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## Sex Determination in Subadults Using Auricular Surface Morphology: A Forensic Science Perspective

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**ABSTRACT:** The determination of sex in subadult skeletons remains a problem for several areas of biological anthropology. To date, univariate and multivariate assessments of sex in the young using adult indicators have failed to produce reliable results. However, research in this area continues.

In 1980, Weaver proposed a modification of adult differences in auricular surface morphology as an effective means for sex determination in subadult remains. His method was indirectly evaluated by Hunt through a comparison of the sex ratios produced by this technique and the expected 1:1 ratio. The present investigation expands upon both studies by using a sample of subadults of known sex, and by evaluating Weaver's method from two perspectives: 1) what percentage of individuals can be correctly sexed using Weaver's criteria? and 2) what is the probability that an individual case will be correctly sexed based on the presence or absence of auricular surface elevation? The first is of interest to those reconstructing population patterns, while the second is critical to the forensic investigator faced with the diagnosis of an individual case.

The sample used in this study consisted of 58 ilia from subadults of known sex ranging in age from birth through 18. In each case, sufficient soft tissues were present to allow absolute sex diagnosis. Each ilium was subjected to a blind examination using Weaver's criteria for auricular surface elevation.

Weaver's technique proved most effective on the males in our sample, with an overall accuracy of 85.3%; however, accuracy in sexing females was only slightly better than chance at 58.3%. Our results corresponded closely to Weaver's own values of 85.4 and 57.7% respectively. Although not significant, the effectiveness of the method improved with age among subadults of both sexes at the population level. The present results suggest that during infancy and early childhood, auricular surface morphology for most individuals conforms to the male pattern.

From the perspective of forensic science, auricular surface morphology proved an effective predictor of sex only among a subset of children older than age nine. All subadults beyond age nine with an elevated surface were female and were therefore diagnosable. However, 26% of our female sample failed to develop an elevated surface thus making the attribute of nonelevation less indicative of male status.

**KEYWORDS:** physical anthropology, auricular surface, human identification, sex determination

The inability to accurately determine sex in subadult skeletal remains has negatively impacted several aspects of biological anthropology, including paleodemography and paleopathology, as well as forensic-science studies. Subadult sex determination is a pre-

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requisite to the reconstruction of paleodemographic patterns of childhood survivorship and mortality, nutritional and disease stress, and growth and development. Accurate determination of sex is equally critical to the proper identification of children in forensic-science cases [1].

The search for effective methods of determining sex in subadult remains has continued since von Fehling and Thomson first reported sex-related differences in the shape of the fetal sciatic notch [2,3]. While a number of methodologic approaches, from the assessment of single morphologic characters to the application of complex multivariate techniques have been proposed, none have proven satisfactory. Suggested approaches have included metric and nonmetric analyses of cadavers [2-6] and of pelvic radiographs of living children [7,8]. The incomplete fusion of the acetabulum and lack of preservation of cartilage in archaeological subadult remains make these sexing techniques difficult to apply. Based on radiographs of living children, Hunt and Gleiser proposed comparing dental and skeletal ages to determine the sex of subadults [9]. Although Sundick has successfully applied this method to skeletal material from individuals 12 years and older, its applicability to younger children remains untested [10].

A variety of metric and nonmetric techniques developed for adults have also been proposed for sexing subadult skeletal remains [11,12]. Although none have been demonstrably successful, the potential of modifying adult sexing techniques for use on subadult material continues to be advocated [10,13,14]. For example, elevation of the auricular surface, a nonmetric characteristic used for sex determination in the osseous remains of adults has been proposed as a method for sex determination in fetal and infant skeletal material [11]. Weaver evaluated the morphology of the auricular surface of the ilia of 153 fetuses and infants (ranging in age from 6 months in utero to 6 months postpartum) based on the following criteria:

if the sacro-iliac surface was elevated from the ilium along its entire length and along both the anterior and posterior edges of the sacro-iliac surface, the auricular surface was considered elevated and was so scored. If the surface was not elevated, it was so scored" [10].

Weaver's premise was that the auricular surface in female subadults is completely elevated, thus contributing to the increased pelvic width in female children (as documented by Reynolds) [8]. Overall, Weaver's determination of sex, based on auricular surface morphology, proved 85.4% accurate for males and 57.7% for females.

