AN INVESTIGATION OF SEX DETERMINATION FROM THE SUBADULT PELVIS: A MORPHOMETRIC ANALYSIS.

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AN INVESTIGATION OF SEX DETERMINATION FROM THE SUBADULT PELVIS: A MORPHOMETRIC ANALYSIS.

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The pelvis, the most sexually dimorphic area of the adult human skeleton, is essential to determine biological sex. Although sex differences have been noted in subadult pelvic bones since the late 1800s, no reliable method has been developed to determine biological sex, and therefore, subadult sex demographics must be omitted from forensic and archaeological investigations. This study examined three North American skeletal samples of documented age and sex, the Forensic Fetal Osteological Collection (n=113), the subadult component of the Hamann-Todd Collection (n=37), and the Trotter Fetal Bone Collection (n=37), to test the hypothesis that subadult pelvic traits, both metric and non-metric, are sufficiently sexually dimorphic in one or more sample or age category. Method accuracy and reliability were also evaluated. Traits included those previously studied: the breadth and angle of the sciatic notch, iliac crest curvature, arch criterion, auricular surface elevation, subpubic angle, pubic length, and ischial length. Two additional feature analyses and three indices were developed for this study: the anterior and posterior sciatic notch lengths, pubic body width, pubic index, anterior/posterior sciatic notch, and sciatic notch width/iliac length index. Both left and right sides were considered using photographic and direct measurement techniques. For t-tests and correlations, at least one trait per sample reached statistically significant levels for sexual dimorphism. Reliable testing methods were not developed because these features were inconsistently sexually dimorphic for each sample; furthermore, male and female measurement ranges overlapped considerably, trait morphology proved variable, and individuals were incorrectly assigned to sex when using

methods outlined in previous studies. Both logistic regression and discriminant function analysis provided low predictive scores, the highest at 0.68, which were insufficient to predict sex consistently or meet the *Daubert* threshold. Two non-metric traits, sciatic notch shape and auricular surface elevation, also proved to be inconsistent across the three samples. Consequently, these traits were unreliable for sex determination. Several features, including the sciatic notch width, sciatic notch shape, and pubic body width, demonstrated differences among older subadults and should be investigated using larger, broadly-aged samples that include adults.

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"It always seems impossible until it's done."
Nelson Mandela

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1.0 INTRODUCTION

1.1 BACKGROUND

Ascertaining a biological profile from the skeleton is a vital component in both forensic and archaeological settings. When skeletal material is discovered, one of the prime attributes that an anthropologist seeks to identify is the individual's sex. Sexual dimorphism, or size and/or shape differences between the males and females of a species, can be best observed primarily on the cranium and pelvis of humans. Reliable methods of sex determination for adult skeletal material have existed for decades; cranial features include the mandibular angles, orbital area, and mastoid processes, while pelvic features include the sciatic notch, subpubic angle, and obturator foramen (Ali and MacLaughlin 1991; Anderson 1990; Bruzek 2002; Coleman 1969; Davivongs 1963; Day and Pitcher-Wilmott 1975; Dibennardo and Taylor 1983; Krogman 1962; Phenice 1969; St. Hoyme and Iscan 1989; Stewart 1954; Thieme and Schull 1957; Washburn 1948). The pelvis, the most sexually dimorphic area of the body, is essential for biological sex determination of the adult skeleton.

Even though several pelvic traits are sexually distinguishable throughout the developmental process, the skeletal remains of infants and children have been primarily excluded from sex determination analyses as researchers believed that sex discrimination does not occur until an individual has reached puberty (Boucher 1955; Boucher 1957; Rösing 1983; Thomson

1899). For forensic cases, only genetic testing can positively identify the sex of the skeleton for law enforcement agencies. Testing can be time consuming, and many government labs currently experience backlogs (Nelson 2011). For bioarchaeological research, genetic testing is also time consuming and destructive to skeletal material. Issues of sample contamination also create problems for researchers in both bioarchaeological and forensic situations (Roberts and Ingham 2008).

Because sex cannot be determined for subadults, this variable must be omitted from the biological profile of these skeletal remains. Forensically, this widens the pool of individuals for comparison and lengthens the process of making positive identification by law enforcement. Bioarchaeologically, as subadults can represent a substantial portion of a typical cemetery population, omitting gender for these individuals limits interpretations of a community's social structure and behavior from burial and skeletal analyses (Baxter 2005; Kamp 2001; Lewis 2007). In these circumstances, the researcher can only infer the sex of the remains from burial goods, clothing, and other items associated with the burial (Gowland 2006). As gender roles are often established early in life, understanding any differential treatment of males and females in childhood provides added insight into the community's life course trajectory. Differential burials between boys and girls also addresses topics such as infanticide as well as differences in inheritance, disease, and activity (Sofaer 2006; Sorensen 2000).

In the more than 100 years since Fehling (1876) first noticed sexually dimorphic differences on the subadult pelvic bones, researchers have struggled to find consistent or universal features on the subadult pelvis to distinguish males from females. Even though several "pronounced and characteristic" features were acknowledged as being present in subadults, puberty is still considered to be the primary defining period between male and female pelvic traits (Thomson 1899, p. 361).

In the last 20 years, researchers have examined a handful of promising subadult pelvic traits with mixed success (Cardoso and Saunders 2008; Holcomb and Konigsberg 1995; Hunt 1990; Mittler and Sheridan 1992; Ridley 2002; Schutkowski 1993; Sutter 2003; Vlak *et al.* 2008; Weaver 1980). The primary study conducted by Schutkowski (1993) examined several pelvic traits, including the angle and shape of the sciatic notch. Since this research, others have attempted to replicate his work, with little success. Vlak and colleagues (2008) evaluated the sciatic notches of a Portuguese sample and determined that age, not sex, was the primary factor influencing the differences within the group. Carodso and Saunders (2008) examined the arch criterion, also with little success, and suggested that morphological variation and lack of association with sex were the two main reasons for their findings. An additional trait, the auricular surface elevation, was examined by Weaver (1980) and subsequently by Hunt (1990), Mittler and Sheridan (1992), and Sutter (2003). Weaver's results at first blush appeared successful in discriminating sex, but the follow-up studies did not generate the same level of success for other samples.

Perhaps the most succinct detailing of the problems and difficulties in attempting to determine subadult skeletal sex was found in Moloy's reply to Morton's (1942) article,

> *"The first deals with the presence or absence of sexual differences in the pelvis of the fetus, infant, or child; the second concerns the changes in the morphology of the pelvis produced by growth and development quite distinct from the sexual characteristics in pelves"*

Not much has changed in over half a century as researchers attempt to tease out differences due to sex and those due to growth factors, as well as environmental, nutritional, and genetic influences. Researchers continue to question which differences are evident in subadult pelves and what is the etiology of those differences? How does the changing size and shape of the child overall affect the size and shape of the pelvis? To understand this, it is imperative that the development of the pelvic elements be understood.

1.2 SEXUAL DIMORPHISM OF THE INNOMINATE

Sexual dimorphism is simply the physical difference between males and females within a species in either overall body size or in specific feature shape. Many species show exaggerated sexual dimorphism, such as the gorilla, as males are often twice the size of females (Leutenegger and Cheverud 1982; Willner and Martin 1985). In contrast, human females are on average roughly 10% smaller than males (Rogers and Mukherjee 1992). Typically, these size differences emerge after puberty when sexual maturity is reached (Willner and Martin 1985). Size is not the only factor that influences physical differences between the sexes. Variation in shape and morphology of a feature or group of features can vary between the sexes. For example, in order to accommodate the large newborn head size found in this species, female squirrel monkeys showed high levels of sexual dimorphism in the pelvis after puberty (Gingerich 1972; Leutenegger 1974); prior to puberty, all immature squirrel monkey pelves displayed the male form.

In the human innominate, several features are known to differ sufficiently between males and females so that sex can be determined from one trait alone, although the combination of several features provides higher levels of accuracy (Bruzek 2002). These features include the greater sciatic notch, subpubic angle, and ventral arc (Bruzek 2002; MacLaughlin and Bruce 1986; Phenice 1969; Rogers and Saunders 1994; Singh and Potturi 1978; Sutherland and Suchey

1991; Washburn 1948). Unfortunately, due to the overlap of values between the sexes, no feature is 100% accurate. These feature variations reflect functional differences placed on the pelvis to allow for childbirth in women. In general, the female pelvis flares more laterally, with wider sciatic notch openings to allow for a wider birth canal, while the male pelvis tends to be more compressed and narrow. The sexually dimorphic traits evaluated in this study reflect these two basic morphological differences.

