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Nonmetric Subadult Skeletal Sexing Traits: I. A Blind Test of the Accuracy of Eight Previously Proposed Methods Using Prehistoric Known-Sex Mummies from Northern Chile*

ABSTRACT: While a number of nonmetric sex-related traits have been proposed, the accurate assignment of sex to subadult skeletal materials is generally considered problematic. Eight previously proposed nonmetric traits of the ilia and mandible have been demonstrated by other researchers to be related to the known-sex of subadults, yet there has been relatively little research attempting to evaluate the utility of these traits using independent collections of known-sex subadult skeletal remains. These eight traits include: elevation of the auricular surface, angle of the greater sciatic notch, depth of the greater sciatic notch, the "arch criteria," curvature of the iliac crest, gonial eversion, mandibular protrusion, and mandibular arcade shape.

The present study blindly tested these eight nonmetric traits using 85 autopsied prehistoric known-sex mummified subadult remains from northern Chile that range in age between newborn and 15 skeletal years of age. The two primary questions examined for each trait are: (1) are the different character states for each of the eight traits related to known-sex, and (2) which of the eight traits are accurate enough for use in forensic cases? These questions are examined for each trait by both sex and age class so as to uncover potential sex- and age-related strengths and weaknesses for each of the characteristics.

The results indicate that all eight of the previously proposed subadult sex-related traits are indeed related to known-sex, but that there is a great deal of variation by both sex and age in terms of the strength of congruent sex-related associations. With the exception of gonial eversion, all of the traits produced statistically significant χ^2 values for their associations with known-sex when all subadult remains were considered. However, when all subadults are considered, only four traits demonstrated acceptable levels of accuracy for forensic applications. These traits include the arch criteria (82.3%), angle of the sciatic notch (80.7%), depth of the sciatic notch (79.0%), and mandibular arcade shape (77.6%). For subadults ranging in age from newborn to five skeletal years of age, only depth of the sciatic notch (81.5%) and the arch criteria (81.5%) approach acceptable levels of accuracy for use in forensic cases. The implications of these results are discussed and recommendations for bioarchaeological and forensic applications are made.

KEYWORDS: forensic science, forensic anthropology, bioarchaeology, human identification, juvenile

The accurate and reliable assignment of sex represents vital data used in both forensic anthropology and bioarchaeological research. Both metric and nonmetric techniques have been proposed for the evaluation of fetal (1–5) and juvenile (4–9) skeletal and dental remains. While recent metric techniques for identifying sex-based differences in skeletal morphology have shown promise (3), metric measurements of fetal and subadult skeletal elements have generally been found to be of limited use for the correct assignment of fetal and subadult sex (3–5), while nonmetric skeletal traits have consistently been found to perform better than chance (5–10). This may be due, in part, to an inability to identify or reproduce useful metric measurements.

In his seminal study, Weaver (5) examined elevation versus nonelevation of the auricular surface of the ilium among a large number of dry skeletal elements for known-sex fetal and neonate remains. Elevation across the entire auricular surface, Weaver demonstrated, was more common among female fetal remains than among males. Using this technique in a blind study he reported accuracies that ranged between 43 to 75% for females and 73 to 92% among males.

Schutkowski (4) later proposed seven nonmetric characteristics of the ilia and mandible that he tested on 61 known age and sex subadults of the "Coffin Plate Sample" from Christ Church Cemetery of Spitalfields, London. The four characteristics of the ilia Schutkowski proposed include the angle of the greater sciatic notch (obtuse for females versus acute for males), depth of the greater sciatic notch (shallow for females versus deep for males), curvature of the ilia when observed superiorly (slight "S" shape for female ilia versus marked "S" shape for male ilia), and the "arch criteria" (the posterior projection of the arcurate line through the auricular surface in females versus a posterior projection of the arcurate line bordering the superior portion of the auricular surface in males). For the mandible, Schutkowski proposed gonial eversion (weak for females versus marked among males), protrusion of the chin (weak for females versus marked among males), and anterior dental arcade shape (parabolic when viewed from above for females versus rectangular-shaped among males) as criteria that could be used to

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distinguish between female and male subadult remains. Rather than examining the accuracy of each trait, Schutkowski reported on the association of each of two possible character states with females and males in the Coffin Plate Sample. This presentation of data was used to demonstrate each trait's usefulness for application to bioarchaeological populations, rather than to illustrate each trait's accuracy for forensic (case-by-case) evaluations of subadult sex. Inspection of his tables reveals that these traits ranged in accuracy between 60.0 and 95.2% for females and 54.2 and 86.7% for males, with traits of the ilia generally being more accurate than those of the mandible.

Subsequently, Loth and Henneberg (9) identified significant sex-related differences in the shape of the inferior border of the mandibular symphysis and outline of the mandibular body. Loth and Henneberg reported an overall accuracy of 82% for a blind test of these traits by three evaluators using 19 known age subadults ranging in age between 7 months and 19 years of age.

While the nine nonmetric skeletal traits reported by Weaver, Schutkowski, and Loth and Henneberg show promise for sex determination of subadult remains, these nine characteristics have been found to be more accurate for sex assignment of subadult males than for subadult females, with female remains often being correctly identified only slightly better than chance (3–4,8–10). This may be because the expression of sex-related skeletal characteristics, especially those of the pelvis, are related to differential growth among females. Rogers and Saunders (11) suggest that, among adults, a greater proportion of individuals characterized by intermediate/indeterminate levels of expression will be classified as males because of a lack of female-trait expression.