This method was subsequently evaluated indirectly by Hunt on a sample of subadult Arikara Indian remains [15]. Although the true sexes of the individuals were unknown, Hunt compared the ratio of elevated to nonelevated auricular surfaces with the expected 1:1 sex distribution. His results showed sex ratios differing greatly from the expected, ranging from a 6:1 elevated:nonelevated ratio in newborns to a 1:4 ratio in young children. Hunt concluded that "the morphology of the auricular surface is not primarily a feature of sex but one of growth variation during prepubescence" [15].

Therefore, the purpose of this research was to expand upon both studies by using a sample of subadults of known sex, and by evaluating Weaver's method from two perspectives: 1) what percentage of individuals can be correctly sexed using Weaver's criteria? (that is, what is the overall success rate for the sample?); and 2) what is the probability that an individual case will be correctly sexed based on the presence or absence of auricular surface elevation? The first is of interest to those reconstructing population patterns, while the second is critical to the forensic investigator faced with the diagnosis of an individual case.

## Materials and Methods

The present investigation was conducted on a sample of naturally mummified subadult remains exhumed from the site of Kulubnarti, Nubia (Fig. 1). This skeletal material dates

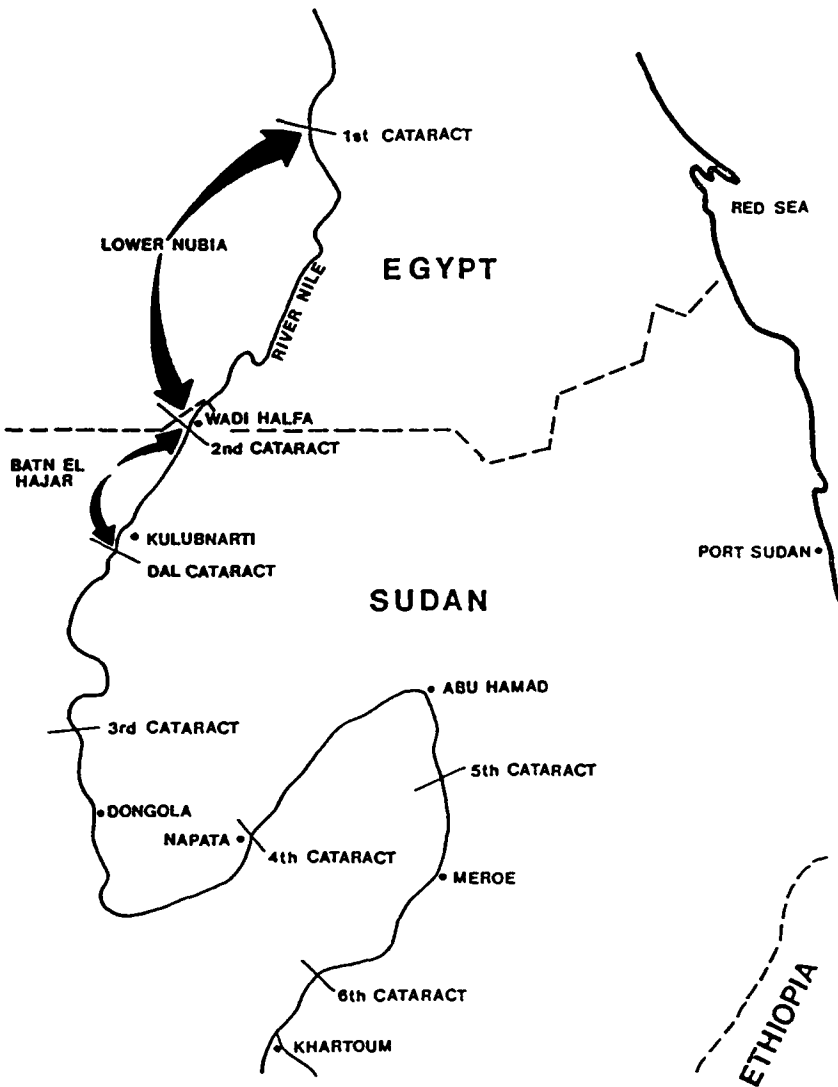


FIG. 1.—Map of Nubia, indicating the site of Kulubnarti.

to medieval Christian times, between 550 and 1450 A.D. The sample consisted of 58 ilia from subadults of known sex, ranging in age from birth through 18. The preservation of external genitalia allowed for accurate determination of sex. The age of each individual was previously established by Van Gerven et al. using multiple aging criteria [16].