1.3 PELVIC ANATOMY

The pelvis consists of multiple bony elements, several of which fuse and become one complete bone in adulthood. This complex skeletal region includes two innominates and a sacrum in the adult form. In subadults, each innominate is made up of three separate bones, the ilium, pubis, and ischium (Figure 1.1); these three elements fuse together to become one bone by the late teen years (Cardoso 2008; Schaefer 2008). For this study, the three bones which compose the innominate will be evaluated.

The ilium comprises the largest component of the innominate and is the site of multiple muscle attachments, including the gluteal muscles. The ilium, positioned on each side of the sacrum, creates the sacroiliac joints. This bone is a plate- or bowl-like bone on the lateral and posterior aspects of the pelvis. Initially, this bone's shape is flat, but as a child experiences hormonal and functional influences, the ilium alters and becomes curved. The pubis is a much smaller, comma-shaped bone anterior in the pelvis. The two pubic bones meet at the most medial and anterior portion of the pelvis and connect via a fibro-cartilaginous symphysis. The ischium lies below the ilium and pubis, creating a stable platform for sitting. The ischium and pubis unite anteriorly at a small bridge of bone called the ischio-pubic ramus, fusing in mid-childhood (Schaefer *et al.* 2009). The three bones assemble at the acetabulum, the socket for the femoral head, which is the area of primary growth for these bones (Figure 1.1). These three bones enlarge at the acetabulum in tandem with the femoral head. This area begins to fuse in the early prepubertal years, usually between 9 and 13 years, and is completely fused by age 19, when the final skeletal growth and pubertal changes have occurred (Cardoso 2008; Fazekas and Kósa 1978; Schaefer 2008).

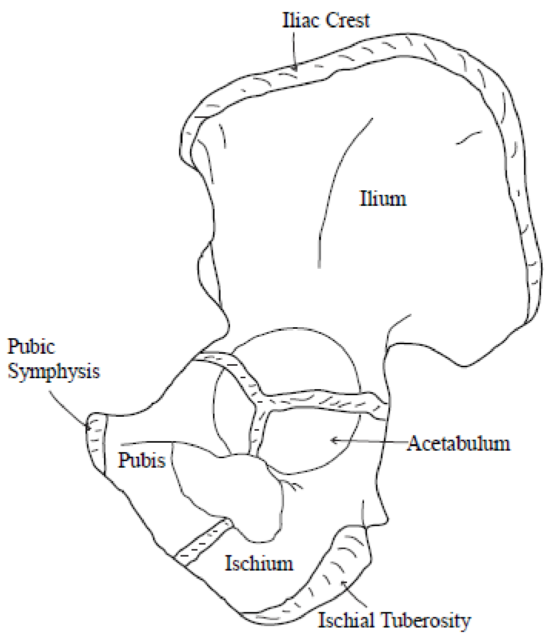


Figure 1.1. Features of innominate, including the three separate components and areas of growth

1.4 HORMONAL INFLUENCES

Hormones influence the growth and development of the three pelvic elements as early as eight weeks *in utero*, with hormonal effects continuing until puberty is completed. Increases in innominate size and shape for males and females varies throughout life and is influenced by both sex and growth hormones (Knickmeyer and Baron-Cohen 2006; Reynolds 1945). Testosterone plays a larger role than estrogen during the fetal and neonatal periods (Knickmeyer and Baron-Cohen 2006). Without this hormone, the fetus would not develop male sex characteristics as testosterone is required to differentiate the genital and reproductive tissues (Challis *et al.* 1976; Grumbach and Kaplan 1974; Siiteri and Wilson 1974).

Appearing at approximately two months after conception, Leydig cells develop and reproduce, secreting testosterone in the developing fetus soon after. The quantity of cells peaks at roughly two months and then declines in number by the fifth month (Grumbach and Kaplan 1974). This increase in cell production corresponds with the increase in testosterone in the male testis at this same time (Challis *et al.* 1976). Even though activity in the male testis eventually reduces, testosterone production is on-going throughout fetal development and growth, although at much lower levels than this initial surge (Siiteri and Wilson 1974). In contrast, fetal ovaries do not produce any significant amount of hormones, either estrogen or progesterone, as much of the fetal estrogen is produced by the placenta (Challis *et al.* 1976; Siiteri and Wilson 1974).

1.5 GROWTH AND DEVELOPMENT OF THE PELVIS

In order to understand the state of the innominate at any given age, it is imperative to be familiar with how each pelvic element develops. These three bones that form the innominate have their own developmental trajectories. Timing of bone development, growth, and maturation each play a role in the changing shape and size of the pelvis.

1.5.1 Embryological Growth and Development

The bones of the skeleton develop in two ways, endochondrally and intramembranously (Arey 1966, p. 399). The pelvic bones are created endochondrally, where initially a cartilaginous anlage or template of the bone develops and is later infiltrated by bone tissue, creating centers of ossification (McAuley and Uhthoff 1990). The three elements of the innominate, the ischium, ilium, and pubis, begin from cartilaginous templates and their own individual primary centers of ossification. Additional, or secondary, ossification centers form, and represent areas of continued bone growth.

The pelvic elements and lower limb become apparent by radiograph or ultrasound at approximately the fifth week *in utero* and cartilage templates develop by seven weeks (Arey 1966, p. 420-422; Fazekas and Kósa 1978; Moore and Persaud 1998). At the end of the embryonic stage at eight weeks, ossification of the ischium, ilium, and pubis begins, with the primary ossification center for the three bones at the region of the acetabulum (Delaere and Dhem 1999; Delaere *et al*. 1992; Fazekas and Kósa 1978; Hill 1939; Noback 1944). The three fetal pelvic bones are visible by ultrasound early in development; specifically, the iliac wings are evident by the end of the first trimester (Medearis and Shields 1984).

The ilium is the first bone to appear in both the cartilaginous template and the ossification centers. The ilium begins ossification at eight to nine weeks, while the ischium begins this process slightly later, in the third or four months (Hill 1939; McAuley and Uhthoff 1990). The pubis ossifies last, at roughly four to five months, often after the ischium has completely ossified (Delaere and Dhem 1999; Fazekas and Kósa 1978; Hill 1939; Krogman 1962; Noback 1944). Several features of the innominate, including the anterior superior iliac spine of the ilium and the ischial tuberosity and spine on the ischium, are evident in the cartilaginous form at eight weeks

(McAuley and Uhthoff 1990; O'Rahilly and Gardner 1975) and ossify by 12 weeks (McAuley and Uhthoff 1990). The pubic symphysis begins ossification at 9.5 weeks but is not clearly visible until 18 weeks (McAuley and Uhthoff 1990). The sacro-iliac joint, both a synovial and synarthrotic joint, is clearly formed by ten weeks (McAuley and Uhthoff 1990).

Differences found in male and female pelvis reflect influences of hormones, particularly testosterone, on the development of the embryo as it progresses from an unsexed to sexed individual at approximately the eighth week (Arey 1966; Knickmeyer and Baron-Cohen 2006; Moore and Persaud 1998; Riesenfeld 1972). At this time, testosterone is secreted at high levels and this continues until roughly week 20 (Knickmeyer and Baron-Cohen 2006). Male and female pelvic dimorphism has been clearly evident by 24 to 25 weeks (Boucher 1955; Merrot *et al.* 2001; Nakao 1998), with specific differences found in the angle and breadth of the sciatic notch, subpubic angle and ischial length (Boucher 1955; Boucher 1957; Fazekas and Kósa 1978; Holcomb and Konigsberg 1995; Hunt 1990; Thomson 1899).

1.5.2 Childhood Growth and Development

All three elements of the innominate are well-formed and recognizable at birth with the distinguishing characteristics of each bone clearly discernible. For example, the anterior and posterior iliac spines of the ilium can be easily identified (Fazekas and Kósa 1978; Schaefer *et al.* 2009). While several features are sexually dimorphic in the pelvis at birth, it is not clear how pelvic changes throughout early childhood affect this dimorphism. Most of the changes arising in childhood occur to the ilium, which moves from a flattened, two-dimensional form, to a more curved, three-dimensional shape. The ischium is known to be sexually dimorphic in length throughout childhood (Berge 1998; Reynolds 1945) and the medial portion of the pubic bone, at the superior edge of the pubic symphysis is also known to be sexually dimorphic (Coleman 1969).