The age of onset and quantity of androgen production will influence the expression of skeletal indicators of sex for fetal and juvenile skeletal remains. Testicular androgens are largely responsible for observed sex differences in the human skeleton. Fetal testosterone is reported to be present as early as the tenth week of fetal development and peaks during the 15th week of fetal development (12,13). However, the onset and quantity of androgen production is influenced by a variety of factors including genetics, development, and fetal environment. Target cells respond differentially to both the timing and quantity of fetal testosterone; therefore, slight differences in the timing and quantity of fetal testosterone may result in dramatic differences in both the degree and rate of a sexually dimorphic trait's expression. These factors may differ from population to population. Because of this, subadult sexing techniques that may be of value for one population may not be of value when applied to others.

The importance of accurate subadult aging techniques for forensic and bioarchaeological applications is self-evident. De Vito and Saunders (14) have recommended that subadult sexing techniques be at least 75% accurate. While no consensus exists among forensic anthropologists as to what constitutes an acceptable level of accuracy, 75% accuracy can be used as an arbitrary minimum standard for acceptability for any given sexing trait. The intent of this research is to test the accuracy of the eight nonmetric subadult sex-related skeletal traits previously proposed by Weaver (5) and Schutkowski (4) using 85 prehistoric known-sex subadult remains from the Atacama Desert Region of northern Chile.

Materials and Methods

The autopsied skeletal remains of 85 pre-Colombian subadult mummies of known-sex from the Atacama Desert Region of northern Chile are examined by this study (Table 1). Remains were excavated from well-provenienced, undisturbed tombs and are currently housed at the Museo San Miguel de Azapa of the Universidad de Tarapacá in Arica, Chile. The sex of each individual was determined by a team of pathologists during standardized autopsy procedures (15) through visual inspection of both external and internal sex organs. The presence of soft tissue is common for prehistoric human remains recovered from the Atacama Desert Region of northern Chile, as the Atacama Desert is one of the driest deserts in the world (16). Fetal and newborn remains are sometimes recovered with the umbilical chord intact and—in some instances—are in direct association with their mother. Indeed, Arriaza and colleagues (17) have reported some spectacular instances where mummified females were found with mummified infant remains still in the birth canal. Although these remains come from a number of different nearby sites and vary in their antiquity, epigenetic studies indicate that the prehistoric northern Chilean populations were characterized by relatively little genetic variability and gene flow (18,19). Therefore, temporal genetic differences among the remains examined by this study are not expected to be a major influence on any given subadult sex-linked trait's expression.

TABLE 1—*Skeletal age distribution for prehistoric northern Chilean known-sex subadult sample examined by this study.*

Skeletal Age Class	Female	Male
0–6 months	2	2
6 month–1	4	5
1	4	11
2	3	8
3	1	1
4	3	1
5	1	2
6	2	1
7	3	4
8	0	1
9	0	2
10	0	2
11	0	2
12	3	1
13	0	1
14	0	1
15	4	10
	30	55

Only those known-sex autopsied remains with a skeletal age ranging between newborn and 15 skeletal years of age were used by this study. Skeletal age was determined using standard subadult dental and long bone aging techniques recommended in Buikstra and Ubelaker (20). Dental development was the primary method of aging, with long bone length being used only when dental aging was not possible. There were instances when subadult mummies were either incomplete (i.e., missing skeletal elements) or the remains were not completely autopsied. Therefore, in some instances, not all eight traits were evaluated for each individual.

The eight aforementioned nonmetric sex-related subadult skeletal traits previously proposed by Weaver (5) and Schutkowski (4) that were evaluated by this study are provided in Table 2. For this study the eight skeletal traits of the pelvis and mandible were scored using a different system from those originally proposed. For each trait—and without knowing the sex of the specimens prior to their scoring—each scoreable skeletal trait was independently seriated in order of progressive expression for the trait in question (i.e., from weakest to strongest expression). An attempt was made to consider only the expression of the trait being scored and to ignore

other skeletal features. To decrease the likelihood of being influenced by the seriation and scoring of a previously scored trait, each trait was scored on a different day. A lab assistant would reorganize the previous day's seriated element (i.e., ilia or mandible) prior to the next trait's seriation and scoring.

While it is realized that during forensic applications one rarely has the multiple cases necessary to seriate the elements being evaluated, it has been demonstrated that the seriation of skeletal elements prior to scoring greatly reduces intra-observer error by forcing the observer to apply relatively consistent scoring standards for the trait being evaluated (21). Following seriation, each of the eight traits was scored using an interval scale of 1 to 5. Skeletal traits scored as 1 and 2 are considered to be "male" (1 = very male, 2 = male), while scores of 4 and 5 are "female" (5 = very female, 4 = female). A score of 3 indicates that the sex of the skeletal element is intermediate in expression (i.e., indeterminate sex) on the 1 to 5 scale from male to female. This scoring procedure was even used to score the auricular elevation. In Weaver's study (5) he defined the presence of auricular elevation only when the auricular surface is elevated over its entire length. For this study, the degree of elevation was scored on a 1–5 scale with a score of 1 representing no elevation and a score of 5 representing Weaver's presence (i.e., complete elevation over the entire length of the auricular surface).

