CHAPTER

Sex Estimation

8

8.1 Principles of sex estimation

Estimating sex from skeletal remains involves the identification and evaluation of characteristics that tend to show differences between male and female skeletons, which are variably expressed throughout the skeleton. These differences are primarily related to size and architecture which result from different biomechanical functions of joints for efficiency in **locomotion** (movement, usually walking) and **parturition** (childbirth). In the analysis and identification of human skeletal remains, the correct determination of sex effectively eliminates approximately 50% of the population from further consideration, thus substantially assisting in the search of missing persons records and databases (see Chapter 14). In addition, many other analyses such as stature and age estimation are sex-specific, making sex estimation an important part of the biological profile, especially in the preliminary stages of an investigation.

The ability to differentiate between male and female skeletons is due to **sexual dimorphism**, or the expression of **phenotypic** differences between males and females of the same species. Sexual dimorphism usually relates primarily to differences in **morphology** (size and shape), but may also refer to differences in physiology and behavior. In forensic anthropology, morphological differences between males and females are the most useful for sex estimation.

In comparison to other animals, humans display relatively little sexual dimorphism (Figure 8.1). For example, many bird species differ significantly in color and ornamentation. Additionally, many male and female non-human primates including gorillas differ greatly in size. Humans, on the other hand, show only modest differences in size and certain body proportions. Human ancestors displayed a greater sexual dimorphism in size than modern humans, showing a reduction of dimorphism over the course of **hominin** evolution (Frayer and Wolpoff, 1985). Sexual dimorphism is also not uniform across all human populations, with some groups being more sexually dimorphic than others. It is therefore often advisable to consider ancestry when estimating sex from unknown remains.

On average, adult human males are larger and more robustly built than females, exceeding them in height, weight, and breadth (France, 1998). Their bones tend to be longer, thicker, and have more prominent muscle attachments (males tend to have

Forensic Anthropology. http://dx.doi.org/10.1016/B978-0-12-418671-2.00008-2

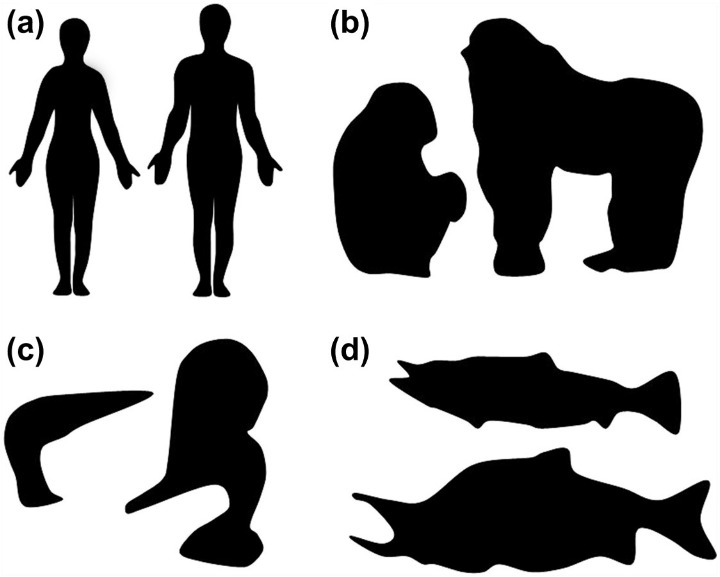

FIGURE 8.1 Sexual dimorphism in: (a) humans, (b) gorillas, (c) *Darwinopterus*, and (d) sockeye salmon

greater muscle mass, which requires greater surface area for attachment to the bone). Because human sexual dimorphism is not extreme, however, there tends to be considerable overlap; smaller males and larger females may be more difficult to differentiate (see Figure 8.2 for an example of male and female height). Many sexually dimorphic traits are secondary sexual characteristics that develop during puberty, largely due to the release of hormones that result in changes in the rate of bone growth and development (Bogin, 1999).

The terms **sex** and **gender** are often used interchangeably in both popular media and scientific (including anthropological) literature, but they do have distinct meanings which should be understood (Walker and Cook, 1998) (see Box 8.1). When referring to analyses and estimates performed by forensic anthropologists based on skeletal characteristics, "sex" is the appropriate term.

Various methods that generally fall into one of two categories have been developed for estimating sex from skeletal remains: non-metric (macroscopic, or visual) analysis and metric analysis. Each utilizes certain bones or overall patterns depending on the degree and quality of sexual dimorphism in that bone or anatomical region. As discussed in Chapter 3, metric methods are generally considered to be more objective, but in the case of sex estimation, visual assessment of the pelvis is the most accurate method. Methods involving dimensions of various long bones of the postcranial skeleton are typically the next most accurate, followed by methods involving the skull (Spradley and Jantz, 2011). Various issues associated

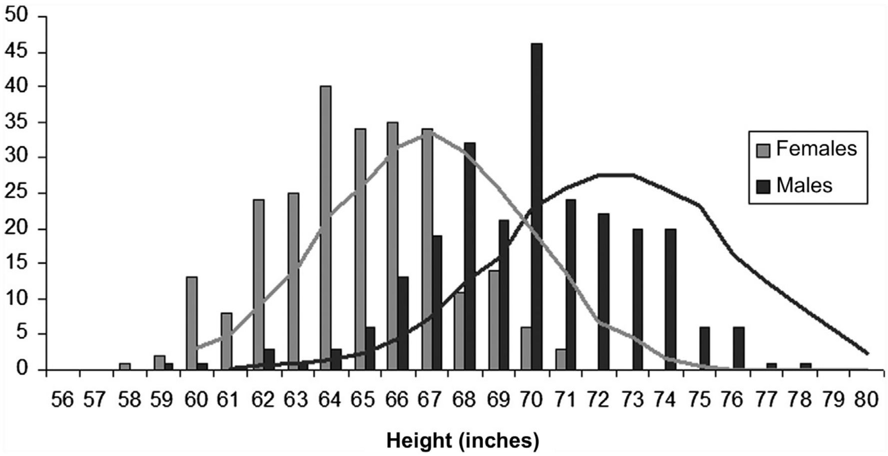

FIGURE 8.2 Distribution of female and male height

BOX 8.1 SEX VERSUS GENDER

Sex refers to the totality of characteristics of reproductive structure, functions, **phenotype**, and **genotype** which differentiate males from females. Such differences are the result of the inheritance and expression of sex chromosomes XX (female) or XY (male), and sex can therefore only be determined on the basis of anatomical or molecular evidence. Note that while sex is typically a binary dichotomy, a small number of individuals have an anatomy and/or biology that does not fit into the standard "male" or "female" classification. **Intersex** refers to individuals who display such characteristics, typically resulting from chromosomal or physical/genital anomalies.