A growth spurt occurs soon after birth in both males and females; boys generally grow faster and are larger at an early age while females show more variation in pelvic development (Reynolds 1945). This early growth spurt slows by early childhood, following the deceleration process begun in infancy (Bogin 1999, p. 67). A mid-childhood growth spurt also occurs at roughly five to nine years of age. It is at this age that the ramus between the pubis and ischium fuses, with females showing earlier fusion in this area than males (Cardoso 2008; Krogman 1962; Schaefer *et al.* 2009) (Figure 1.1). During childhood, size differences between the male and female pelvis decrease, while sexually dimorphic differences increase (Moerman 1981) and by age nine, the width of the ilium has reached 70% of adult size (Humphrey 1998).

At puberty, when hormones surge, further defining characteristics are distinguishable between male and female pelves (Humphrey 1998; Rogers and Saunders 1994). The pubertal growth spurt, when a rapid increase in growth occurs to prepare the body for its adult form, is a time of pelvic remodeling in anticipation for reproduction (Bogin 1999; LaVelle 1995). Puberty occurs earlier in females than males, and relates to the needs of childbirth placed upon the female pelvis (Greulich and Thoms 1938), especially as it may take five years for the female pelvis to become reproductively mature (Bogin 1999). This pattern of pelvic alteration can be observed in other species, such as in the squirrel monkey, where female pelves modify from the male form at puberty to accommodate the large head and body size of their offspring (Gingerich 1972; Leutenegger 1974)

Acetabular growth is composite, involving multiple epiphyses, which mature in conjunction with the femoral head (Cardoso 2008; Schaefer 2008) (Figure 1.1). Although fusion of the acetabulum begins as early as nine years, the three pelvic elements do not completely fuse until age 15 in females and age 17 in males (Cardoso 2008; Krogman 1962). No substantial differences in growth of the acetabulum occur between males and females (Coleman 1969). For the overall pelvic shape, females show more variability than males (Coleman 1969; Reynolds 1947). Growth continues throughout puberty at several secondary ossification centers at the pubic symphysis, iliac crest, anterior inferior iliac spine, and ischial ramus and tuberosity, fusing at varying times (Cardoso 2008; Coleman 1969; Schaefer 2008; Webb and Suchey 1985) (Figure 2.1). All areas are largely fused by age 20, when 90% of iliac breadth dimensions have been attained (Humphrey 1998).

Furthermore, sexually dimorphic differences do not occur equally for the pelvic bones, but in a complex fashion, with growth occurring in multiple areas at differing rates for males and females (Bogin 1999; Coleman 1969; LaVelle 1995; Tague 1994). One area of differential growth between males and females is the pubis, as this bone exhibits prolonged growth in females along the pubic symphysis growth center. This center is the final area of the pelvis to fuse (Johnston and Zimmer 1989; Krogman 1962). Specifically, the ventral and medial portions of the pubic symphysis continue growing into early adulthood, creating a longer pubic length as well as the ventral arc, one particularly sexually dimorphic feature of the pelvis (Anderson 1990; Coleman 1969; Phenice 1969; Sutherland and Suchey 1991; Tague 1994). The subpubic angle is created as the ischial tuberosities shift laterally and are not due to increased growth of the pubic bone (Coleman 1969).

While environmental factors, such as diet and health, may delay fusion of innominate bones, the sequence in which the ossification centers fuse does not alter (Krogman 1962). Nutritional deficiencies in Vitamin D, calcium, or protein can affect pelvic form in addition to posture and activities (Abitbol 1991; DelPrete 2006; Greulich and Thoms 1938). These influences must be considered when evaluating any pelvic material.

1.6 ADULT SEX DETERMINATION METHODS ON THE INNOMINATE

Adult innominates have been useful to determine adult biological sex in both archaeological and forensic settings. As the innominate is the most sexually dimorphic area in adult skeletal material, it provides sufficient evidence for sex determination even when fragmentary (Albanese 2003; Ali and MacLaughlin 1991; Bruzek 2002; Bytheway 2003; Đurić *et al.* 2005; France 1998; Gonzalez *et al.* 2007; Kimura 1982; MacLaughlin and Bruce 1980; Patriquin *et al.* 2003; Rogers and Saunders 1994; St. Hoyme and Iscan 1989; Weiss 1972). Most techniques for sex determination are based on visual assessment as most features are easy to evaluate for a trained observer (Hsiao *et al*. 2010; Walker 2008). The development of quantitative methods has been attempted in an effort to decrease ambiguity in assessment methods; results have been mixed as difficulties arise when attempting to depict metrically what is evident visually (Phenice 1969; Stewart 1954; Taylor and Dibennardo 1984; Walker 2008). A small amount of overlap, usually less than 5% (Bruzek 2002), does occur between males and females in these features, so that some individuals fall into an ambiguous or intermediate category (Davivongs 1963; Meindl *et al.* 1985; Rogers and Saunders 1994). While some regional variation of sexually dimorphic traits has been noted, researchers suggest that this difference does not affect sex determination (Abitbol 1991; Boucher 1957; Patriquin *et al.* 2003; Patriquin *et al.* 2005; Washburn 1948)

The requirements of reproduction are thought to be the source of the differences between males and female pelves, as females display more splayed and wide pelves while males are narrower. Males are typically larger in overall body size, but have smaller pelves than females (DelPrete 2006; Tague 1992). Most early studies of the pelvis dealt with the size and structure of the pelvic inlet, assessing the pelvic bowl as a single element (Caldwell and Moloy 1938; Emmons 1913; Greulich and Thoms 1938). Later studies incorporated the entire pelvis, with common features reviewed including the greater sciatic notch breadth and angle, subpubic angle, ventral arc, pubic bone length, preauricular sulcus, subpubic concavity, and the ischio-pubic index, which is pubic length divided by ischial length multiplied by 100 (Anderson 1990; Budinoff and Tague 1990; Flander 1978; Genovés 1959; Singh and Potturi 1978; St. Hoyme and Iscan 1989; Sutter 2003; Washburn 1948). Rogers and Saunders (1994) identified 17 features, both singly and in combination, that reliably determine adult sex. These authors conclude the following traits to be sexually dimorphic: subpubic angle, sciatic notch shape and size, ischio-pubic ramus ridge, ventral arc presence, shape of pubic bone, dorsal pubic pitting, auricular surface height, preauricular sulcus presence and shape, ilium shape, pelvic inlet shape, true pelvis size and shape, obturator foramen shape, acetabulum size and orientation, muscle markings, sacral shape, number of sacral segments, and posterior sacral joint visibility. Additional scholars have suggested features such as the breadth, depth, and angle of sciatic notch; pubic length; ischial length; ischio-pubic index; pubic body width; and acetabular diameter (1980; Davivongs 1963; Day and Pitcher-Wilmott 1975; Krogman 1962; Phenice 1969; Schulter-Ellis *et al.* 1983; Segebarth-Orban 1980; Steyn and Patriquin 2009; Thieme and Schull 1957). These traits have been evaluated in tandem or individually, with mixed results. Some traits are more reliable than others, but those stated above have shown some level of sexual dimorphism.

One of the pioneering studies on the differences between the sexes for the pubic and ischial bones was conducted by Washburn (1948). This investigation reviewed documented skeletal material of American White and Black adults from the Hamann-Todd collection held at the Natural History Museum in Cleveland. Washburn found both sex and populational differences, with the sex determination reliability rate over 90% when using the ischio-pubic index. He also determined that by combining the sciatic notch with the ischio-pubic index nearly all skeletons were sexed accurately. Another influential pubic bone analysis was Phenice's (1969) visual assessment of the pubis, where the ventral arc, subpubic concavity, and medial aspect of the ischio-pubic ramus were evaluated in combination, with highly accurate sex determination levels.

Studies of the sciatic notch have been most numerous, as this trait is evident early in human development, and has been noted as sexually dimorphic in subadult and adult populations (Boucher 1955; Davivongs 1963; Krogman 1962; Pretorius *et al.* 2006; Reynolds 1945; Rogers and Saunders 1994; Schutkowski 1993; Singh and Potturi 1978; Thomson 1899; Vlak *et al.* 2008; Walker 2005). The breadth, height, angle, and shape have been analyzed for this feature, in both visual and metric assessments, with variations observed between and within populations (Bruzek 2002; Stewart 1954).

