carried out for the traits "protrusion of the chin region", "shape of the anterior dental arcade", and "eversion of the gonion area". The chin and gonion area exhibit marked sexual dimorphism in the adult skeleton (e.g., Krogman and Işcan, 1986; Sjøvold, 1988; Herrmann et al., 1990). In the "Coffin Plate Sample", these areas showed sex differences between boys and girls most clearly for individuals from 0–5 years of age.

Within each sex, however, there was considerable variation in each of the sex-correlated traits, leading to a certain overlap of sex-typical appearances. Nevertheless, significant sexual differences become apparent when all individuals scored the same way for a particular trait are broken down into boys and girls. Table 2 shows the distribution of traits according to age. Percentage values given below refer to the total subsample for the respective trait. Above all, a prominent and angular chin and a wide anterior dental arcade can be significantly attributed to boys (94.1% and 82.6% of the cases), whereas these traits have a clearly lower occurrence in girls' mandibles. Even the eversion of the gonion region allows an accuracy of 73.9% for the boys' subsample. In contrast, an allocation of appearances which seemed typical for girls does not produce significant results. It is evident that the selected traits clearly distinguish male individuals, but fail to allocate girls reliably (Table 3). When marked differences are observed in the frequency of traits between the sexes, they are continuously shown throughout all age groups investigated and are not limited to certain age classes.

The few individuals of more than five years of age did not exhibit the sex-typical distribution of shape characters. This is very likely to be due to the small sample. The observations are therefore not further discussed here.

In the case of the *ilium*, morphognostic sexual differences were described by the traits "angle of the greater sciatic notch", "depth of the greater sciatic notch", "arch criterion", and "curvature of the iliac crest."

TABLE 2. Distribution of sex-typical shape conditions in the mandible for boys and girls from the Spitalfields "Coffin Plate Sample" according to age[1]

Trait	Age	Boys (n = 27)	Girls (n = 17)
Chin prominent, angular	0–0.5	6	0
	0.5–1	2	0
	2	3	1
	3	4	0
	4	0	0
	5	1	0
Chin smooth, nonprominent	0–0.5	1	4
	0.5–1	4	2
	2	1	2
	3	2	2
	4	1	2
	5	2	0
Anterior dental arcade wide	0–0.5	5	2
	0.5–1	3	1
	2	4	1
	3	5	0
	4	0	0
	5	2	0
Anterior dental arcade rounded	0–0.5	2	2
	0.5–1	2	1
	2	0	2
	3	1	2
	4	1	2
	5	1	0
Gonion everted	0–0.5	4	1
	0.5–1	1	1
	2	3	3
	3	6	0
	4	1	1
	5	2	0
Gonion not everted	0–0.5	3	3
	0.5–1	3	2
	2	1	1
	3	1	2
	4	0	1
	5	0	0

[1] Figures refer to all individuals with the same appearance of the respective trait. Subsample consisting of individuals between birth and five years of age.

At least for the first three traits a high discrimination capacity is reported in the adult skeleton (e.g., Novotný, 1972; Krogman and Işcan, 1986; Herrmann et al., 1990). In the "Coffin Plate Sample", these characters reveal a clear sexual dimorphism between boys and girls.

Table 4 shows the distribution of sex-typical appearances in boys and girls for the Spitalfields sample according to age. The reported percentage values refer to the total subsample for the respective trait. In all four criteria, sex-typical shapes can be significantly attributed to either sex (Table 5). Traits connected with the greater sciatic notch are the best discriminators: 95.0% of

TABLE 3. Percentage distribution of mandibular traits in boys and girls, pooled subsample of ages 0–5 years[1]

Trait	Boys (n = 27)	Girls (n = 17)	χ^2	P two-tailed
Chin prominent, angular	94.1	5.9		
Chin smooth, nonprominent	47.8	52.2	7.55	0.006
Anterior dental arcade wide	82.6	17.4		
Anterior dental arcade rounded	43.7	56.3	4.78	0.030
Gonion everted	73.9	26.1		
Gonion not everted	47.1	52.9	1.97	0.168

[1] Figures refer to all individuals with the same appearance of the respective trait. Frequencies according to Table 2 are transformed to percentage values. Calculation of significance by means of the χ^2-test for 2 × 2 contingency tables with Yates's correction (Sachs, 1972).

TABLE 4. Distribution of sex-typical shape conditions in the ilium for boys and girls from the Spitalfields "Coffin Plate Sample" according to age[1]

Trait	Age	Boys (n = 29)	Girls (n = 22)
Greater sciatic notch angle:			
~90°	0–0.5	3	0
	0.5–1	3	0
	2	5	1
	3	6	0
	4	0	0
	5	3	0
>/ >> 90°	0–0.5	4	7
	0.5–1	1	4
	2	1	3
	3	2	3
	4	0	3
	5	0	0
Greater sciatic notch depth:			
deeper	0–0.5	5	3
	0.5–1	4	2
	2	6	1
	3	8	0
	4	0	0
	5	3	0
shallower	0–0.5	2	4
	0.5–1	0	2
	2	0	3
	3	0	3
	4	2	1
	5	0	0
Arch:			
bordering auricular surface	0–0.5	6	3
	0.5–1	3	0
	2	5	1
	3	5	2
	4	0	2
	5	3	0
crosses auricular surface	0–0.5	1	3
	0.5–1	1	4
	2	1	3
	3	2	1
	4	0	1
	5	0	0
Iliac crest:			
marked S-shape	0–0.5	1	2
	0.5–1	3	0
	2	3	0
	3	3	1
	4	0	0
	5	3	0
faint S-shape	0–0.5	5	5
	0.5–1	1	3
	2	2	5
	3	3	2
	4	0	3
	5	0	0