Gender, on the other hand, refers to cultural expressions of feminine and masculine behaviors and attributes which are considered appropriate for men and women in a given society. Gender is culturally defined and context specific, and therefore does not necessarily correspond to traditions of masculine and feminine roles in any one particular culture. Some cultures, in fact, recognize multiple genders (often related to intersexuality or **androgeny**). Prior to the late 1960s, the term "gender" was only used to refer to feminine and masculine words in a language, but the feminist movement of the 1960s extended the meaning to refer to differences between men and women (Nicholson, 1994). The term "gender" was appropriated by scientists in the 1980s and 1990s as a politically correct way to refer to "sex" which was viewed as a loaded term, but disciplines such as anthropology, psychology, and physiology have been increasingly emphasizing the distinction between gender and sex in their discourse (Torgrimson and Minson, 2005).

While a person's sex is biologically fixed, their expression of the feminine-masculine continuum is more fluid, and gender therefore cannot be estimated from skeletal remains. Gender may be suggested by evidence associated with skeletal remains, however, and may be appropriate to note, especially for potential use in identification. For example, anatomically male skeletal remains found dressed in clothing typically associated with women should be noted since it may allow investigators to focus on certain social groups with which the individual may have associated during life.

FIGURE 8.3 Female (bottom) and male (top) pelvis

with sex estimation such as estimation of sex from **juvenile** remains and molecular/genetic methods are addressed at the end of this chapter.

8.2 Morphoscopic (non-metric) analysis

Non-metric analysis in sex estimation involves a visual, qualitative assessment of skeletal features that tend to vary between males and females. These assessments involve observations of the degree of expression of certain traits, or a determination of the presence or absence of a particular feature.

Owing to the functions of childbirth, the pelvis is the most sexually dimorphic region of the human skeleton, displaying the most sexual variation in architecture, meaning that assessment of the pelvis is the most accurate method for estimating sex from skeletal material. In general, the different features reflect a wider female pelvis and pelvic inlet as a result of selective pressures to expand the birth canal. This expansion is necessary due to the large size of the human fetus (particularly the head) in relation to the size of the birth canal. There is, in fact, a direct relationship between a species' neonatal brain size relative to the birth canal and pelvic sexual dimorphism (Ridley, 1995). Other animals, including other primates, who have relatively small-brained infants show very little sexual dimorphism in the pelvis, other than overall size.

In general, the pelvis is shorter and broader in females than in males, with a more widely configured pelvic inlet and a wider sub-pubic angle (see Figure 8.3). On the ilium, a variably developed preauricular sulcus is often present in females but absent in males (Figure 8.4). The obturator foramen in females tends to be more triangular, while it is more oval in males. Some of the more varied morphological differences that are commonly utilized in sex estimation are described in Table 8.1.

The wider pelvis in females requires concomitant adaptations in other bones, notably, the angles of the knee and elbow (often called the "**Q-angle**" in the knee and the "**carrying angle**" in the elbow) (Figure 8.5). Due to having wider hips, the angle at which the femur meets the tibia at the knee is necessarily greater in females so that the knees are oriented under the trunk in a configuration efficient for locomotion (Livingston, 1998). Similarly, in order to clear the hips during arm swinging while walking, females have a greater carrying angle of the elbow (Potter, 1895; Atkinson and Elftman, 1945).

The Phenice (1969) method involves the evaluation of three traits of the *os pubis* and has a reported accuracy of around 96%. It is one of the most validated and commonly used methods of estimating sex from the pelvis when the pubic region is available for study. The three Phenice traits are:

(1) The *ventral arc* which is typically present in females and absent in males.
(2) The *sub-pubic concavity* of the ischiopubic ramus which is typically present in females and absent in males.
(3) The *medial aspect of the ischiopubic ramus* which is sharp and narrow in females and dull and wide in males (Figure 8.6).

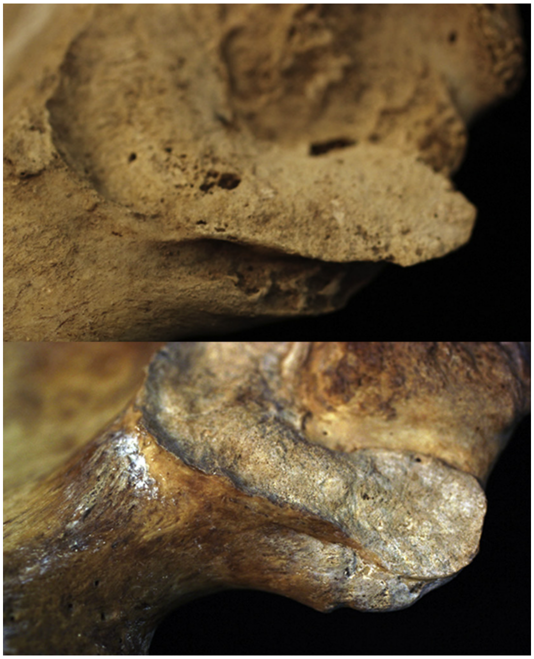

FIGURE 8.4 Preauricular sulcus, present in females (top) and absent in males (bottom)

Table 8.1 Traits of the female and male pelvis

Pelvic feature	Female pelvis	Male pelvis
Ilium	Low, wide, flared	High and vertical
Pelvic inlet	Oval	Heart-shaped
Ventral arc	Present	Absent
Sub-pubic concavity	Present	Absent
Medial ischiopubic ramus	Narrow and sharp	Wide and dull
Obturator foramen	Small and triangular	Large and ovoid
Sub-pubic angle	Larger	Smaller
Greater sciatic notch	Larger	Smaller
Preauricular sulcus	Present	Absent
Sacral shape	Short, wide, straight	Long, narrow, curved
Auricular surface (sacroiliac articulation)	Elevated	Flush with ilium
Pubic bone shape	Rectangular	Triangular
Acetabulum	Smaller	Larger
Sacral dimensions	Alae wider than promontory	Alae narrower than promontory

Some studies have reported very high accuracy (around 96%) based on the ventral arc alone (Sutherland and Suchey, 1991; Lovell, 1989; Ubelaker and Volk, 2002) and may even be useful in younger individuals as it is usually recognizable even in its "precursor" condition.

In addition to the Phenice traits, sexual dimorphism has been noted in the shape and width of the sciatic notch (Walker, 2005), with females having a wider notch and males having a narrower notch (Figures 8.7 and 8.8). Studies of documented collections have found that males sometimes have a wide notch, whereas females rarely show evidence of a narrow notch. Due to some overlap in the intermediate expressions of the sciatic notch, it is not recommended to estimate sex based solely on this feature.

Another source of sexual dimorphism is that human females tend to be more **neotenous** or **pedomorphic** than males, retaining more juvenile-like traits anatomically, including skeletally. Some pedomorphic traits include having less body hair, a higher voice, smaller teeth, larger eyes, and a more gracile skeleton. With age, however, skeletal remodeling may result in morphological changes in females that appear more masculine; thus, this should be taken into account during sex estimation of older individuals.