Morphological studies have evaluated the shapes and appearance of many features found in the pelvic bones (Rogers and Saunders 1994). While some features are based solely on presence or absence, other features are estimated along a continuum of narrow to broad, marked to smooth, or small to large. Attempting to understand the exact definition of these subjective terms can be difficult, especially when one individual is studied in isolation. For this study, quantifying several of these features will be attempted to create a more objective analysis. For example, the sciatic notch shape and size have often been described as either small and deep or wide and shallow; this study will evaluate actual length measurements for the width and depth of the notch. Other subjective features to be analyzed metrically for this study are the sciatic notch angle and the subpubic angle, which both are typically categorized as broad or narrow.

Taylor and Dibennardo (1984) used statistics to evaluate adult pelvic traits for sex determination. Utilizing discriminant function analysis of several pelvic traits, including measurements of the sciatic notch width and depth, these researchers were able to obtain a 90% accuracy rate when race was known. These authors found the male sciatic notch shape more "J" shaped, while female shape was more like "an open "C" shape" (Taylor and Dibennardo 1984, p. 319).

Various regional populations have been considered in the development of sex determination techniques, including North American, European, and African groups (Davivongs 1963; Đurić *et al.* 2005; Emmons 1913; Greulich and Thoms 1938; Kimura 1982; MacLaughlin and Bruce 1986; Patriquin *et al.* 2003; Patriquin *et al.* 2005; Steyn and Patriquin 2009). The level of sexual dimorphism can vary from population to population; however, while differences are noted between populations, studies reveal that sex assessment results are not greatly affected by these differences (Choi and Trotter 1970; Steyn and Patriquin 2009; Walker 2008).

1.7 SUBADULT PELVIC SEX DETERMINATION METHODS

Subadult sex determination has been a goal of anthropologists since sexual dimorphism was detected by Fehling (1876). Several features listed for adults in the previous section have been noted as being dimorphic in subadult males and females, with the breadth and angle of the sciatic notch and subpubic angle the most prominent features. The greater sciatic notch has been studied more than any other feature in subadults due to its early fetal development and its likelihood of being preserved (Vlak *et al.* 2008). Although a great deal of research has been conducted on these traits, especially within the past 20 years, the results have been mixed, and no sex determination method is currently acceptable for subadults (Boucher 1955; Boucher 1957; Cardoso and Saunders 2008; Holcomb and Konigsberg 1995; Hunt 1990; Merrot *et al.* 2001; Mittler and Sheridan 1992; Reynolds 1945; Reynolds 1947; Schutkowski 1993; Sutter 2003; Thomson 1899; Washburn 1948; Weaver 1980; Wilson *et al*. 2008). Much of the ambiguity stems from a narrow research study focus, i.e., examination of only one trait or use of subjective features. This is compounded by the fact that samples of subadults with known age and sex are rare and usually small, with fewer than 50 individuals.

Innominate traits considered in previous subadult studies include the breadth and angle of the sciatic notch, curvature of the iliac crest, arch criterion, raised or not raised auricular surface on the ilium, subpubic angle of the pubis, and length of the ischium (Cardoso and Saunders 2008; Holcomb and Konigsberg 1995; Hunt 1990; Merrot *et al.* 2001; Mittler and Sheridan 1992; Schutkowski 1993; Vlak *et al.* 2008; Weaver 1980). Hungarian, British, Portuguese, American White, American Native, and even a Chilean mummy population have been evaluated to determine subadult sexual dimorphism (Cardoso and Saunders 2008; Fazekas and Kósa 1978; Holcomb and Konigsberg 1995; Hunt 1990; Schutkowski 1993; Sutter 2003; Weaver 1980).

Most of these samples were quite small and no cross-populational comparisons were made within one study. In addition, several researchers experienced difficulties replicating results from previous studies on different ancestral samples (Cardoso and Saunders 2008; Sutter 2003; Vlak *et al.* 2008).

1.7.1 Radiographic studies

Some of the initial evaluations of immature individuals were performed on a generalized, longitudinal study of subadult individuals using radiographs, not skeletal material. The Fels Research Institute's longitudinal examination of radiographs of children, now located at Wright State University, Boonshoft School of Medicine, began in 1930 and is part of the Lifespan Health Research Center in Kettering, Ohio (Roche 1992). The Fels Institute provided material for many studies examining multiple aspects of the growth and development of children; Reynolds (1945; 1947) and Coleman (1969) have been the primary researchers of the pelvic material (Roche 1992).

In his first research project, Reynolds (1945) analyzed radiographs taken of children at one, three, six, nine, and twelve months and evaluated growth changes, sex differences and functional effects. He found several sex differences, as boys were larger in size, particularly in the pelvis height and iliac breadth. Females showed longer pubic length, sciatic notch breadth and pelvic inlet measures. Reynolds (1947) follow-up inquiries of older children, between 15 months and 9.5 years, again reviewed growth changes and sex differences, but also looked at patterns of growth. Sex differences found were similar to the infant analysis, with boys leading in overall size of pelvic measures and females showed larger pelvic inlet measures, including pubic length, sciatic notch breadth and pubic angle.

Additional research utilizing the Fels Research Institute program was conducted by Coleman (1969), who reviewed radiographs of older individuals, from age 9 to 18 years, and focused on growth patterns. This author found that sex differences were a result of complex growth based on different systems for each bone within the innominate, affecting the size and shape of the pelvic inlet and sciatic notch. He also determined that the subpubic angle was clearly dimorphic as it was associated with a separate growth system and was less variable than the sciatic notch morphology.

1.7.2 Ilium evaluations

The greater sciatic notch has been studied more than any other element of the fetal innominate. As stated by Vlak and colleagues (2008):

> *"The greater sciatic notch is recognizable early in fetal development, it is usually well preserved in archaeological and forensic remains, and results of previous studies (Schutkowski 1993; Sutter 2003) have shown a statistically significant level of sexual dimorphism."*

While there have been multiple studies of the sciatic notch, much of the assessment has been subjective in nature and only recently have more objective analyses been performed. These qualitative examinations included the symmetry of the sciatic notch shape (symmetric or asymmetric), an angle evaluation (visual estimate of greater or equal to 90°), and a sciatic notch depth assessment (shallow or deep). The auricular surface elevation, iliac blade curvature, and arch criterion were also studied.

One of the earliest studies of the sciatic notch was Thomson's (1899) review of the fetal pelvis. In this study, Thomson states that the sciatic notch was wider and shallower in females than in males, a fact which he found surprising. It should be noted that Thomson examined intact pelves and measured the width of the sciatic notch as the length from the anterior greater sciatic notch to the margin of the sacrum that met the posterior inferior iliac spine posteriorly. The technique used in this study does not correspond with standardized measurements currently applied. Additionally, while the researcher explained quite thoroughly how he prepared the specimens, he did not give any information regarding age, ancestry, or even total number of individuals analyzed.

Boucher (1955), when analyzing British and American fetal pelves from a collection of British White stillborn infants, created the sciatic notch index of width divided by depth and determined that females had a larger index than males. In a follow-up article, Boucher (1957) noted a difference between British and American fetal samples in the width and depth of the sciatic notch, as British Whites and American Black females had considerably larger indices; this result was not seen in American Whites. Fazekas and Kósa (1978) tested Boucher's techniques for the sciatic notch on 104 Hungarian fetal skeletal remains. They found a correlation between sciatic notch depth and the length of the ilium, with males showing more significant notch depth and females displaying larger notch length.

In a study by Weaver (1980), the ilia from the Forensic Fetal Osteological Collection at the Smithsonian Institution were evaluated both metrically and non-metrically. Measurements included the sciatic notch width and depth, iliac height and width, and the non-metric trait of the auricular surface elevation. From these measures, Weaver developed or utilized several indices, including a sciatic notch over depth index used by Boucher (1955), iliac posterior and anterior length index, and iliac width or iliac height index. Only the iliac breadth index provided a statistically significant metric measure; the sciatic notch index was not statistically dimorphic between the sexes. It should be noted that Weaver used non-standardized iliac width and height measurements. His auricular surface elevation findings will be discussed separately below.

Schutkowski (1993) examined the Spitalfields London, juvenile skeletal collection, which contained individuals aged from birth to 11 years. The iliac traits evaluated included the greater sciatic notch depth and angle, iliac crest curvature, and arch criterion. Schutkowski determined that the sciatic notch was particularly diagnostic of sex. He visually assessed females as having angles greater than 90° and males as having angles at approximately 90°. While males were correctly identified 95% of the time, this trait had a fairly low reliability rate of only 70-75% because while males often presented the male feature, females often lacked the definitive female trait. Using an adjusted version of Genovés (1959) composite arch method, Schutkowski used an arch criterion method evaluating whether an arch along the anterior border of the sciatic notch either crossed the center or the anterior rim of the auricular surface. Schutkowski determined that 73.3% of males and 70.6% of females were correctly sexed with this trait. However, sample size of only 29 males and 22 females has an effect on the overall reliability of this study.