[1] Figures refer to all individuals with the same appearance of the respective trait. Subsample consists of individuals between birth and five years of age.

the individuals with a narrow notch were boys, whereas 71.4% of those with a wider sciatic notch were girls. The criterion "depth of the greater sciatic notch" correctly allocated 81.2% of boys (deep notch) and 76.5% of girls (shallow notch). For the "arch criterion", 73.3% of the boys showed an arch bordering the auricular surface, whereas an arch crossing the auricular surface was found in 70.6% of the girls. Even the "curvature of the iliac crest" showed a distinct separation, particularly for boys: a pronounced S-shape was found in 81.2% of boys, a faint S-shape in 62.1% of girls. With the exception of the curvature trait, all iliac features separate clearly between girls and boys. As in the mandible, sex-typical shapes appear for all age classes. While a narrow greater sciatic notch is distinctive of boys from birth onward, in the other traits, definite sexual dimorphism seems to develop during the first year of life, although significant differences exist even in the 0–0.5 years age group (Table 4).

For individuals of more than five years of age, boys especially continue to show the sex-typical features described for the younger children. This is true for both sexes as far as the "arch criterion" is concerned. Although the observations suggest that a sexual diagnosis of older children is possible, they should be evaluated with caution, because the sample is too small to make a valid statement.

The results for both mandibular and iliac traits show a high degree of accuracy in sex diagnosis. When a certain appearance of a morphognostic trait was found in the "Coffin Plate Sample", it could usually be allocated to one of the sexes with high significance.

TABLE 5. Percentage distribution of iliac traits in boys and girls. Pooled subsample of ages 0–5 years [1]

Trait	Boys (n = 29)	Girls (n = 22)	χ^2	P two-tailed
Greater sciatic notch				
angle ~90°	95.0	5.0		
angle >/ >> 90°	28.6	71.4	19.14	<<0.001
Greater sciatic notch				
deeper	81.2	18.8		
shallower	23.5	76.5	13.24	<<0.001
Arch				
bordering auricular surface	73.3	26.7		
crosses auricular surface	29.4	70.6	6.86	0.009
Iliac crest				
marked S-shape	81.2	18.8		
faint S-shape	37.9	62.1	6.13	0.014

[1] Figures refer to all individuals with the same appearance of the respective trait. Frequencies according to Table 4 are transformed to percentage values. Calculation of significance by means of the χ^2-test for 2 × 2 contingency tables with Yates's correction (Sachs, 1972).

DISCUSSION

The results obtained for the "Coffin Plate Sample" show that morphognostic sex differences are detectable in children's skeletons. The occurrence of typical appearances differs significantly in boys and girls for most mandibular traits and all selected criteria in the ilium.

Morphognostic sex differences in the mandible have not been previously reported in children's skeletons, and sexual dimorphism with respect to shape criteria is demonstrated here for the first time. For the ilium, this investigation confirms previously published statements about the possible diagnostic value of relative width of the angle in the greater sciatic notch in early ontogenetic stages. The data presented here for the isolated skeletal elements suggest that certain shape conditions of the fetal pelvis are maintained throughout early childhood stages.

Comparable data available for pelvic features of adult skeletons allow us to evaluate the diagnostic capacity of the observed sexual dimorphisms. Reliabilities of determination are reported to be 70–75% for the greater sciatic notch (Acsádi and Nemeskéri, 1970; Novotný, 1972) and 60% for the "composed arch" (corresponding to the "arch criterion" used in this study) (Novotný, 1972). Other figures given for the discriminating ability of morphognostic traits (e.g., Acsádi and Nemeskéri, 1970; Leopold, 1978) mostly refer to the classification results obtained by Krogman with the Hamann-Todd Collection (80% certainty with long bones, 100% with whole skeleton). These figures, however, are highly biased due to a considerably unbalanced sex ratio of the study sample, and therefore should be lowered by 5–10% (Krogman and Işcan, 1986). There are no comparable data on the classificatory reliability of mandibular traits for adult individuals.

Because the collection of immature skeletons from the "Coffin Plate Sample" is unique, both with respect to sample size and historic provenience, for the time being it is not possible to check the significantly differing frequency distributions given here for sex-typical morphognostic traits against a comparable series of known sex, and the general reliability of these traits in sex classification cannot be estimated at present. However, the reliability in the sample from Spitalfields is about as high as that reported for similar morphognostic traits in adult skeletons. Thus, with the characters introduced here, the basis for a sexual determination of immature skeletal individuals is provided with a diagnostic accuracy comparable to that known for adult individuals. Additionally, no greater observer experience is required for the application of the traits than has been necessary in previous work on adult material.

CONCLUSION

The possibility of assessing sex in children's skeletons has repeatedly been recognized as a diagnostic desideratum. While metric approaches (e.g., Black, 1978; Schutkowski, 1987) to the sexual diagnosis of infants and children have been published, an efficient method of morphognostic diagnosis was not available. With the characters presented here, it is now possible to include children in paleodemographic investigations of historic populations. Against the background of the increasing importance of deductive theory-bound anthropological work (e.g., Grupe, 1985; Herrmann, 1989; Ulrich-Bochsler, 1990), the value of being able to incorporate data on children from historic cemeteries is obvious. The present work offers a contribution of methodological prerequisites to a Historic Demography of skeletal populations.

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