Following the scoring of all skeletal traits, the assigned sex was compared with the known-sex of each specimen. So as to evaluate the accuracy for each trait in a manner that is more consistent with proposed applications of these techniques, the assigned scores were collapsed into categories of either "correct" or "incorrect." A subsequent publication will explore the associations of each trait's interval scores with sex and the associations among the traits' interval scores. For this study, scores of 1 and 2 are considered to be the correct assignment of sex for males, whereas scores of 3 (i.e., intermediate or indeterminate), 4 and 5 are considered the incorrect assignment of sex using that trait. Conversely, for females, a score of 4 and 5 are considered to be the correct assignment of sex, whereas scores of 1, 2, and 3 are considered to be incorrect. The accuracy of the eight skeletal traits is evaluated using χ^2 analysis of the assigned sex and the actual sex of the individual using a 0.05 level of significance. Accuracy is examined for both newborn to 5 skeletal years of age and for all subadult age classes (i.e., newborn to 15 years) combined. The former was conducted so as to make the results of this study comparable to the results previously reported by Weaver (5) and Schutkowski (4).

TABLE 2—*The distribution of sexual traits of the ilium for known-sex prehistoric mummified subadults of northern Chile by age class.*

Trait	Sex	Associated Expression
Sciatic Notch	Female	>90
	Male	~90
Depth of Sciatic Notch	Female	Shallow
	Male	Deep
Arch Criteria	Female	Boardering
	Male	Crosses
Iliac Crest Curvature	Female	Slight
	Male	Marked
Auricular Elevation	Female	Elevated
	Male	Flat
Mandibular Protrusion	Female	Smooth
	Male	Protrudes
Mandibular Arcade Shape	Female	Rounded
	Male	Rectangular
Gonial Eversion	Female	Absent
	Male	Present

Results

There are two separate but related issues regarding the value of any given trait for determining the sex of subadult skeletal remains. The first issue of interest to bioarchaeological research relates to whether the presence of any given trait is more commonly associated with either of the two sexes. A given trait's accuracy in predicting the sex of a subadult on a case-by-case basis is an issue of interest in forensic science. In order to examine the value of each of the eight traits examined by this study for bioarchaeological applications, the distribution by age of the five traits of the ilia evaluated by this study is provided in Table 3, while the distribution of sex by age class for the three mandibular traits is presented in Table 4.

Congruent sex-related associations for traits' character states by age class of the ilia range between a low of 0% for male expression of marked s-shaped iliac crest to a high of 100% for greater sciatic notch angle >90 degrees (6 to 10 and 11 to 15-year-old females), deep greater sciatic notch depth for 2 to 5-year-old males, shallow greater sciatic notch depth for 6 to 10 and 11 to 15-year-old females, auricular surface elevation for 2 to 5 and 6 to 10-year-old females, the arch criteria bordering the auricular surface for 2 to 5, 6 to 10, and 11 to 15-year-old females and arch criteria crossing the auricular surface for 2 to 5-year-old males, and marked s-shape for the iliac crest among 2 to 5-year-old males. For the mandible, the lowest congruence among the sex-related associations for trait character state is 43% for non-eversion of the gonial angle among newborn to 1-year-old females and to a high of 100% for a smooth and non-prominent chin among newborn to 1, 2 to 5, and 6 to 10-year-old females, and a rounded dental arcade among newborn to 1-year-old females.

In general, it can be said that for the 85 autopsied prehistoric mummified remains from northern Chile, the previously proposed sex-related character states are more often associated among subadults older than 1 year of skeletal age and more commonly among traits of the ilia than the mandible. For the newborn to 1-year-age class, five of the eight traits' character states conformed to the predicted sex-related associations. These traits include the sciatic notch angle, sciatic notch depth, the arch criteria, mandibular protrusion, and arcade shape. Iliac crest shape, auricular elevation, and gonial eversion did not conform to the predicted sex-related character state associations for autopsied known-sex prehistoric subadult Chileans between newborn and 1 year of age. For this age class, mandibular protrusion and greater sciatic notch depth performed better than did other traits for this age class.

For known-sex subadults from northern Chile, of both the 2 to 5 and 6 to 10-year age class, six of the eight traits' character states conform to the predicted sex-related associations. These traits include the sciatic notch angle, sciatic notch depth, the arch criteria, iliac crest shape, mandibular protrusion, and arcade shape. Auricular elevation and gonial eversion did not conform to the predicted sex-related character state associations. Similar sex-related character state associations were also observed among prehistoric known-sex subadults from northern Chile, of the 11 to 15-year age class. The only exception is that mental protrusion is less valuable for the assignment of sex among 11 to 15 year olds than it is for subadults between the ages of 2 and 10.

The accuracy for each of the eight nonmetric sex-related subadult skeletal traits and their associated χ^2 and significance val-

TABLE 3—*The distribution of sexual traits of the ilium for known-sex prehistoric mummified subadults of northern Chile by age class.*