Schutkowski's findings were not replicated when Vlak and colleagues (2008) used Schutkowski's sciatic notch methods on a modern subadult Portuguese sample (n=56). These researchers were not successful in reproducing similar results and determined that age affected the sciatic notch appraisal. Cardoso and Saunders (2008) conducted tests of the same modern Portuguese sample that Vlak (2008) assessed, but on a larger group (n=97). Only the arch criterion was tested, and these authors determined that this trait was unreliable for sex assessment in subadults and speculated that this pelvic trait showed considerable variation between different ancestral populations.

1.7.3 Shape analyses

Morphometric analyses have also been conducted on the pelvis, chiefly on the sciatic notch. Holcomb and Konigsberg (1995) found in their examination of 133 fetal ilia from the Trotter Collection housed at the Washington University School of Medicine, that statistically significant correlations between the fetal sciatic notch shape and sex were present. However, this correlation had a lower reliability rate due to a large amount of overlap between the sexes. In this study, only the left ilium was used, and photographs were printed out, and then digitized on a tablet to assess iliac shape, including the sciatic notch shape.

Wilson *et al.* (2008) utilized digitizing techniques to evaluate the shape and angle of the sciatic notch, auricular surface morphology, and iliac blade curvature of 25 individuals from birth to eight years. This study was conducted on the Christ Church Spitalfields Collection, London, which derived the sex and age data from coffin plates. Of the traits reviewed, the greater sciatic notch shape had the highest accuracy level at 96%. For those individuals over six months of age, iliac crest curvature shape more accurately identified sex, with males showing higher levels of accuracy than females.

1.7.4 Auricular surface elevation

The raised or not raised state of the auricular surface is the final trait considered on the ilium. This is the area where the sacrum articulates with the ilium. Weaver (1980) was the first to examine this, using a raised or not raised methodology that required both anterior and posterior sides to be completely elevated for the surface to be considered as raised. This trait had varying levels of accuracy, from 75 to 92%, and showed considerable differences between males and females, with most males correctly assessed while females were not.

Hunt (1990) tested Weaver's study on 275 subadult ilia from three Amerindian samples, and was not able to find any correlation to sex. Hunt suggested that this may not only be a population specific trait, but a trait correlating more closely to age than sex. This research was followed-up by Mittler and Sheridan (1992) who assessed the auricular surfaces of a known-sex subadult sample of mummified remains from medieval Nubia. While males were fairly accurately sexed at 85%, females were not readily identifiable, with only a 58% accuracy rate. These authors found accuracy rates increased for individuals over nine years of age; notwithstanding, nearly a quarter of the females did not exhibit a raised auricular surface. Sutter (2003) used a ranked technique to evaluate the auricular surface elevation, with none or one side raised considered to be not raised, three to four sides raised equal to raised, and two sides raised classed as indeterminate. In this study, the overall classification rate was 72%, with females 58.3% correct and males 84.6% correct.

1.7.5 Ischium and pubic assessment

The ischium and pubis have also been assessed for sexual dimorphism in subadults. Traits observed included the ischial and pubic lengths and subpubic angle. Boucher (1957) found no differences in ischial or pubic lengths. Rissech and colleagues (2003) found that ischial length was longer in boys, especially those over five years of age, indicating growth differences between the sexes. However, males and females were found to have similar length means until age 15-19. Both the subpubic angle and the pubic length have been reviewed in pubic bone studies. Unfortunately, the pubic bone is less frequently recovered than other pelvic bones

(Bruzek 2002), so fewer studies have been conducted on this element in subadults. Tague (1994) suggested that the pubic bone grows later in females than in males, even into adulthood; and yet, Fuller (1998) was not able to replicate these findings and suggests that age of menarche plays a role in growth of the pubis.

The subpubic angle was first examined by Thomson (1899) and found to be easily evaluated. In his study, he determined that male angles were smaller than female angles. Again, no background information was available for the Thomson study. Boucher's (1957) investigation of subadult ischial and pubic bones found no differences in bone size between the sexes, but found major differences in the subpubic angle measurement for the American samples. No sex differences were found for the ischial or pubic lengths or the ischio-pubic index.

1.7.6 Landmark determination

Gonzalez and colleagues (2007) examined the sciatic notch using landmarks similar to Holcomb and Konigsberg (1995). These authors were not attempting to examine sex differences, but rather wished to assess error rates in landmark determination. These researchers examined three collections from different areas of Argentina. These authors established that even inexperienced osteologists identified and correctly established the sciatic notch landmarks. In addition, these authors found that in the three samples evaluated, sciatic notch shape varied. It should be noted that these samples were quite small, with 30 or fewer individuals in each group.

1.7.7 Critiques of subadult studies

Despite the fact that many studies have evaluated subadult pelvic skeletal material, no clear-cut sex determination methods have been generated. One reason for this is the lack of known sexed and aged material from which to create solid methods. With few sample populations available for study, many early studies were conducted on radiographs (Morton and Hayden 1941; Reynolds 1945; Reynolds 1947). The results of these studies have been compared directly to studies of dry bones. However, determination of landmarks and measurements do not necessarily correlate between radiographs of articulated pelvic elements, attached by cartilage, and direct measure of disarticulated pelvic bones without cartilage. In particular, landmarks of the sciatic notch and within the acetabulum are more difficult to determine on radiographs (Blake *et al*. 2010). Other measures, such as the subpubic angle, are easier to determine in radiographs than on individual dry bones as this angle is more easily viewed when the two pubic bones are united at the pubic symphysis (Thomson 1899).

Another issue affecting method development is the limited scope of samples, for example, sample sizes are small or contain narrow age groups, such as only fetal individuals (Boucher 1957; Weaver 1980). As fetal remains are composed of individuals who died before birth, the assessment of these individuals may not accurately represent those who survived to grow and develop normally. Growth and development may be compromised by the problems that led to the premature death. Most subadult samples are small in number, sometimes only 25 individuals spread over multiple ages, making statistical evaluation and accuracy of results uncertain without further review (Wilson *et al.* 2008). Additionally, while a collection may contain children across multiple age ranges, sample sizes for each age group may be quite small (less than 10 individuals). This may explain many conflicting results between studies. For example, Schutkowski recommended caution when evaluating children older than five years while other researchers concluded that children under two years were not useful for sex determination (Weaver 1980; Wilson *et al.* 2008). These mixed results show how research may be constrained by sample composition.

A further issue affecting the development of sex assessment methods is inconsistent techniques. Specifically, Boucher (1957) did not define the particular landmarks used in her evaluation methods, making it difficult to recreate that radiographic study on skeletal remains. Choi and Trotter (1970) measured the skeletal "hip", yet never defined what this measurement entailed. Weaver (1980) used non-standard measures for iliac length and sciatic notch depth and width, making it difficult to compare his result with others. Replication of research by others on additional groups is challenging if feature descriptions are unclear, or the technique is unconventional.

The use of subjective terms and techniques is an additional problem with studies of subadult skeletal material as these oftentimes do not meet the high scientific levels needed in forensic circumstances. For example, Schutkowski (1993) utilized subjective methods for the pelvic traits, such as a shallow or deep sciatic notch assessment and a visual approximation of the sciatic notch angle. Due to the vagueness of descriptors, method replication is more difficult and may be one reason why other researchers have not been able to successfully duplicate his results (Sutter 2003; Vlak *et al.* 2008). Additionally, Sutter stated that the female condition for the arch criterion crosses the auricular surface in one area of his article and later indicated that the arch borders the auricular surface, causing confusion as to which method was used for the arch criterion assessment. When analyzing his data, most male arches crossed the auricular surface, particularly in older males, while females showed a mix of those bordering and crossing the auricular surface.

Forensic anthropologists must also utilize standards acceptable in a court of law, according to evidentiary rules, in particular the *Daubert* criteria. The *Daubert v. Merrell Dow Pharmaceuticals* (Daubert 1993) was a landmark case which increased the requirements for scientific evidence presented in a court of law from generally accepted practices to valid and reliable methods (Majmudar 1993). Three important aspects of these updated standards were that quantitative methods should be used, high levels of statistical reliability must be met, and the method must be reliable and repeatable (Bernstein 1994; Dirkmaat *et al*. 2008; Majmudar 1993). Researchers strive to develop methods that will reach a high threshold of reliability, such as 90 – 95%, in order to meet these requirements. In addition, methods must be repeatable on multiple groups from other geographic locations with similar results. Developing methods that are standardized, quantitative, and provide probability level high enough to meet the *Daubert* requirements are essential; however, as discussed above, many of the subadult pelvic studies do not meet these conditions, particularly studies utilizing non-metric analysis methods.