Following the criteria established by Weaver, sex was estimated based on the morphology of the auricular surface of each ilium. If the entire auricular surface was elevated above the remainder of the ilium, it was diagnosed as a female (Fig. 2); when any portion of the auricular surface was not elevated in this manner, the individual was classified as male (Fig. 3). This was a blind test; the auricular surface was the only area of the innominate visible to the researchers. Age, catalogue number, and all other sex indicators were concealed.

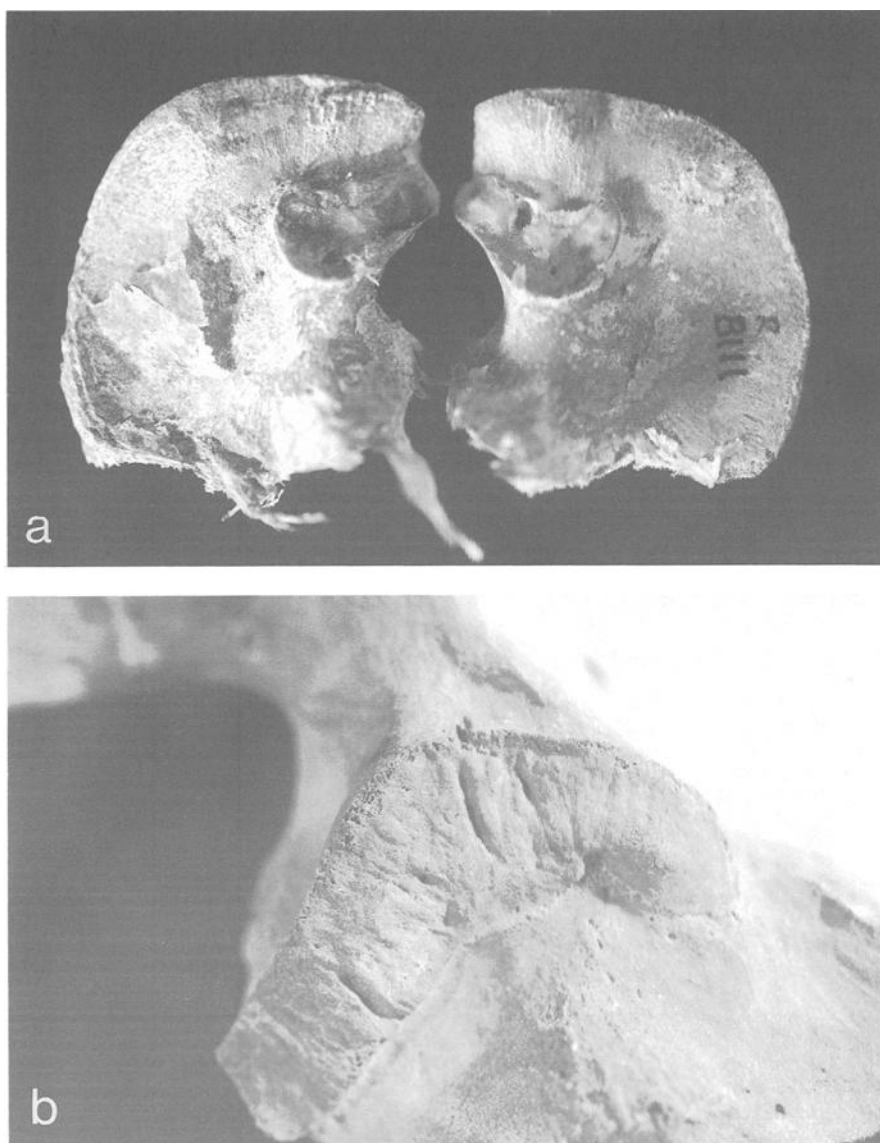


FIG. 2—An auricular surface demonstrating the elevated pattern associated with females age 6 months (a) and age 15 years (b).