Sexual dimorphism may also develop as a function of different musculoskeletal activity (Buffa et al., 2001). In many cultures, males are more frequently involved in more laborious activities and therefore subject their skeletons to greater mechanical

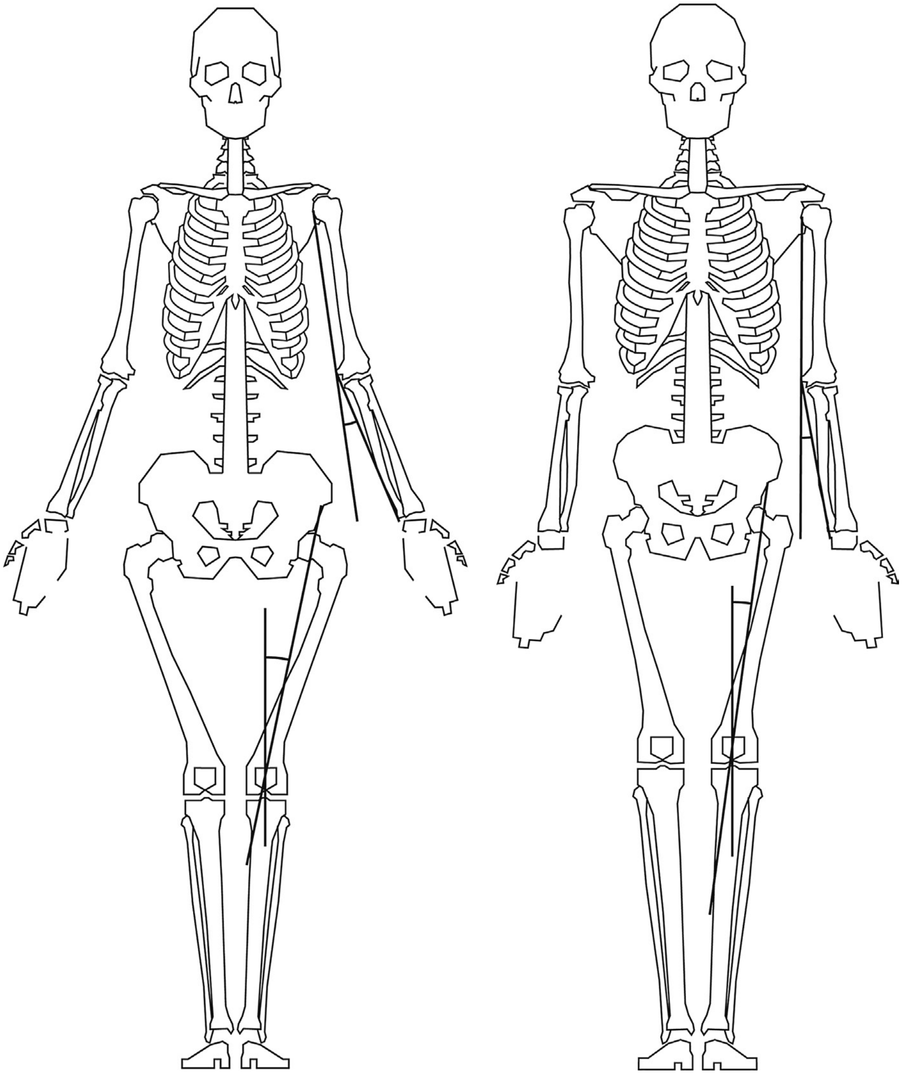

FIGURE 8.5 Angles of the elbow and knee in females (left) and males (right)

(Artwork by Craig Brodfuehrer)

loads. Bones that are subjected to greater mechanical loading and stress (especially the femur and tibia) tend to increase in cortical area (see Chapter 2). Where these loading and stress differences are greater between males and females, the bones may be more sexually dimorphic in terms of cortical area and/or the size of muscle attachments.

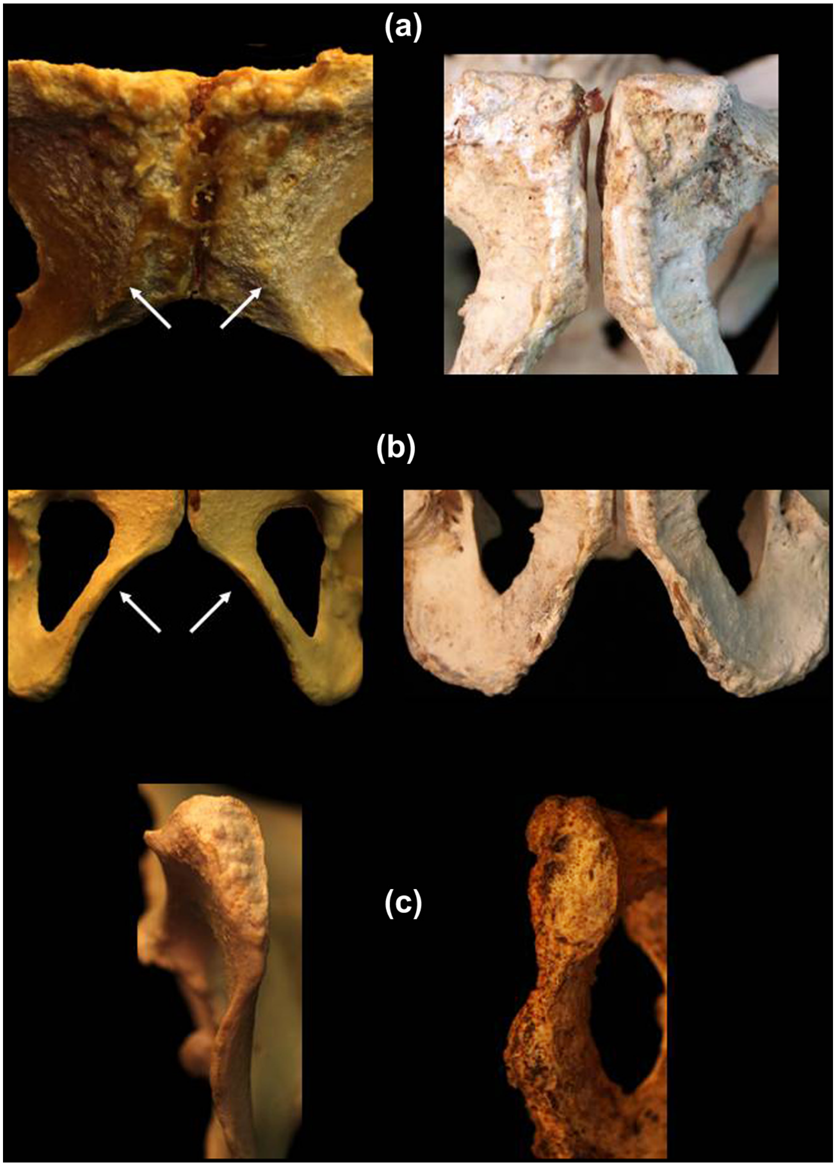

FIGURE 8.6 Phenice traits of the *os pubis* in the female (left) and male (right)

(a) Ventral arc – present in females, absent in males, (b) sub-pubic concavity – present in females, absent in males, and (c) medial ischiopubic ramus – sharp and narrow in females, wide and blunt in males