For the bioarchaeologist, the issue of repatriation greatly affects the access to skeletal material (Kakaliouras 2008; Ousley et al. 2005). Many skeletal remains formerly housed in museums are being returned to the areas and the native groups from which they were found originally. These remains are usually reburied within local communities and no longer accessible to researchers. Additionally, when unmarked burials are discovered, perhaps during construction of modern roads or buildings, these remains are typically only available for a short time for analysis before being reinterred elsewhere (Sample 2011). Therefore, researchers may only have access to measurements and photographs taken by other investigators prior to reburial for use in later analysis. Creating methods that take these issues into account is imperative for any future study of material that is no longer available for first-hand examination.

Lastly, the use of digitizing equipment has presented statistically significant sex determination results; however, this technique does not allow for easy replication by other researchers without this equipment or software, nor can these results be applied to skeletal remains. In the Wilson *et al.* (2008) analysis, while the sciatic notch shape method was extremely accurate, it was not clear how to extrapolate these findings into a usable, user-friendly method for sex determination. Only typical male and typical female shapes can be indicated in morphometric analysis, with no assessment method created. As a result, these analyses are inapplicable to other samples as noted by Wilson and colleagues, who suggested that a more readily available technique needs to be developed, which was low in cost and straightforward to use for every researcher. A valued technique must be accurate, easy to replicate, standardized, and accessible to future researchers in laboratory and field conditions, where access to facilities and even electricity may restrict the use of high-tech sophisticated methods.

1.8 GOALS OF THIS RESEARCH

Understanding the variation found in the subadult human pelvis and developing a method of identifying subadult sex at an acceptable forensic level of 90% to 95% accuracy were the goals of this study. This will be achieved by 1) establishing if sexually dimorphic features exist on the subadult ilium, ischium, and pubis, 2) determining whether these traits occur in isolation or collectively, 3) ascertaining if age is a factor in the presence of these dimorphic traits, 4) comparing visual, metric, and photographic techniques, 5) determining if dimorphic traits are evident in more than one sample, and, 6) testing any method developed on a population of subadults of known sex to determine accuracy and ease of use.

1.9 CONTRIBUTIONS OF THIS RESEARCH

This current project will contribute on several levels to the current state of the discipline. In particular, by utilizing the three pelvic elements, a more holistic inquiry of the subadult pelvis will be conducted that has been neglected in the past. The inclusion of both metric and non-metric traits and creation of clear definitions for qualitative traits will provide a broader foundation of research not seen in other studies. As the requirements of forensic anthropologists must meet legal standards, providing clearly described landmarks and easily repeatable techniques will aid in the development of methods that meet these requirements. The inclusion of photographic methods facilitates evaluation, particularly for the angle and shape of the sciatic notch and the subpubic angle that is difficult to assess on dry bone and that has only previously been conducted with digitizing equipment or on radiographs. The comparison of multiple geographic groups for these traits will expand the literature, as currently relatively little research has compared multiple subadult groups. Furthermore, the three samples selected have not been subjected to this depth of analysis previously or compared to one another. This analysis will provide an in-depth understanding of how these traits can be assessed throughout childhood when locomotion and hormonal changes shape pelvic morphology.

2.0 MATERIALS AND METHODS

2.1 SAMPLES

Three skeletal collections of documented subadults were selected for this study (Table 2.1). These samples were chosen as they represent the largest collections of subadult individuals with known age and sex available in the United States. For this study, the documentation of sex was essential to potentially develop a sex determination method. Additionally, the documented age was fundamental to account for growth and development variation within the pelvis. If an ambiguous or broad age was listed, such as “infant”, dental formation and long bone measurements were evaluated to provide a more precise age (Fazekas and Kósa 1978; Gindhart 1973; Maresh 1970). The lower limit for this study was eight lunar months, or the individuals from the eighth month of gestation. This threshold was selected as these individuals are similar to newborns in development of the pelvic features reviewed in this study. Age 16 was selected as upper age limit as the process of reproductive maturation is well underway by this age in most individuals and adult sexually dimorphic traits may be visible. Moreover, by this age, the three elements of the innominate have fused together at the acetabulum for most individuals (Cardoso 2008; Fazekas and Kósa 1978; Schaefer 2008). Data obtained from these collections included age-at-death, sex, and ancestry when available. Other pertinent information, e.g., cause of death, was also documented. Measurements were taken from both right and left sides for each individual when obtainable. Ethical approval was received from the University of Pittsburgh's Committee for Oversight of Research Involving the Dead (No. 237) to study the three samples (Appendix A).

Table 2.1. Summary of sample composition, with age and sex distributions

Number in samples				
Collection and location	Total	Females	Males	Age range
The Forensic Fetal Osteological Collection, Smithsonian Institute, Washington, DC	113	57	56	8 lunar months to 8 postnatal months
Subadult component, Hamann-Todd Collection, Cleveland Museum of Natural History, Cleveland, OH	37	19	18	1 year to 16 years
Trotter Fetal Bone Collection, Washington University, St. Louis, MO	37	21	16	8 lunar months to 2 postnatal months
Total	185	97	90	

2.1.1 The Forensic Fetal Osteological Collection.

The Forensic Fetal Osteological Collection at the National Museum of Natural History (NMNH) at the Smithsonian Institute, the primary collection for this study, provided the basis for determining sexual dimorphism in fetal remains (Hunt 1990; Huxley 2005; Weaver 1980). This collection, collected between 1902 and 1917 by Dr. A. Hrdlička, consists of 271 fetal and newborn individuals, with at least 130 of those remains with documented age, sex, and ancestry. For this project, 113 individuals provided sufficient skeletal material for evaluation, i.e., intact pelvic material, and fell within the required age categorizations, as only those listed as late fetal, newborn, infant, or child or with specific ages over eight lunar months were used. Data were collected from this location in March and May 2010, with follow-up collection in December 2010.

2.1.2 The Hamann-Todd Collection

The second collection examined was the subadult component of the Hamann-Todd (HTH) Collection located at the Cleveland Museum of Natural History (Jellema 2009). Beginning in 1912, T.W. Todd amassed over 3700 individuals before his death in 1938 to create an assemblage representing one of the largest known human skeletal collections in the world (Cobb 1981). However, from this large collection, only 37 individuals aged birth to 16 years of known sex, age, and ancestry were suitable for use in this study. Supplementary data collected for each individual included medical and autopsy information when available. Data were collected from this location in November 2009.

2.1.3 The Trotter Fetal Bone Collection

The Trotter Fetal Bone Collection, housed at Washington University, St. Louis, was the final collection analyzed. This assemblage of fetal cadavers, collected by Dr. Mildred Trotter and allocated to Washington University School of Medicine throughout the 1950s until the 1960s, was comprised of exclusively of femora and pelvic skeletal material (Choi and Trotter 1970; Holcomb and Konigsberg 1995; Trotter and Peterson 1968; Trotter and Peterson 1969). While the collection contained 144 fetal individuals of known age, sex, and ancestry, only 37 individuals were of sufficient age (8+ lunar months), size, and completeness to be evaluated. The age of the individuals was collected from the number of weeks since the mother's last menstruation date and not from date of birth. These weeks were converted into number of months for this analysis, with those over 40 weeks considered newborn or older. Measurements were collected from this group in June 2010.

2.2 DATA COLLECTION

Age-at-death, sex, ancestry and available background data were obtained from the museum records for each individual and recorded on the data collection sheets (Appendix B). Preliminary analysis was conducted for each bone to assess condition and determine landmark location. If the bone was damaged at a measurement site, that measurement was eliminated and the condition was noted on the data collection sheet; the remaining measurements for that bone were collected. Sliding digital calipers were used for the direct measurements and an angle ruler was used to assess the angles. Bones were placed on graph paper to assist in feature placement for several of the measurements, especially sciatic notch depth, as the graph line provided the same guide as the dotted line found on Figure 2.1. The left and right pelvic elements were analyzed for each individual before moving on to another individual. When available, medical and autopsy information was recorded. Pathologies or defects evident on the bone were also noted, with particular attention toward any abnormalities that may have affected measurements or overall assessments. All data was recorded on a data collection form and then compiled in Microsoft Access, Microsoft Excel, and SPSS 16.0 files for analysis.