Trait	Skeletal Age	Female ($n = 25$)	Male ($n = 39$)
Greater Sciatic Notch Angle			
~90	NB–1 ($n = 5$)	40% ($n = 2$)	60% ($n = 3$)
	2–5 ($n = 7$)	14% ($n = 1$)	86% ($n = 6$)
	6–10 ($n = 13$)	23% ($n = 3$)	77% ($n = 10$)
	11–15 ($n = 17$)	12% ($n = 2$)	88% ($n = 15$)
>90	NB–1 ($n = 8$)	63% ($n = 5$)	37% ($n = 3$)
	2–5 ($n = 7$)	86% ($n = 6$)	14% ($n = 1$)
	6–10 ($n = 1$)	100% ($n = 1$)	0% ($n = 0$)
	11–15 ($n = 5$)	100% ($n = 5$)	0% ($n = 1$)
Greater Sciatic Notch Depth			
Deeper	NB–1 ($n = 4$)	25% ($n = 1$)	75% ($n = 3$)
	2–5 ($n = 6$)	0% ($n = 0$)	100% ($n = 6$)
	6–10 ($n = 11$)	27% ($n = 3$)	73% ($n = 8$)
	11–15 ($n = 22$)	23% ($n = 5$)	77% ($n = 17$)
Shallow	NB–1 ($n = 9$)	67% ($n = 6$)	33% ($n = 3$)
	2–5 ($n = 8$)	88% ($n = 7$)	12% ($n = 1$)
	6–10 ($n = 1$)	100% ($n = 1$)	0% ($n = 0$)
	11–15 ($n = 2$)	100% ($n = 2$)	0% ($n = 0$)
Auricular Elevation			
Elevation	NB–1 ($n = 5$)	60% ($n = 3$)	40% ($n = 2$)
	2–5 ($n = 4$)	100% ($n = 4$)	0% ($n = 0$)
	6–10 ($n = 2$)	100% ($n = 2$)	0% ($n = 0$)
	11–15 ($n = 12$)	42% ($n = 5$)	58% ($n = 7$)
Not elevated	NB–1 ($n = 8$)	50% ($n = 4$)	50% ($n = 4$)
	2–5 ($n = 8$)	13% ($n = 1$)	87% ($n = 7$)
	6–10 ($n = 9$)	22% ($n = 2$)	78% ($n = 7$)
	11–15 ($n = 12$)	17% ($n = 2$)	83% ($n = 10$)
Arch Criteria			
Bordering auricular surface	NB–1 ($n = 8$)	63% ($n = 5$)	37% ($n = 3$)
	2–5 ($n = 7$)	100% ($n = 7$)	0% ($n = 0$)
	6–10 ($n = 1$)	100% ($n = 1$)	0% ($n = 0$)
	11–15 ($n =1$)	100% ($n = 1$)	0% ($n = 0$)
Crosses auricular surface	NB–1 ($n = 5$)	40% ($n = 2$)	60% ($n = 3$)
	2–5 ($n = 7$)	0% ($n = 0$)	100% ($n = 7$)
	6–10 ($n = 13$)	23% ($n = 3$)	77% ($n = 10$)
	11–15 ($n = 18$)	17% ($n = 3$)	83% ($n = 15$)
Iliac Crest			
Marked S-shape	NB–1 ($n = 1$)	100% ($n = 1$)	0% ($n = 0$)
	2–5 ($n = 5$)	0% ($n = 0$)	100% ($n = 5$)
	6–10 ($n = 10$)	20% ($n = 2$)	80% ($n = 8$)
	11–15 ($n = 19$)	26% ($n = 5$)	74% ($n = 14$)
Faint S-shape	NB–1 ($n = 12$)	50% ($n = 6$)	50% ($n = 6$)
	2–5 ($n = 9$)	78% ($n = 7$)	22% ($n = 2$)
	6–10 ($n = 3$)	33% ($n = 1$)	66% ($n = 2$)
	11–15 ($n = 4$)	50% ($n = 2$)	50% ($n = 2$)

ues are provided in Table 7. For purposes of comparability of results, the accuracies of the seven traits previously reported by Schutkowski (4) observed by this study for newborns to 5 year olds are provided in Table 6. Comparisons of previously reported accuracies for the auricular surface elevation and accuracy reported by this study is provided in Table 7, while comparisons of the accuracies of each of the seven traits of the ilia reported by Schutkowski (4) and those reported by this study are presented in Table 8. The accuracies for mandibular traits reported by both Schutkowski (4) and this study are presented in Table 9.

Seven of the eight previously proposed subadult sex-related traits produced statistically significant χ^2 results at the 0.05 level for all subadults (newborn to 15 skeletal years of age) examined by this study (Table 5). The only trait that did not produce a statistically significant result was gonial eversion ($p = 0.07$). While the remaining seven traits—the sciatic notch, depth of the sciatic notch, the arch criteria, iliac crest curvature, auricular elevation, mandibular protrusion, and mandibular arcade shape—all produced statistically significant results, only four of those seven meet the minimum acceptable level of 75% accuracy criteria established by De Vito and Saunders (14). For the known-sex subadult sample from northern Chile, the four traits that demonstrated both statistically significant and marginally acceptable values include the arch criteria (82.3%), the sciatic notch (80.7%), depth of the sciatic notch (79.0%), and mandibular arcade shape (77.6%). It is noteworthy that three of these four traits represent traits of the ilia, while only one is a mandibular trait.

For subadults ranging in age from newborn to five skeletal years of age, five of the eight traits examined by this study produced statistically significant χ^2 results. These traits include the angle of the

TABLE 4—*The distribution of sexual traits of the mandible for known-sex prehistoric mummified subadults of northern Chile by age class.*