## Results

### *Overall Success Rate at the Populational Level*

Weaver's method accurately sexed 74.1% of the subadults considered in this study. The technique, however, did not diagnose males and females equally well. The correspondence between known sex and sex based upon auricular surface morphology is reported in Table 1. Of the 34 male innominates included in the sample, 29 (85.3%) had nonelevated auricular surfaces and were therefore correctly classified. Only five of the

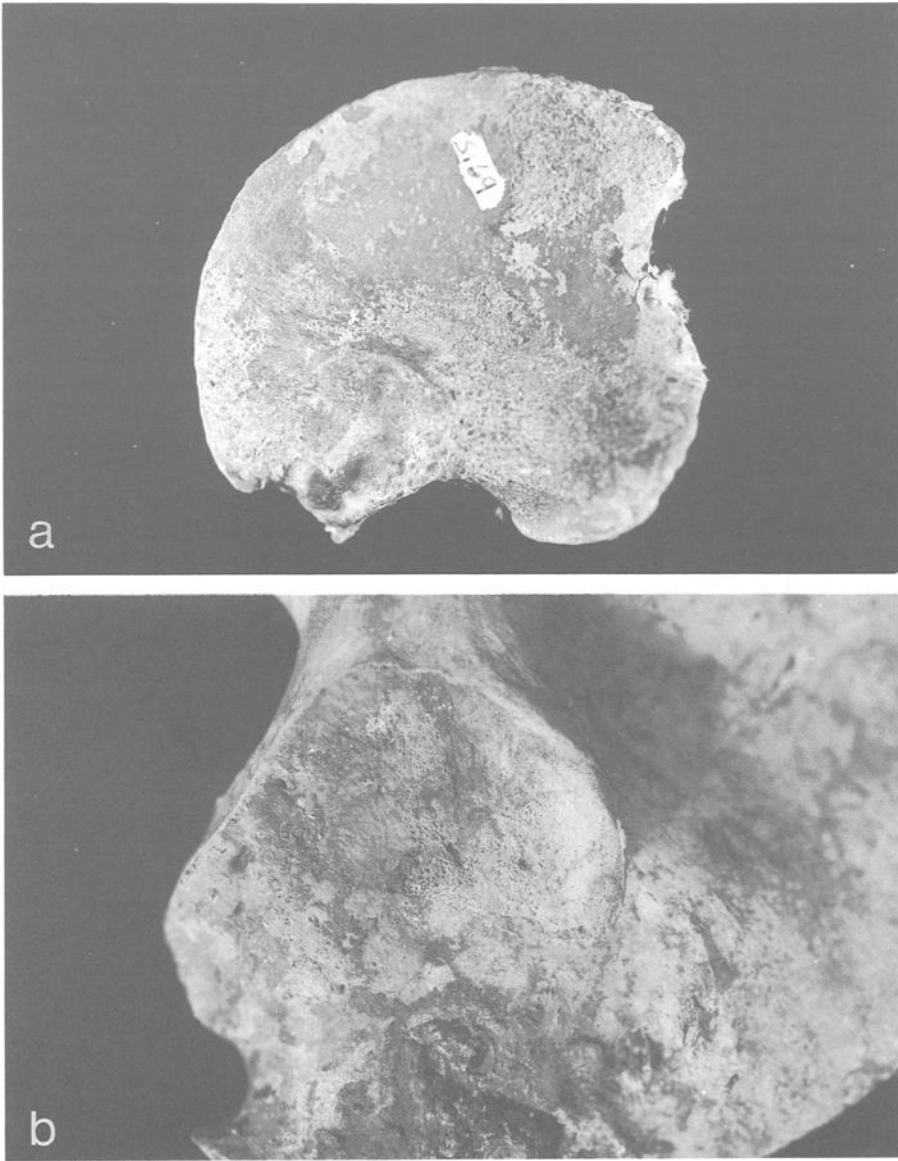


FIG. 3—The nonelevated pattern of the auricular surface is evident in these males age six years (a) and age 16 years (b).

TABLE 1—Correspondence between known sex and sex diagnosed from auricular surface morphology.

Parameters	Males		Females	
	Sexed correctly	Sexed incorrectly	Sexed correctly	Sexed incorrectly
N	29	5	14	10
%	85.3	14.7	58.3	41.7

males (14.7%) had elevated auricular surfaces and were incorrectly sexed. However, the females were successfully sexed only slightly better than chance. Fourteen of the 24 females (58.3%) had elevated auricular surfaces and were therefore sexed correctly, whereas 10 (41.7%) were sexed as males based on a lack of elevation.