2.3 MEASUREMENTS

This study analyzed both metric and non-metric traits and measurements were taken as outlined below. Below is a description of all measurements used in this study. The following iliac measurements are found on Figure 2.1:

2.3.1 Iliac length

Maximum length from anterior to posterior iliac spine (A to B) (Schaefer *et al*. 2009). Note: when developed iliac spines were not present, maximum length at the end-point area was used.

2.3.2 Sciatic Notch Angle

Using the apex of the notch (D) as the angle point of origin, the maximum angle was formed by the anterior and posterior edges of the sciatic notch (Angle C-D-E).

2.3.3 Sciatic Notch Width

Maximum breadth from anterior and posterior sciatic notch edges (C to E). When these points were indeterminate, the widest points were taken where the arch of the notch turned toward the exterior edge (Vlak *et al.* 2008).

2.3.4 Sciatic Notch Depth

Maximum length of line drawn perpendicular from notch apex (D) to horizontal axis created by sciatic notch width (C to E), based on the technique conducted by Vlak *et al.* (2008), Sutter (2003), Schutkowski (1993) and Day and Pitcher-Wilmott (1975).

2.3.5 Anterior Sciatic Notch

Maximum length from anterior sciatic notch edge to apex (E to D).

2.3.6 Posterior Sciatic Notch

Maximum length from posterior sciatic notch edge to apex (C to D).

2.3.7 Sciatic Notch Shape

The shape of the sciatic notch is determined to be symmetric when the apex was roughly equidistant between the two end-points (C and E) and asymmetric when the apex was shifted anteriorly, located closer to the anterior endpoint (E). Shape represents a non-metric trait following guidelines provided by (Rogers and Saunders 2003; Taylor and Dibennardo 1984).

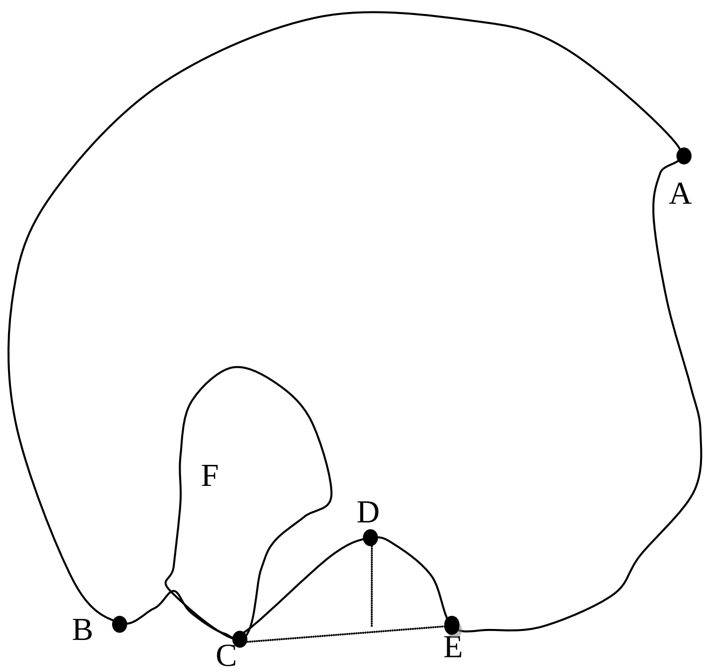


Figure 2.1. The measurement points for the ilium

2.3.8 Auricular surface elevation

Elevation of the auricular surface (F) along anterior and posterior edges denoted a raised surface, while no elevation denoted a not raised surface. Additionally, if only a portion of the auricular surface was raised, the portion of the bone raised was recorded as superior, anterior, inferior and/or posterior raised. The number of sides raised was documented following Sutter's (2003) rank system from 0 to 4. To analyze the auricular surface with this method, each raised side was scored as follows: no sides raised = 0, one side raised = 1, two sides raised = 2, three sides raised = 3, completely raised = 4. According to Sutter (2003), zero and one were considered the male forms (Figure 2.2), two was intermediate and three and four were considered female forms (Figure 2.3). The auricular surface elevation is a non-metric trait.

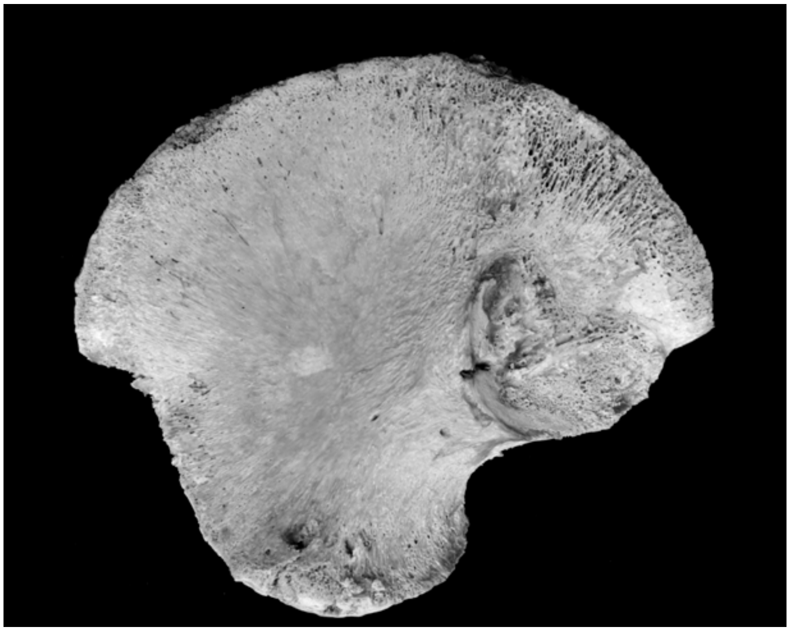


Figure 2.2. Not raised auricular surface, indicative of male, HTH1168

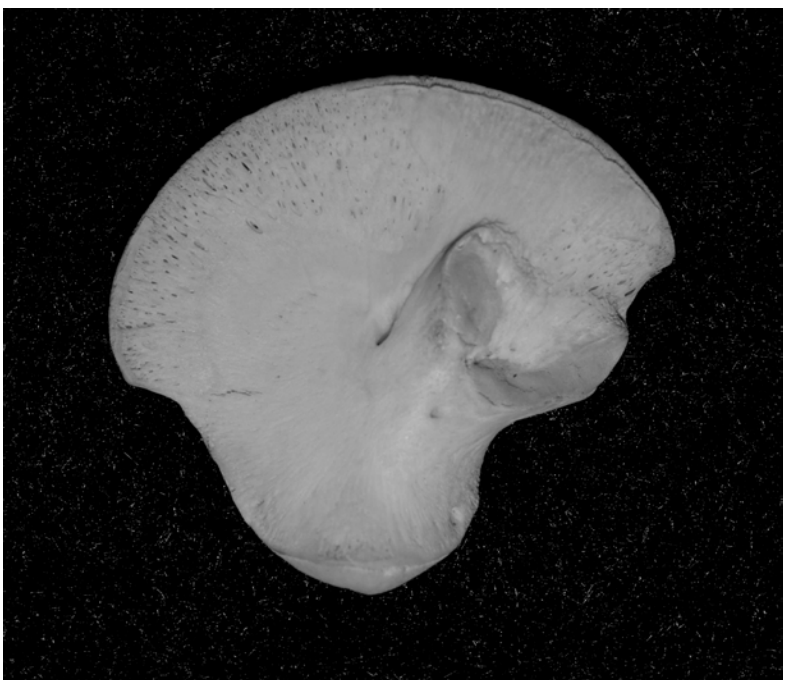


Figure 2.3. Raised auricular surface, indicative of female, NMNH228449

2.3.9 Arch criterion

The ilium was arranged in the same manner as outlined by Schutkowski (1993), with the length of the anterior sciatic notch vertically oriented. An arch was drawn, starting from the anterior portion of the notch and either crossing through or above the auricular surface. Arch criterion was noted as “center” or “top” depending on the location of the arch in relation to the auricular surface. “Center” included any arch crossing the midsection of the auricular surface (Figure 2.4). “Top” included any arch traversing the top of the upper lobe of the auricular surface (Figure 2.5). According to Schutkowski (1993), if the arch crossed the center of the auricular surface, it suggested a female, while if the arch traveled along the anterior margin of the auricular surface, it indicated a male.