Trait	Skeletal Age	Female ($n = 28$)	Male ($n = 49$)
Chin			
Prominent and angular	NB–1 ($n = 23$)	30% ($n = 7$)	70% ($n = 16$)
	2–5 ($n = 17$)	29% ($n = 5$)	71% ($n = 12$)
	6–10 ($n = 8$)	25% ($n = 2$)	75% ($n = 6$)
	11–15 ($n = 16$)	25% ($n = 4$)	75% ($n = 12$)
Smooth and nonprominent	NB–1 ($n = 2$)	100% ($n = 2$)	0% ($n = 0$)
	2–5 ($n = 2$)	100% ($n = 2$)	0% ($n = 0$)
	6–10 ($n = 3$)	100% ($n = 3$)	0% ($n = 0$)
	11–15 ($n = 6$)	50% ($n = 3$)	50% ($n = 3$)
Anterior dental arcade			
Wide and rectangular	NB–1 ($n = 24$)	33% ($n = 8$)	67% ($n = 16$)
	2–5 ($n = 14$)	21% ($n = 3$)	79% ($n = 11$)
	6–10 ($n = 6$)	17% ($n = 1$)	83% ($n = 5$)
	11–15 ($n = 13$)	8% ($n = 1$)	92% ($n = 12$)
Rounded	NB–1 ($n = 1$)	100% ($n = 1$)	0% ($n = 0$)
	2–5 ($n = 5$)	80% ($n = 4$)	20% ($n = 1$)
	6–10 ($n = 5$)	80% ($n = 4$)	20% ($n = 1$)
	11–15 ($n = 9$)	67% ($n = 6$)	33% ($n = 3$)
Gonial angle			
Everted	NB–1 ($n = 18$)	33% ($n = 6$)	67% ($n = 12$)
	2–5 ($n = 6$)	17% ($n = 1$)	83% ($n = 5$)
	6–10 ($n = 5$)	40% ($n = 2$)	60% ($n = 3$)
	11–15 ($n = 11$)	9% ($n = 1$)	91% ($n = 10$)
Not everted	NB–1 ($n = 7$)	43% ($n = 3$)	57% ($n = 4$)
	2–5 ($n = 13$)	46% ($n = 6$)	54% ($n = 7$)
	6–10 ($n = 6$)	50% ($n = 3$)	50% ($n = 3$)
	11–15 ($n = 11$)	55% ($n = 6$)	45% ($n = 5$)

TABLE 5—*Percent distribution of sex-related skeletal traits for known-sex prehistoric mummified remains from northern Chile: newborn to 15 years of skeletal age.*

Trait	Sex	Classification		Overall % Correct	Chi-Square*	*p-value*
Sciatic Notch		>90	~90			
	Female (25)	68.0%	32.0%	80.7%	19.31	*0.00001*
	Male (37)	10.8%	89.2%			
Depth of Sciatic Notch		Shallow	Deep			
	Female (25)	64.0%	36.0%	79.0%	16.96	*0.00004*
	Male (37)	10.8%	89.2%			
Arch Criteria		Boardering	Crosses			
	Female (25)	68.0%	32.0%	82.3%	21.83	*0.00000*
	Male (37)	8.1%	91.9%			
Iliac Crest Curvature		Slight	Marked			
	Female (25)	68.0%	32.0%	69.4%	7.35	*0.00672*
	Male (37)	29.7%	70.3%			
Auricular Elevation		Elevated	Flat			
	Female (23)	60.9%	39.1%	71.7%	7.39	*0.00657*
	Male (37)	22.2%	77.8%			
Mandibular Protrusion		Smooth	Protrudes			
	Female (28)	35.7%	64.3%	73.7%	10.97	*0.00093*
	Male (48)	4.2%	95.8%			
Mandibular Arcade Shape		Rounded	Rectangular			
	Female (28)	53.6%	46.4%	77.6%	16.96	*0.00004*
	Male (48)	8.3%	91.7%			
Gonial Eversion		Absent	Present			
	Female (28)	64.3%	35.7%	61.8%	3.39	0.06570
	Male (48)	39.6%	60.4%			

* Yates' Continuity Correction

TABLE 6—*Percent distribution of sex-related skeletal traits for known-sex prehistoric mummified remains from northern Chile: newborn to 5 years of age.*

Trait	Sex	Classification		Overall % Correct	Chi-Square*	*p - value*
Sciatic Notch		>90	~90			
	Female (14)	78.6%	21.4%	74.1%	4.45	*0.03485*
	Male (13)	30.8%	69.2%			
Depth of Sciatic Notch		Shallow	Deep			
	Female (14)	92.6%	7.1%	81.5%	8.64	*0.00329*
	Male (13)	30.8%	69.2%			
Arch Criteria		Boardering	Crosses			
	Female (14)	85.7%	14.3%	81.5%	8.32	*0.00391*
	Male (13)	23.1%	76.9%			
Iliac Crest Curvature		Slight	Marked			
	Female (14)	92.9%	7.1%	66.7%	2.23	0.13554
	Male (13)	64.5%	38.5%			
Auricular Elevation		Elevated	Flat			
	Female (12)	58.3%	41.7%	72.0%	3.31	0.06905
	Male (13)	15.4%	84.6%			
Mandibular Protrusion		Smooth	Protrudes			
	Female (16)	25.0%	75.0%	72.7%	4.97	*0.02576*
	Male (28)	0.0%	100.0%			
Mandibular Arcade Shape		Rounded	Rectangular			
	Female (16)	31.3%	68.8%	72.7%	4.48	*0.03426*
	Male (28)	3.6%	96.4%			
Gonial Eversion		Absent	Present			
	Female (16)	56.3%	43.8%	59.1%	0.60	0.43986
	Male (28)	39.3%	60.7%			

* Yates' Continuity Correction

TABLE 7—*Comparison of reported accuracies for subadult auricular elevation.*

	NB - 1			Overall Study		
Study	Male	Female	Combined	Male	Female	Combined
Weaver	85.7% ($n = 56$)	48.9% ($n = 47$)	68.9% ($n = 103$)	85.4% ($n = 80$)	57.7% ($n = 71$)	73.5% ($n = 151$)
Mittler & Sheridan	. . .	. . .	. . .	85.3% ($n = 34$)	58.3% ($n = 24$)	74.1% ($n = 58$)
This Study	42.8% ($n = 7$)	66.7% ($n = 6$)	53.8% ($n = 13$)	77.8% ($n = 37$)	60.9% ($n = 23$)	71.7% ($n = 60$)