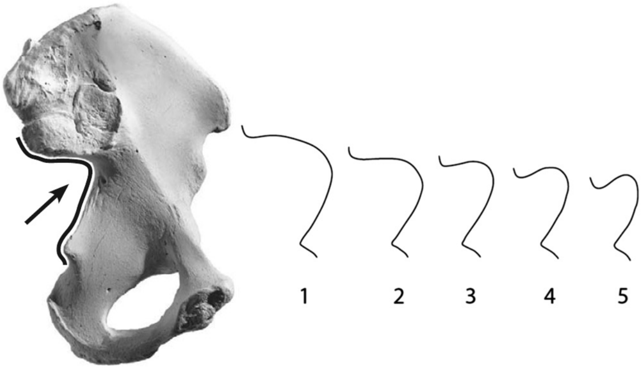

FIGURE 8.7 Variation in the sciatic notch

1 represents a more female configuration while 5 represents a more male configuration

(From Buikstra and Ubelaker, 1994)

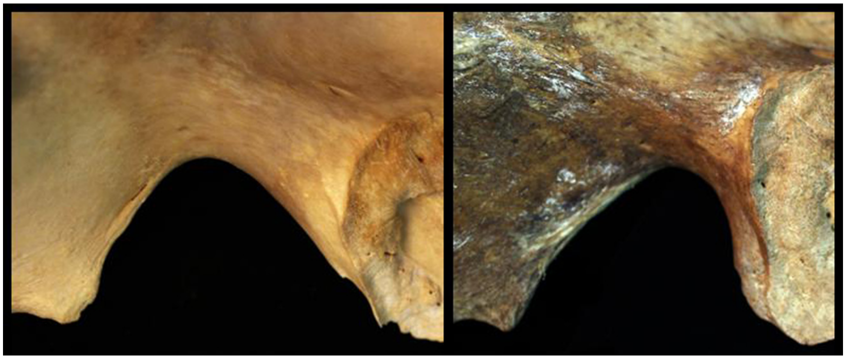

FIGURE 8.8 Female (left) and male (right) sciatic notch

Parturition and related events may leave various lesions on bones. Many of these have been the subject of anthropological study for the estimation of sex including the preauricular sulcus, separation of the pubic symphysis, osteitis condensans ilii, osteitis pubis, pubic pitting (Figure 8.9), bone density loss, and extension of the pubic tubercle. Many of these conditions, however, are not exclusively related to obstetrical events. Some may be found in nulliparous women and men, and may be absent in parous and multiparous women (Ubelaker and De La Paz, 2012).

Non-metric sex estimation based on the skull involves analysis of overall shape and relative size of certain cranial and mandibular features (see Figure 8.10, Figure 8.11, and Figure 8.12). In general, the skulls of males are larger and more rugged and robust than those of females which tend to be smaller and smoother (see Table 8.2). Although

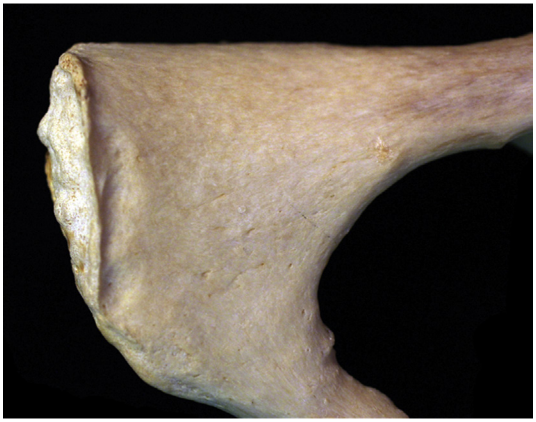

FIGURE 8.9 Dorsal pitting on a female pubis

FIGURE 8.10 Female (top) and male (bottom) skull

FIGURE 8.11 Female (top) and male (bottom) mandible

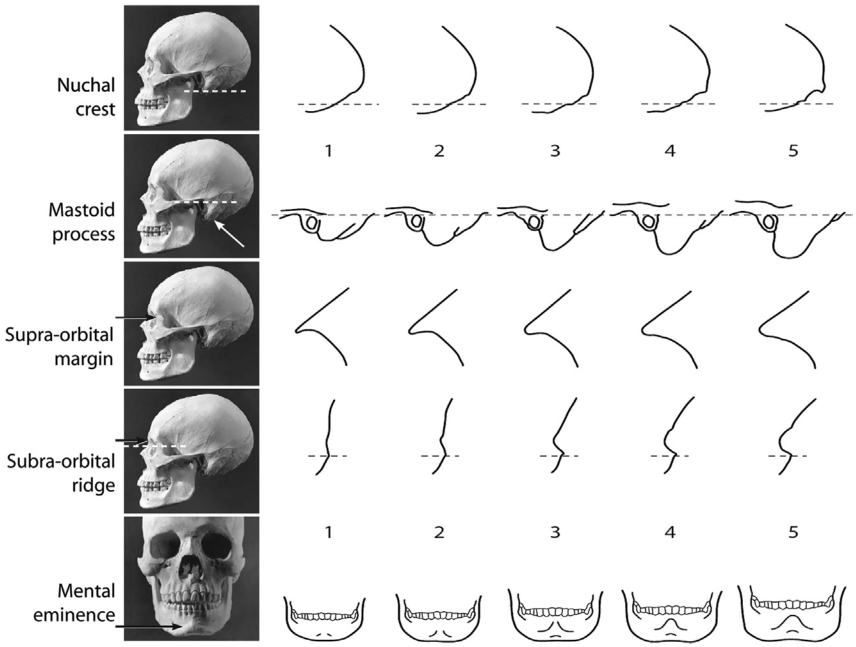

FIGURE 8.12 Differences in the male and female skull

1 represents a more female configuration while 5 represents a more male configuration

(From Buikstra and Ubelaker [1994], reprinted in White and Folkens [2005:390-391])

Table 8.2 Traits of the female and male skull

Skull feature	Female skull	Male skull
Nuchal crest	Small	Large
Mastoid process	Small	Large
Supraorbital margin	Sharp	Blunt
Superciliary arch/Glabella	Small/absent	Large
Chin shape	Round	Square
Mental eminence	Less pronounced	More pronounced
Frontals and parietals	More bossed	Less bossed
Gonial eversion	Less	Greater
Teeth	Smaller	Larger
Muscle attachments	Smaller	Larger
Palate depth	Shallow	Deep

relatively high accuracy can be achieved using certain features, inter-observer error rates for non-metric sex estimation from the skull have been shown to be relatively high (Konigsberg and Hens, 1998; Rogers, 2005; Williams and Rogers, 2006). The most reliable features tend to be mastoid size, supraorbital ridge size, general size and architecture, rugosity of the suprameatal and supramastoid crest, size and shape of the nasal aperture, and gonial angle. In some cases, it may even be possible to apply statistical tools such as regression models to these visual assessments (Konigsberg and Hens, 1998).

Various other bones and features have also been shown to display some degree of sexual dimorphism and to have some utility in sex estimation. The pattern of costal cartilage calcification (observed either directly or radiographically) shows sexual differences, with females showing a more central ossification pattern while the male pattern is more marginal (Navani et al., 1970; McCormick and Stewart, 1983; Stewart and McCormick, 1984; McCormick et al., 1985) (Figure 8.13). The accuracy of this method is age-dependent and may vary between populations.