Analysis of occurrence by age provided additional insight into the utility of this technique. The present results suggest that Weaver's method is least effective on younger children. Within the birth through nine year age group, only one third (33.3%) of the females had elevated auricular surfaces and were thereby correctly diagnosed. Weaver's method proved more effective among males of this age group, with 70.6% of the males sexed correctly.

The effectiveness of Weaver's technique increased with age in both males and females. Among older females (10 to 18 years), 66.7% of the individuals were sexed correctly. Within this group, accuracy in sexing adolescent females (14 to 18 years) increased to 71.4%. A similar increase in accuracy occurred among the males. All males (100%) aged 10 and older exhibited nonelevated auricular surfaces and were therefore sexed correctly.

### *Forensic Application*

The potential of this method for use in forensic cases was then evaluated directly through a consideration of the ability to individually predict sex based on auricular surface morphology. Of those with nonelevated auricular surfaces, 74.4% were male; similarly, of those with elevated auricular surfaces, 73.7% were females. However, examination within age categories paints a strikingly different picture (Table 2). Among those individuals between birth and age nine, auricular surface morphology cannot be used to effectively diagnose sex. Although 75% of those with nonelevated auricular surfaces proved to be males, only 28.6% of those with elevated auricular areas were female. Between birth and age nine, then, the relationship between auricular surface morphology and sex is random and therefore cannot be reliably used as a predictor of sex in forensic cases involving young children.

Among children over nine, however, the predictive value of auricular surface morphology becomes evident. All of the individuals 10 years and older with elevated auricular surfaces were female. Indeed, based on a statistical comparison of the subadult females and males, 10 years of age and older, there is a greater than 99% probability that an individual with an elevated auricular surface is female.

Conversely, of those with nonelevated auricular surfaces, 73.9% were male, while 26.1% were female. In other words, while all other subadults with elevated auricular surfaces were female, not all females had an elevated auricular surface. As a result, lack of surface elevation is less reliable as an indicator of sex after age 10.

### **Discussion**

The search for features by which the subadult skeleton can be sexed is by its very nature a search for features minimally dependent upon growth and development. The

TABLE 2—*Correspondence between auricular surface morphology and known sex.*

ELEVATED				NON-ELEVATED			
Age	% Female	% Male	N	Age	% Female	% Male	N
Birth-9	28.6	71.4	7	Birth-9	25.0	75.0	16
10-18	100.0	0	12	10-18	26.1	73.9	23
Overall	73.7	26.3	19	Overall	25.6	74.4	39

results of the present investigation suggest that elevation of the auricular surface fails to meet this criteria. Among the Nubian children of known sex, the majority of the youngest individuals conformed to the male pattern. Indeed 67% of the females and 71% of the males between birth and nine years were classified as male because of their nonelevated auricular surfaces. This suggests that elevation of the auricular surface is an age-dependent growth event with only a minimal appearance among young children. During later childhood, about half of the females undergo growth changes resulting in elevation of the auricular surface. Unfortunately this pattern, while strongly dimorphic, is not sufficiently prevalent among even older female subadults, to permit adequate (better than chance) diagnosis in a populational setting. However, in individual forensic cases, this method demonstrates a real predictive value. If the auricular surface of an older subadult ( $\geq 10$  years) is elevated, it is highly probable that this is a female.

In conclusion, this study demonstrated the following: 1) At the populational level, while these results parallel Weaver's quite closely, they do not support his suggestion that auricular surface elevation provides a useful basis for diagnosing sex in subadult skeletal remains. These results do not support the notion of early onset dimorphism in auricular surface morphology; rather, the seeming accuracy of male diagnosis results from a male (nonelevated) default pattern common to the majority of the younger-aged children. The later appearance of auricular elevation, while indicative of a strongly dimorphic feature of the adult innominate, does not lead to an adequate diagnosis of even older female subadults (14 to 18 years). This results from the maintenance of the nonelevated pattern in approximately one-third of the females. 2) This method proved to be an effective predictor of sex for the purposes of forensic-science diagnosis only for individuals over age nine with an elevated auricular surface. For individuals meeting these criteria, the probability of being female is virtually 100%. However, inasmuch as 25% of females fail to develop surface elevation, a lack of elevation, even among older subadults (up to age 18) does not provide a comparably reliable diagnosis for males.

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