TABLE 8—*Comparison of reported accuracies for four subadult sexing techniques of the ilia proposed by Schutkowski.*

Trait & Study	Sex	NB–1	2–5 yrs	Overall (NB–5)
Greater Sciatic Notch Angle				
Schutkowski	Male	54.6% ($n = 11$)	82.4% ($n = 17$)	71.4% ($n = 28$)
	Females	100% ($n = 11$)	90.0% ($n = 10$)	95.2% ($n = 21$)
	Combined	77.3% ($n = 22$)	85.2% ($n = 27$)	81.6% ($n = 49$)
This Study	Male	50.0% ($n = 6$)	85.7% ($n = 7$)	69.2% ($n = 13$)
	Females	71.4% ($n = 7$)	85.7% ($n = 7$)	78.6% ($n = 14$)
	Combined	61.5% ($n = 13$)	85.7% ($n = 14$)	74.1% ($n = 27$)
Greater Sciatic Notch Depth				
Schutkowski	Male	81.8% ($n = 11$)	89.5% ($n = 19$)	86.7% ($n = 30$)
	Females	54.5% ($n = 11$)	87.5% ($n = 8$)	68.4% ($n = 19$)
	Combined	68.2% ($n = 22$)	88.9% ($n = 27$)	79.6% ($n = 49$)
This Study	Male	50.0% ($n = 6$)	85.7% ($n = 7$)	69.2% ($n = 13$)
	Females	85.7% ($n = 7$)	100% ($n = 7$)	92.9% ($n = 14$)
	Combined	69.2% ($n = 13$)	92.8% ($n = 14$)	81.5% ($n = 27$)
Arch Criteria				
Schutkowski	Male	81.8% ($n = 11$)	81.3% ($n = 16$)	81.5% ($n = 27$)
	Females	70.0% ($n = 10$)	50.0% ($n = 10$)	60.0% ($n = 20$)
	Combined	76.2% ($n = 21$)	69.2% ($n = 26$)	72.3% ($n = 47$)
This Study	Male	50.0% ($n = 6$)	100% ($n = 7$)	76.9% ($n = 13$)
	Females	71.4% ($n = 7$)	100% ($n = 7$)	85.7% ($n = 14$)
	Combined	61.5% ($n = 13$)	100% ($n = 14$)	81.5% ($n = 27$)
Iliac Crest				
Schutkowski	Male	40.0% ($n = 10$)	64.3% ($n = 14$)	54.2% ($n = 24$)
	Females	80.0% ($n = 10$)	90.9% ($n = 11$)	85.7% ($n = 21$)
	Combined	60.0% ($n = 20$)	76.0% ($n = 25$)	68.9% ($n = 45$)
This Study	Male	0.0% ($n = 6$)	71.4% ($n = 7$)	38.5% ($n = 13$)
	Females	85.7% ($n = 7$)	100% ($n = 7$)	92.9% ($n = 14$)
	Combined	46.2% ($n = 13$)	85.7% ($n = 14$)	66.6% ($n = 27$)

TABLE 9—*Comparison of reported accuracies for three subadult sexing techniques of the mandible proposed by Schutkowski.*

Trait & Study	Sex	NB–1	2–5 years	Overall (NB–5)
Chin Prominence				
Schutkowski	Male	61.5% ($n = 13$)	57.1% ($n = 14$)	59.3% ($n = 27$)
	Females	100.0% ($n = 6$)	85.7% ($n = 7$)	92.3% ($n = 13$)
	Combined	73.7% ($n = 19$)	66.7% ($n = 21$)	80.0% ($n = 40$)
This Study	Male	100% ($n = 16$)	100% ($n = 12$)	100% ($n = 28$)
	Females	22.2% ($n = 9$)	40.0% ($n = 7$)	25.0% ($n = 16$)
	Combined	72.0% ($n = 25$)	73.7% ($n = 19$)	72.7% ($n = 44$)
Anterior Dental Arcade Shape				
Schutkowski	Male	66.6% ($n = 12$)	78.6% ($n = 14$)	73.1% ($n = 26$)
	Females	50.0% ($n = 6$)	85.7% ($n = 7$)	69.2% ($n = 13$)
	Combined	61.1% ($n = 18$)	81.0% ($n = 21$)	71.8% ($n = 39$)
This Study	Male	100% ($n = 16$)	91.7% ($n = 12$)	96.4% ($n = 28$)
	Females	11.1% ($n = 9$)	42.9% ($n = 7$)	31.3% ($n = 16$)
	Combined	68.0% ($n = 25$)	73.7% ($n = 19$)	72.7% ($n = 44$)
Gonial Eversion				
Schutkowski	Male	45.5% ($n = 11$)	85.7% ($n = 14$)	68.0% ($n = 25$)
	Females	71.4% ($n = 7$)	55.6% ($n = 9$)	62.5% ($n = 16$)
	Combined	55.6% ($n = 18$)	73.9% ($n = 23$)	65.9% ($n = 41$)
This Study	Male	75.0% ($n = 16$)	41.7% ($n = 12$)	60.7% ($n = 28$)
	Females	33.3% ($n = 9$)	85.7% ($n = 7$)	56.3% ($n = 16$)
	Combined	60.0% ($n = 25$)	57.9% ($n = 19$)	59.1% ($n = 44$)

sciatic notch, depth of the sciatic notch, arch criteria, mandibular protrusion, and mandibular arcade shape. Iliac crest curvature, auricular elevation, and gonial eversion failed to produce statistically significant results among the known-sex subadults from northern Chile, which range between newborn and five skeletal years of age. Among the five statistically significant characteristics for the newborn to five-year-old age class, only depth of the sciatic notch (81.5%) and the arch criteria (81.5%) demonstrated minimally acceptable levels of accuracy (i.e., equal to or greater than 75%).