Various other features show differences in their presence or expression between males and females. A suprascapular notch is often present in males and absent in females, and the presence of a septal aperture is more common in females than males (Finnegan, 1978) (Figure 8.14). The presence of a rhomboid fossa of the clavicle is more common in males (Rogers et al., 2000; Santos et al., 2008). Features of the posterior distal humerus have also been shown to be sexually dimorphic (Rogers, 1999) including trochlear constriction, trochlear symmetry, olecranon fossa shape, and the angle of medial epicondyle.

Certain diseases and skeletal conditions affect one sex more frequently than the other, and while there are few conditions that are reliably diagnostic as a sex estimation method, such assessments may suggest probabilities or corroborate other skeletal evidence of sex (Reichs, 1986). For example, groups from the genus *Streptococcus*

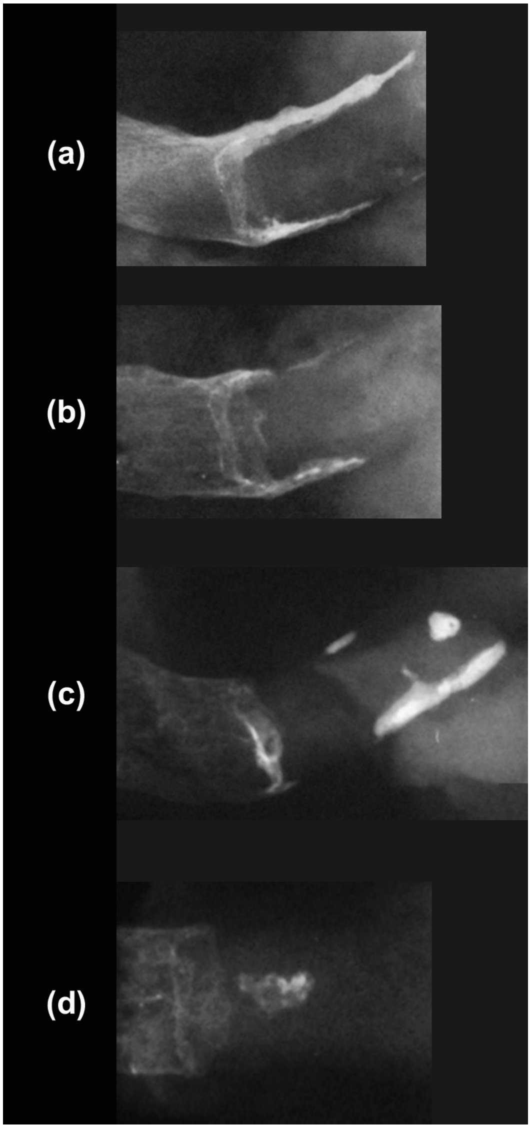

FIGURE 8.13 Male and female patterns of marginal costal cartilage ossification

Male pattern (a and b), and female pattern (c and d)

as well as avascular necrosis (tissue death from obstruction of arterial blood supply) are many times more common in males than females, many bone tumors and gout are more common in males, ankylosing spondylitis is 9–10 times more common in males, and rheumatoid arthritis and internal frontal hyperostosis (Figure 8.15) are more common in females (Reichs, 1986).

FIGURE 8.14 Septal aperture in a female humerus

(Image courtesy of Karen Gardner)

FIGURE 8.15 Radiological image of internal frontal hyperostosis (more common in females than males)

(From Brogdon, 2010)

8.3 Metric analysis

Metric analysis in sex estimation involves measuring maximum or minimum dimensions or taking measurements based on osteological landmarks to quantitatively evaluate size and shape differences between males and females. Some metric methods involve the evaluation of a single measurement or index of two measurements, while other more complex multivariate methods may combine numerous measurements into a single analysis (e.g., discriminant function analysis).

Among the most reliable metric methods for estimating sex are those involving dimensions of the long bones of the postcranial skeleton (Spradley and Jantz, 2011). Various approaches have been investigated involving measurements of postcranial bones, but most are based on the basic principle that males exceed females in size, especially in more weight-bearing joint areas. One recent comprehensive study (Spradley and Jantz, 2011) provides sectioning points and correct classification rates for sex estimation of American Whites and Blacks based on a series of standard postcranial measurements. Measurements with correct classification rates of 80% or greater are shown in Tables 8.3 and 8.4 for American Blacks and Whites, respectively. Examples of the more extensively studied and commonly employed long bone measurements for sex estimation include the maximum diameter of the femoral head (Stewart, 1979; Albanese, 2003) (Figure 8.16), femoral neck diameter (Seidemann et al., 1998), and vertical diameter of the humeral head (Stewart, 1979; France, 1998). Other postcranial bones including the scapula have also been studied for their utility in sex estimation (Stewart, 1979; Dabbs and Moore-Jansen, 2010).

Metric methods for sex estimation from the skull are generally considered less reliable than those based on the postcranial skeleton, but are still widely applied and useful in cases where no postcranial elements are available for analysis. Discriminant function analysis (see Chapter 3) was first applied to the estimation of sex from the skull in the 1960s (Giles and Elliot, 1963). Using measurements from more than 400 skulls, the method could correctly estimate sex at a rate of about 85%, which is considered to compare favorably to non-metric assessments (Meindl et al., 1985). A more widely used discriminant function tool for estimating sex currently is Fordisc (Ousley and Jantz, 2005).

Other metric assessments have also been investigated based on the skull including the lateral angle of the internal acoustic meatus which tends to be greater in females (Noren et al, 2005; Akansel et al, 2008; Lynnerup et al., 2006), and tooth size which tends to be larger in males.

Table 8.3 Univariate sectioning points and classification rates for American Blacks

Measurement (in mm)	Female			Male			SP	Class. Rate
	N	Mean	SD	N	Mean	SD		
Fem. Epicondylar Br. (62)[1]	33	72.88	3.86	65	83.35	3.97	78	0.89
Tib. Prox. Epiphyseal. Br. (70)	29	69.14	3.68	60	78.73	5.07	74	0.88
Scapula Height (38)	36	138.61	8.46	64	160.7	8.6	150	0.87
Fem. Max. Head Diam. (63)	39	41.33	2.18	69	47.22	2.47	44	0.86
Humerus Epicondylar Br. (41)	34	55.38	2.66	65	64.14	3.87	60	0.86
Humerus Head Diameter (42)	37	41.03	2.46	68	46.99	2.3	44	0.86
Scapula Breadth (39)	36	95.92	6.52	64	109.55	6.71	103	0.86
Radius Max. Length (45)	37	239.19	12.45	69	267.58	13.68	253	0.85
Clavicle Max. Length (35)	38	142.21	7.77	62	156.81	7.41	150	0.84
Calcaneus Max. Length (77)	20	76.45	4.62	50	85.38	4.74	81	0.83
Fem. AP Subtroch Diam. (64)	37	25.86	2.56	66	28.73	2.28	27	0.83
Ischium Length (59)	30	77.33	4.91	47	89.15	6.23	83	0.83
Ulna Max. Length (48)	33	256.42	15.01	63	285.56	13.89	271	0.83
Ulna Phys. Length (51)	25	226.48	13.38	53	254.51	13.94	240	0.83
Fibula Maximum Length (75)	32	367.09	22.11	65	400.55	22.05	384	0.82
Fem. Bicondylar Length (61)	36	444.94	25.63	65	484.32	25.9	465	0.81
Humerus Max. Length (40)	39	309.46	15.95	76	340.91	17.1	325	0.81
Os Coxa Height (56)	36	191.69	11.78	61	211.59	10.1	202	0.81
Tib. Diameter Nut. For. (72)	30	32.23	2.81	59	37.31	2.85	35	0.8

[1]*Numbers correspond to measurements in Moore-Jansen et al., 1994*
(From Spradley and Jantz, 2011)

Table 8.4 Univariate sectioning points and classification rates for American Whites

Measurement (in mm)	Female			Male			SP	Class. Rate
	N	Mean	SD	N	Mean	SD		
Tib. Prox. Epiphyseal. Br. (70)[1]	113	69.19	3.37	226	79.31	4.1	74	0.9
Scapula Height (38)	127	141.87	9.48	231	163.33	8.95	153	0.89
Fem. Epicondylar Br. (62)	129	74.53	3.8	248	85.27	4.38	80	0.88
Fem. Max. Head Diam. (63)	142	42.05	2.09	261	48.4	2.6	45	0.88
Humerus Epicondylar Br. (41)	136	54.9	3.8	258	64.38	3.64	60	0.87
Radius Max. Length (45)	130	228.22	11.21	251	253.41	12.95	241	0.86
Os Coxa Height (56)	124	201.06	13.71	235	222.94	10.8	212	0.85
Scapula Breadth (39)	127	95.48	5.07	237	108.15	6.33	102	0.84
Ulna Max. Length (48)	127	244.94	11.66	250	271.07	13.49	258	0.84
Humerus Head Diameter (42)	139	42.47	2.44	256	48.81	3.22	46	0.83
Clavicle Max. Length (35)	123	139.79	7.04	224	156.96	9.33	148	0.82
Humerus Max. Length (40)	144	305.75	14.43	263	333.99	17.03	320	0.82
Hum. Min. Diam. MS (44)	139	15.32	1.35	256	18.9	1.79	17	0.82
Ulna Phys. Length (51)	105	217.69	11.71	217	240.17	12.68	229	0.82
Fem. Bicondylar Length (61)	134	431.96	20.87	250	470.75	23.63	451	0.82
Tibia Circum. Nut. For. (74)	106	85.36	6.31	199	97.65	7.16	92	0.81
Fibula Maximum Length (75)	117	351.29	19.65	235	386.49	22.11	369	0.81
Femur Max. Length (60)	151	436.15	20.63	268	474.21	23.23	455	0.8

[1] *Numbers correspond to measurements in Moore-Jansen et al., 1994*
(From Spradley and Jantz, 2011)

FIGURE 8.16 Measurement of maximum femoral head diameter

8.4 Other considerations in sex estimation

The review of various sex estimation methods above clearly demonstrates that sexual dimorphism is differentially expressed throughout the skeleton. Moreover, it can be influenced by genetic factors, nutrition, and health status. These factors should be considered when undertaking estimates of sex from skeletal remains.

There is no absolute cut-off for how valid or reliable a sex estimation method should be, but bear in mind that sex estimation is a binary (two-sided) decision, and a random guess will be correct 50% of the time. Sex estimation methods should therefore have significantly greater than 50% accuracy in order to be considered useful. Osteological sex estimation methods that are accurate less than 80% of the time are typically considered unreliable for most medicolegal cases.

Sex estimation methods from other bones may become available as shape differences are better understood, especially through the application of more robust analytical approaches. Geometric morphometric analysis, for example, examines the shapes of bones while controlling for size, and has been used to evaluate subtle shape differences between male and female skeletal elements (Passalacqua et al., 2010). These methods may reveal quantifiable differences between male and female skeletons that were previously not recognized or poorly understood (Figure 8.17).

Estimating sex in juveniles is generally considered unadvisable because widely validated methods are currently unavailable (Scientific Working Group for Forensic Anthropology [SWGANTH], 2010). This is due to the fact that most sexual differences in the skeleton do not appear until the increase in sex hormones which stimulate the development of secondary sexual characteristics during puberty. Estimates of sex from the skeleton are therefore not considered reliable prior to around age 14. Another factor affecting the accuracy of subadult sex estimation is the limited availability of juvenile skeletal material of known sex to study.

Sexual differentiation has been noted to begin as early as the 10th fetal week (Weaver, 1986), and numerous studies have attempted to derive methods for estimating the sex of juveniles. For example, differences have been noted in the elevation of the auricular surface, with females generally exhibiting an auricular surface that is raised entirely above the plane of the ilium, while the male auricular surface is in

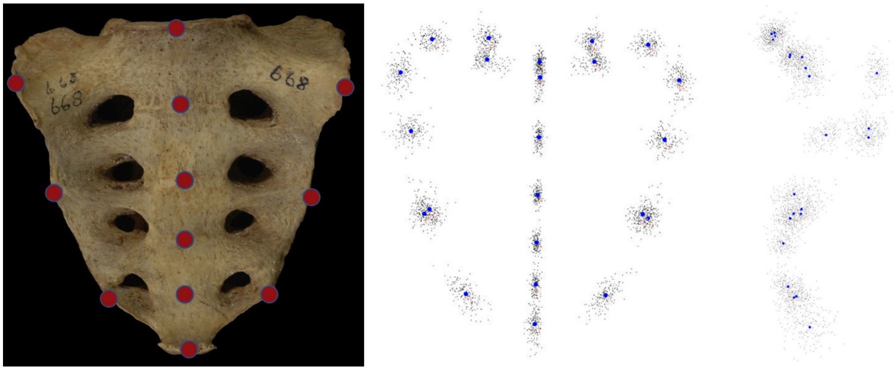

FIGURE 8.17 Geometric morphometric analysis of the sacrum in males and females

(From Passalacqua et al., 2010)

line with the ilium (Weaver, 1980; Mittler and Sheridan, 1992). Sex differences have also been reported in the fetal sciatic notch and sub-pubic angle (Boucher, 1955, 1957; Schutowski, 1993), as well as the mandibular arcade shape (Schutowski, 1993; Sutter, 2003). In general, however, accuracies of these methods are low and inter-observer error is high (Cardoso and Saunders, 2008).

Although not typically within the purview of forensic anthropologists, it is sometimes possible to determine the sex of skeletal remains based on molecular methods (DNA) (Stone et al., 1996). The amelogenin gene is found on the X and Y chromosomes, and differences in base pair number (from specific primers) between males and females can aid in sex determination (Stone et al., 1996). This method requires the amplification of DNA by Polymerase Chain Reaction (PCR). In rare cases, mutations can produce a false result, although this was found to occur less than 1% of the time in a sample of 1,224 individuals (Francès et al., 2007). Anthropologists may facilitate this process by selecting skeletal samples that are likely to yield DNA.