Discussion

An examination and comparison of the associations of sex-related traits of the ilia and mandible by their respective character states presented in Table 3 and Table 4 indicate that most of the traits' character-state expressions are indeed sex-related and become even more so with increasing age. For bioarchaeological applications, the most useful characteristics include greater sciatic notch angle, greater sciatic notch depth, the arch criteria, and chin prominence. For these nonmetric traits, each of the sex-related character state tendencies reported by Schutkowski (4) also characterize the known-sex subadult remains from northern Chile.

Exceptions to the proposed sex-related character states include auricular elevation, a faint s-shaped iliac crest, a rounded dental arcade shape, and non-eversion of the gonial angle. All four of these traits' character state expressions are proposed to be associated with females. However, among the known-sex subadult remains from northern Chile, it is clear that the character states for these features are less frequently associated with subadult females than previously reported by Weaver (5) and Schutkowski (4). Further, in the case of auricular elevation, 11 to 15-year-old males examined by this study were more commonly associated with elevated auricular surfaces (58%) than were females. However, this result may be due, in part, to a skewed sex ratio of 11 to 15-year age class, which consisted of only seven females and 17 males.

For the sample reported here, there is a clear age-related component to the associations of specific character states. Congruent associations of specific character states for auricular elevation, a faint s-shaped iliac crest, a rounded dental arcade shape, and non-eversion of the gonial angle become greater among older subadults than they are among subadults ranging in age between newborn to 1 year of age. Among subadults of the youngest age class (newborn to 1 year of age), greater sciatic notch depth and mandibular protrusion are the most valuable among the eight characteristics for the sample reported by this study. Overall, it is recommended that one should use caution when assigning sex to bioarchaeological human remains of this age class as many of the proposed sex-related skeletal traits are only weakly associated with sex.

The bioarchaeological assignment of sex to prehistoric subadult remains can be done with greater accuracy for individuals older than one year of skeletal age. Results from this study suggest that the greater sciatic notch angle, depth of the sciatic notch, arch criteria, mandibular protrusion, and arcade shape are the most valuable characteristics for the assignment of sex to prehistoric subadult skeletal remains two skeletal years of age and older. While it is possible that results reported here may be population specific or due to different scoring procedures, findings of this study are largely in agreement with those reported by Schutkowski (4).

Interestingly, Loth and Henneberg (9) suggest that mandibular symphysis morphology may be more useful for determining subadult sex through age six. The investigators suggest that prior to age six, the morphology of the mandibular symphysis may be more related to sex-based differences in developing anterior tooth size than morphological differences after age six. Once the mandibular incisors have erupted, the authors suggest, sex-based differences in mandibular symphysis morphology are likely to become less apparent. While this sex- and age-related trend observed for the mandibular symphysis by Loth and Henneberg is promising, the results of both Schutkowski's (4) and this study do not confirm the age-related trends for the anterior mandibular traits proposed by Schutkowski (i.e., mandibular protrusion and arcade shape). In any case, when applied to bioarchaeological samples, results from this study indicate that auricular elevation, iliac crest shape, dental arcade shape, and the gonial angle are

more useful for the correct assignment of sex for males than they are for females.

For forensic applications where one is likely to apply these traits one case at a time, the primary concern is accuracy. With the exception of gonial eversion, all of the traits' associations with known-sex for all subadults examined by this study were statistically significant at the 0.05 level. However, only the arch criteria, sciatic notch angle, depth of the sciatic notch, and mandibular arcade shape accurately predicted sex greater than 75% of the time among the 85 autopsied prehistoric mummified subadults of known-sex from northern Chile. A comparison of previously reported accuracies of elevation of the auricular surface for the correct assignment of sex among subadults by Weaver (5) and Mittler and Sheridan (10) with those achieved by this study (Table 7) indicates that males are correctly identified more often than females. For subadults ranging from newborn to one year of skeletal age, Weaver (5) reports that males were accurately identified 85.7% of the time, whereas females were accurately identified only 48.9% of the time, while this study finds that only 42.8% of males of this age class are accurately identified while 66.7% of females are accurately identified. Overall accuracies for the newborn to one year of age class are 68.9% for Weaver's study and only 53.9% for this study.

For overall accuracies for elevations of the auricular elevation, Weaver (5) reports 85.4% accuracy for males and 57.7% for females, while Mittler and Sheridan (10) report 85.3% for males and 58.3% for females. For this study, males for all age classes are accurately identified using auricular elevation criteria 77.8% of the time, while females are accurately identified 60.9% of the time. It should be noted, however, that all three of these studies examined remains of different age ranges. Weaver (5) only examined fetal and infant remains ranging in age from newborn to 6 months age, while Mittler and Sheridan (10) examined mummified remains ranging in age from newborn to 18 skeletal years of age. This study examined remains that ranged in age between newborn and 15 skeletal years of age. The different age ranges of these studies may account for some of the reported differences. In spite of the differences among the overall age ranges considered by these studies, it is noteworthy that females were correctly identified more often by this study than were females in the other two studies. This is likely due, in part, to the modified scoring procedure employed by this study, but may also be due, to some degree, to genetic and environmental difference among the samples reported. Despite the more flexible and accurate scoring procedure used by this study, both the newborn to 1 and overall combined accuracies are lower than those reported by Weaver and Mittler and Sheridan. Importantly, none of the studies report combined accuracies equal to or greater than 75%. While auricular elevation is clearly sex related and may be of use in bioarchaeological applications, it does not meet the minimally acceptable criteria necessary to make this trait useful for forensic applications.