8.5 Case study – sex estimation

In 2006, human remains were recovered from a shallow grave in northern California. The skeleton was nearly complete, allowing for an in-depth assessment of the biological profile. The decedent expressed a number of characteristically male pelvic traits, including: a blunt expression of the ischiopubic ramus ridge, a narrow sub-pubic angle, lack of a sub-pubic concavity, absence of a ventral arc, and a narrow sciatic notch (Figure 8.18). In addition, the degree of robusticity of cranial features, such as the supraorbital region, supraorbital margins, external occipital protuberance, mastoid processes, temporal lines, and nuchal lines were consistent with male sex (Figure 8.19). Statistical comparisons of the postcranial measurements with samples from the Forensic Anthropology Databank (Fordisc 3.0, University of Tennessee) also strongly suggested the individual was male. The decedent was later identified as a 26-year-old white male with a living stature of 5 feet, 8 inches.

FIGURE 8.18 Case study innominates

FIGURE 8.19 Case study cranium

8.6 Summary

- It is possible for forensic anthropologists to differentiate between male and female skeletons because humans are sexually dimorphic, that is, they differ in size and shape.
- Sex differences in the skeleton are related primarily to the functions of parturition and locomotion. Females must have a wide pelvis and birth canal due to the large size of human infant heads, while maintaining efficient locomotion.
- "Sex" refers to biological differences between males and females of an organism while "gender" refers to cultural expressions of femininity and masculinity.
- The pelvis is the most sexually dimorphic region of the human skeleton, and visual assessment of the pelvis is the most accurate method for estimating sex.

The Phenice method using the *os pubis* is one of the most validated, accurate, and widely used methods of estimating sex.
- Metric assessment of postcranial limb bones (based on the fact that males are larger on average than females, especially in weight-bearing joints) is the second most reliable method for sex estimation.
- Sex differences in the skull are less reliable than those of the pelvis and limb bones but still have utility in sex estimation; male skulls tend to be larger, rugged, and more robust than female skulls, which tend to be smaller, smoother, and more gracile.
- Since most sex differences in skeletal structure do not appear until puberty, estimating sex in juveniles is unreliable and generally considered unadvisable.
- Sex can sometimes be determined from skeletal remains using DNA. While anthropologists typically do not perform DNA analysis themselves, they may be responsible for selecting skeletal specimens for DNA sampling.

8.7 Test yourself

- What is sexual dimorphism? How does human sexual dimorphism differ from that of other animals?
- A decomposed body is discovered in a forest. There is extensive scavenging of the pelvis. What areas of the skeleton might you use for estimating sex? What methods would you employ?
- What are carrying and Q-angles, and what is their significance in sex estimation from the skeleton?
- Using Table 8.4 for sex estimation from measurements of postcranial bones, what would you conclude about the sex of an American White individual with a maximum femoral head diameter of 47 mm?
- You are asked to help estimate a biological profile for an unidentified individual for whom only numerous radiographs (and no skeletal remains) are currently available. What methods might you be able to use to estimate sex?
- Why should parturition lesions or pathological conditions alone not be used to estimate sex?
- Why is sex estimation in subadults problematic? What methods *could* be employed to estimate sex of an individual who was 16 years old?
- What is the difference between gender and sex? Why is this distinction important? How would you report sex estimation findings on a case where clothing found at the scene pointed to the opposite sex as your skeletal findings?

Definitions

Androgeny Physical or psychological sexual ambiguity

Carrying angle The angle at which the upper and lower portions of the arm articulate; osteologically in humans, the angle at which the humerus articulates with the radius and ulna

Gender Socially constructed roles, behaviors, activities, and attributes considered appropriate for men and women

Genotype The genetic make up of an organism

Hominin Of the tribe Hominini (order Primates, family Hominidae, sub-family Homininae) which includes humans and their ancestors after the split from the tribe Panini

Intersex The condition of having anomalous or intermediate features that typically distinguish males and females in a species

Locomotion The act of or the ability to move from place to place; in humans, usually walking

Morphology The structure, size, and form of an organism or its parts

Neotenous/Pedomorphic Retaining juvenile characteristics into adulthood

Parturition Childbirth; the process of giving birth to offspring

Phenotype/Phenotypic Observable physical characteristics of an organism as determined by both genetics and environmental influences

Q-angle Quadriceps angle; the angle at which the upper and lower portions of the leg articulate; osteologically in humans, the angle at which the femur articulates with the tibia

Sex The classification of an organism as male or female based on reproductive organs and functions

Sexual dimorphism Phenotypic differences between males and females of the same species

Subadult An individual who has not reached physiological adulthood or has not yet attained adult characteristics; osteologically, an individual who has not reached skeletal maturity; juvenile

References

Akansel, G., Inan, N., Kurtas, O., Sarisoy, H.T., Arslan, A., Demirci, A., 2008. Gender and the lateral angle of the internal acoustic canal meatus as measured on computerized tomography of the temporal bone. Forensic Sci. Int. 178, 93–95.

Albanese, J., 2003. A metric method for sex determination using the hip bone and the femur. J. Forensic Sci. 48 (2), 263–273.

Atkinson, W.B., Elftman, H., 1945. The carrying angle of the human arm as a secondary sex character. Anat. Rec. 91, 49–52.

Bogin, B., 1999. Patterns of human growth, second ed. Cambridge University Press, Cambridge.

Boucher, B.J., 1955. Sex differences in the foetal sciatic notch. J. Forensic Med. 2, 51–54.

Boucher, B.J., 1957. Sex differences in the foetal pelvis. Am. J. Phys. Anthropol. 155, 81–600.

Brogdon, G.B., 2010. Radiological identification: Anthropological Parameters. In: Thali, M.J., Viner, M.D., Brogdon, B.G. (Eds.), Brogdon's Forensic Radiology, second ed. CRC Press, Boca Raton, pp 85–106.

Buffa, R., Marini, E., Giovanni, F., 2001. Variation in sexual dimorphism in relation to physical activity. Am. J. Human. Biol. 13 (3), 341–348.

Buikstra, J.E., Ubelaker, D.H., 1994. Standards for data collection from Human Skeletal Remains. Archaeological. Surv. Res. Semin Ser. 44 Fayeteville.

Cardoso, F.V., Saunders, S.R., 2008. Two arch criteria of the ilium for sex determination of immature skeletal remains: A test of their accuracy and an assessment of intra- and inter-observer error. Forensic Sci. Int. 178, 24–29.

Dabbs, G.R., Moore-Jansen, P.H., 2010. A method for estimating sex using metric analysis of the scapula. J. Forensic Sci. 55 (1), 149–152.

Finnegan, M.J., 1978. Non-metric variation of the infra-cranial skeleton. J. Anat. 125, 23–37.

France, D.L., 1998. Observational and metric analysis of sex in the skeleton. In: Reichs, K.J. (Ed.), Forensic Osteology: Advances in the Identification of Human Remains, second ed. Charles C. Thomas Press, Springfield, pp. 441–458.

Francès, F., Portolés, O., González, J.I., Coltell, O., Verdú, F., Castelló, A., Corella, D., 2007. Amelogenin test: from forensics to quality control in clinical and biochemical genomics. Clin. Chim. Acta. 386 (1–2), 53–56.

Frayer, D.W., Wolpoff, M.H., 1985. Sexual dimorphism. Annu. Rev. Anthropol. 14, 429–473.

Giles, E., Elliot, O., 1963. Sex determination by discriminant function analysis of crania. Am. J. Phys. Anthropol. 21 (1), 53–68.

Konigsberg, L.W., Hens, S.M., 1998. Use of ordinal categorical variables in skeletal assessment of sex from the cranium. Am. J. Phys. Anthropol. 107 (1), 97–112.

Livingston, L.A., 1998. The quadriceps angle: A review of the literature. J. Orthop & Sports Phys. Ther. 28 (2), 105–109.

Lovell, N.C, 1989. Test of Phenice's technique for determining sex from the os pubis. Am. J. Phys. Anthropol. 79, 117–120.

Lynnerup, N., Schultz, M., Madelung, A., Graw, M., 2006. Diameter of the human internal acoustic meatus and sex determination. Int. J. Osteoarchaeology 16 (2), 118–123.

Moore-Jansen, P.M., Ousley, S.D., Jantz, R.L., 1994. Data Collection Procedures for Forensic Skeletal Material. Report of Investigations No. 48, Department of Anthropology, University of Tennessee, Knoxville.

McCormick, W.F., Stewart, J.H., 1983. Ossification patterns of costal cartilages as an indicator of sex. Arch. Pathol. Lab. Med. 107 (4), 206–210.

McCormick, W.F., Stewart, J.H., Langford, L.A., 1985. Sex determination from chest plate roentgenograms. Am. J. Phys. Anthropol. 68 (2), 173–195.

Meindl, R.S., Lovejoy, C., Mensforth, R.P., Don Carlos, L., 1985. Accuracy and direction of error in sexing of the skeleton: Implications for paleodemography. Am. J. Phys. Anthropol. 68, 79–85.

Mittler, D.M., Sheridan, S.G., 1992. Sex determination in subadults using auricular surface morphology: A forensic science perspective. J. Forensic Sci. 37, 1068–1075.

Navani, S., Shah, J.R., Levy, P.S., 1970. Determination of sex by costal cartilage calcification. Am. J. Roentgenol. Radiogr. 108 (4), 771–774.

Nicholson, L., 1994. Interpreting gender. Signs: J. Women in Cul. and Society 20, 79–105.

Noren, A., Lynnerup, N., Czarnetzki, A., Graw, M., 2005. Lateral angle: A method for sexing using the petrous bone. Am. J. Phys. Anthropol. 128 (2), 318–323.

Ousley, S.D., Jantz, R.L., 2005. FORDISC 3.0: Personal computer forensic discriminant functions. The University of Tennessee, Knoxville.

Passalacqua, N.V., Vollner, J.M., Rainwater, C.W., 2010. Geometric morphometric analysis of the human sacrum and its utility in sex estimation. Poster presented at the American Association of Physical Anthropology 79th annual meeting, Albuquerque, NM.

Phenice, T.W., 1969. A newly developed visual method of sexing the Os pubis. Am. J. Phys. Anthropol. 30, 297–302.

Potter, H.P., 1895. The obliquity of the arm of the female in extension. The relation of the forearm with the upper arm in flexion. J. Anat. London 29, 488–493.

Reichs, K.J., 1986. Forensic implications of skeletal pathologies: Sex. In: Reichs, K.J. (Ed.), Forensic Osteology: Advances in the Identification of Human Remains. Charles C. Thomas, Springfield, pp. 196–217.

Ridley, M., 1995. Pelvic sexual dimorphism and relative neonatal brain size really are related. Am. J. Phys. Anthropol. 97 (2), 197–200.

Rogers, T.L., 1999. A visual method of determining the sex of skeletal remains using the distal humerus. J. Forensic Sci. 44 (1), 57–60.

Rogers, T.L., 2005. Determining the sex of human remains through cranial morphology. J. Forensic Sci. 50 (3), 493–500.

Rogers, T.L., Flournoy, L.E., McCormick, W.F., 2000. The rhomboid fossa of the clavicle as a sex and age estimator. J. Forensic Sci. 39, 1047–1056.

Santos, L.S.M., Berzin, F., Prado, F.B., Preza, A.D.G., Daruge, E., 2008. Gender determination using rhomboid fossa from the clavicle. Brazilian Journal of Morphological Sciences 25 (1–4), 157–214.

Schutowski, H., 1993. Sex determination of infant and juvenile skeletons: I. morphognostic features. Am. J. Phys. Anthropol. 90, 199–205.

Scientific Working Group for Forensic Anthropology, 2010. Sex Assessment Revision 0. Accessed from www.swganth.org.

Seidemann, R.W., Stajanowski, C.M., Doran, G.H., 1998. The use of the supero-inferior femoral neck diameter as a sex assessor. Am. J. Phys. Anthropol. 107 (3), 305–313.

Spradley, M.K., Jantz, R.L., 2011. Sex estimation in forensic anthropology: Skull versus postcranial elements. J. Forensic Sci. 56 (2), 289–296.

Stewart, J.H., McCormick, W.F., 1984. A sex- and age-limited ossification pattern in human costal cartilages. Am. J. Clin. Pathol. 81 (6), 765–769.

Stewart, T.D., 1979. Essentials of Forensic Anthropology. Charles C. Thomas, Springfield.

Stone, A.C., Milner, G.R., Pääbo, S., Stoneking, M., 1996. Sex determination of ancient human skeletons using DNA. Am. J. Phys. Anthropol. 99, 231–238.

Sutherland, L.D., Suchey, J.M., 1991. Use of the ventral arc in pubic sex determination. J. Forensic Sci. 36 (2), 501–511.

Sutter, R.C., 2003. 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. J. Forensic Sci. 48 (5), 927–935.

Torgrimson, B.N., Minson, C.T., 2005. Sex and gender: what is the difference? J. Appl. Phys. 99 (3), 785–787.

Ubelaker, D.H., De La Paz, J.S., 2012. Skeletal indicators of pregnancy and parturition: A historical review. J. Forensic Sci. 57 (4), 866–872.

Ubelaker, D.H., Volk, C., 2002. A test of the Phenice method for the estimation of sex. J. Forensic Sci. 47 (1), 19–24.

Walker, P.L., 2005. Greater sciatic notch morphology: sex, age, and population differences. Am. J. Phys. Anthropol. 127, 385–391.

Walker, P.L., Cook, D.C., 1998. Gender and sex: Vive la difference. Am. J. Phys. Anthropol. 106, 255–259.

Weaver, D.S., 1980. Sex differences in the ilia of a known sex and age sample of fetal and infant skeletons. Am. J. Phys. Anthropol. 52, 191–195.

Weaver, D.S., 1986. Forensic aspects of fetal and neonatal skeletons. In: Reichs, K.J. (Ed.), Forensic Osteology: Advances in the Identification of Human Remains. Charles C. Thomas, Springfield, pp. 90–100.

Williams, B.A., Rogers, T.L., 2006. Evaluating accuracy and precision of cranial morphological traits for sex determination. J. Forensic Sci. 51 (4), 729–735.