For the four traits of the ilia proposed by Schutkowski (4) (i.e., greater sciatic notch angle, greater sciatic notch depth, arch criteria, iliac crest), comparisons of accuracies achieved by this study with those reported by Schutkowski indicate that, in general, these traits are less accurate when applied to newborn to 1-year-olds from the known-sex subadult sample from northern Chile, but are generally more accurate for prehistoric subadult Chileans of known-sex between 2 to 5 skeletal years of age. For this study, none of the combined accuracies for the four aforementioned traits of the ilia are accurate enough for correct assignment of sex for subadult remains under two years of age, while Schutkowski's (4) data indicate the greater sciatic notch (77.3%) and arch criteria (76.2%) marginally surpass the minimal standard of accuracy for use in forensic cases for infants under two. While further testing of these traits using additional known-sex subadult collections is necessary, at this time it is difficult to recommend the use of any of the four aforementioned traits of the ilia in forensic cases for children under two years of age, given that even Schutkowski's data indicate marginally acceptable accuracy.

For the 2 to 5-year-age category, this study finds that all four traits of the ilia (i.e., greater sciatic notch angle, greater sciatic notch depth, arch criteria, iliac crest) meet the minimal criteria for accuracy, whereas Schutkowski's (4) data indicates that the greater sciatic notch angle (85.2%), greater sciatic notch depth (88.9%), and iliac crest curvature (76.0%) surpassed the minimal standards of accuracy for forensic applications, while the arch criteria failed to achieve 75% accuracy (Table 8). Based upon results from this study and those reported by Schutkowski, it is suggested that the greater sciatic notch depth, greater sciatic notch angle, and iliac curvature may be useful for forensic cases involving children ages two to five.

Comparisons of the accuracies for the three mandibular traits reported by Schutkowski (4) (i.e., mandibular protrusion, dental arcade shape, and gonial eversion) to those reported by this study (Table 9) indicate that none of the mandibular traits meet the minimal standards of accuracy necessary to be of use in forensic cases involving newborn to one-year-old children. While results of this study indicate that none of the mandibular traits are sufficiently accurate for the 2 to 5-year-age class, Schutkowski's (4) data indicate that dental arcade shape (81.0%) is the only trait that approaches acceptable levels of accuracy for forensic applications. Indeed, Loth's (22) independent test of sex prediction based upon mandibular protrusion was only accurate 33% of the time, while gonial eversion was accurate only 37% of the time. Given the lack of replicability of Schutkowski's results by this study and those reported by Loth, it is difficult to recommend any of the mandibular traits proposed by Schutkowski for the sexing of juveniles of any age in forensic cases. However, Loth and Henneberg (9) report an overall accuracy of 82% when examining mandibular symphysis and outline of the mandibular body. While this study did not examine these characteristics, Loth and Henneberg's results indicate that there are mandibular traits among subadults that meet the minimally acceptable criteria for forensic application.

Although Schutkowski was not able to report accuracies for subadults greater than five years of age for lack of an adequate number of individuals, it is suggested that greater sciatic notch depth, greater sciatic notch angle, the arch criteria, and mandibular arcade shape can cautiously be applied to forensic cases involving children ages 6 to 15 years of age based upon results reported by this study (Table 5).

Summary

Results presented here clearly indicate that all eight of the subadult sexing traits evaluated by this study are associated with sex. Results from both this study and those reported by others indicate that, even among the youngest of subadults, the sex-related expression of these traits is age related, with their expression generally becoming more pronounced with age. For bioarchaeological applications, the most useful characteristics include greater sciatic notch angle, greater sciatic notch depth, the arch criteria, and chin prominence. Caution should be used when applying these traits to subadults under two years of age.

While nearly all of the sex-related skeletal traits examined by this study are statistically significant, some traits perform only

slightly better than chance. Although none of the eight traits examined by this study demonstrated minimally acceptable accuracies for forensic cases involving subadults under two years of age, Schutkowski's (4) results indicate that the greater sciatic notch and arch criteria meet the minimal standards for accuracy. Research using additional known-sex subadult collections is necessary to determine whether the greater sciatic notch and arch criteria are sufficiently accurate to be used with other populations. For cases involving children ages 2 to 5 years of age, greater sciatic notch depth, greater sciatic notch angle, and iliac curvature demonstrate minimally acceptable accuracies for forensic applications. Based upon the accuracies reported by this study, it is suggested that greater sciatic notch depth, greater sciatic notch angle, the arch criteria, and mandibular arcade shape can tentatively be considered in forensic cases involving children ages 6 to 15 years of age.

The results of this and other studies involving subadult remains of known-sex clearly demonstrate that there are nonmetric traits that are useful for both forensic and bioarchaeological applications. It is suggested that additional research may uncover other sex-related nonmetric traits that will prove useful for correctly assigning sex to subadult remains. Given the age-related expression of these traits, it is recommended that future investigations report accuracies of subadult sexing techniques by both sex and age when evaluating their usefulness in forensic applications.

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