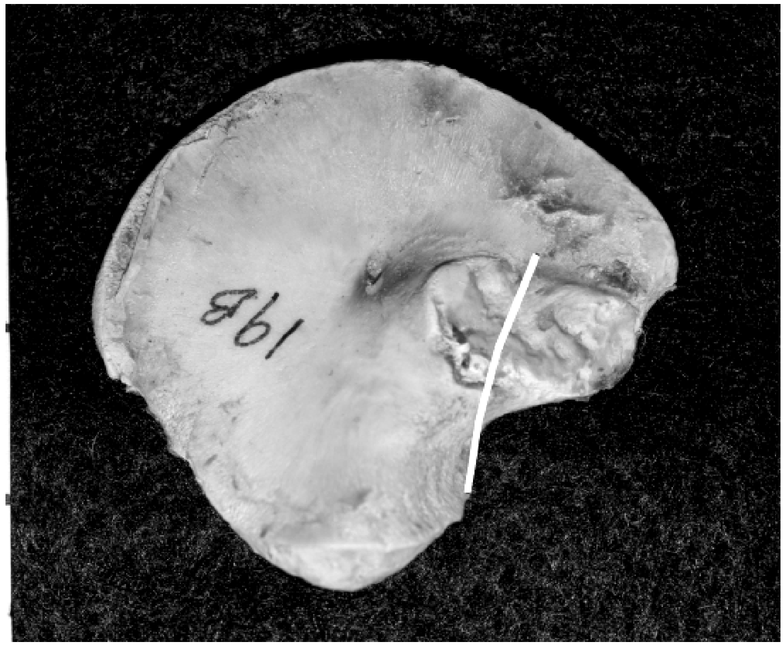


Figure 2.4. “Center” Arch Criterion, indicative of female, Trotter 19B

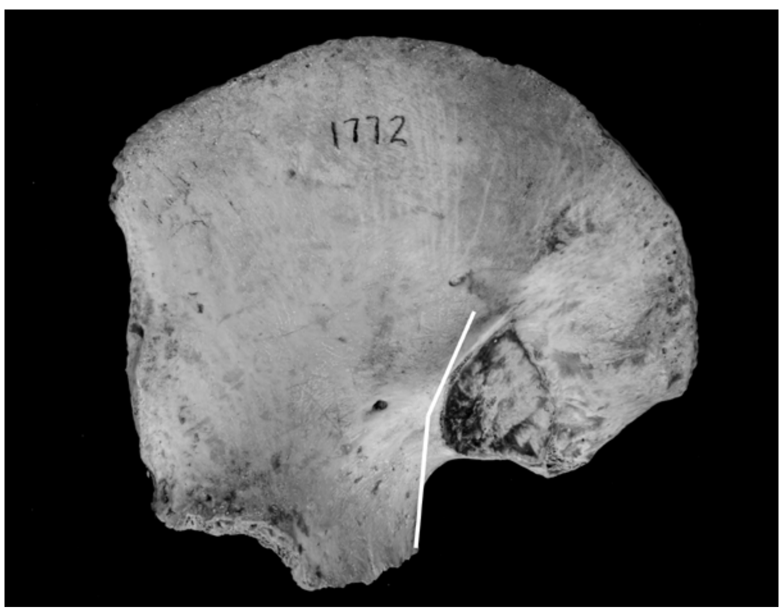


Figure 2.5. “Top” Arch Criterion, indicative of male, HTH1772

2.3.10 Ischial length

Maximum length between acetabular articular end (A) and ramus base (B) (Schaefer *et al*. 2009) (Figure 2.6).

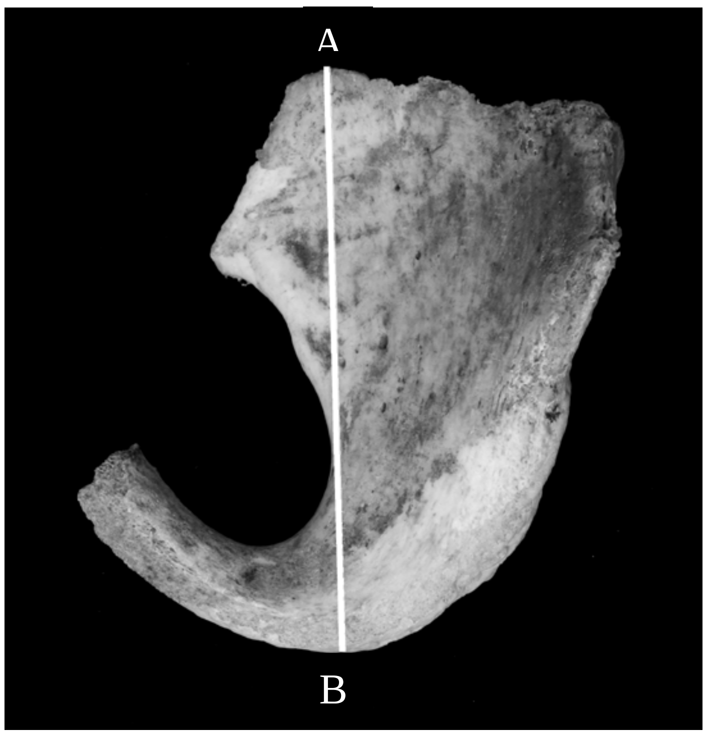


Figure 2.6. Ischial length, HTH 0404

2.3.11 Pubic length

Maximum length between acetabular articular end (A) and symphyseal surface (B) (Schaefer *et al*. 2009) (Figure 2.7). For photographs where both ventral and dorsal measurements were taken, the ventral measurement was used. This reflects the standard direct measurement taken for this feature.

2.3.12 Pubic body width

Minimum width of the pubic body from the pubic symphyseal face (C), usually near the base of the pubic symphysis, to the obturator foramen (D) (Figure 2.7). This measurement was taken from the dorsal surface of the pubic bone.

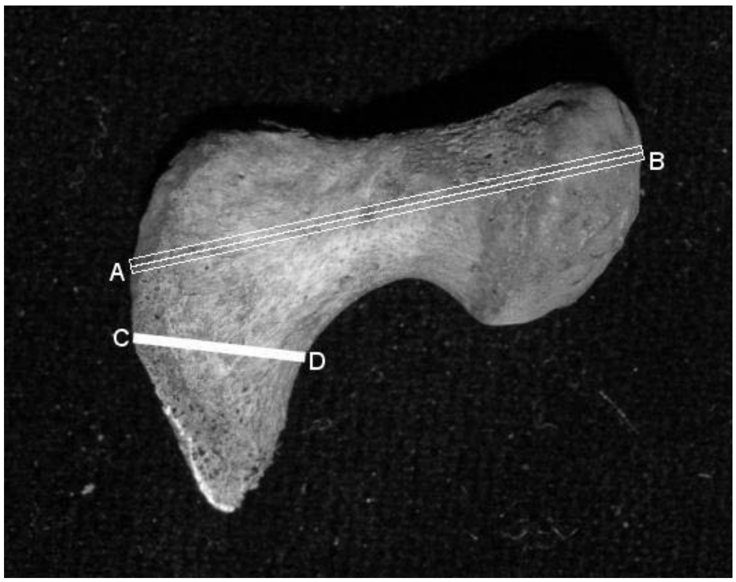


Figure 2.7. Pubic length and pubic body width, right pubis, NMNH 249599

2.3.13 Subpubic angle

Angle created below the pubic symphysis, determined by the maximum angle along the pubic ramus and a line extending down from the symphyseal face (Figure 2.8).

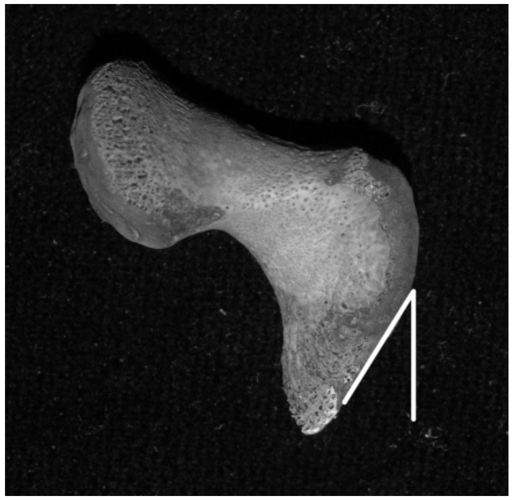


Figure 2.8. Subpubic angle, right pubis, NMNH 249599

2.3.14 Indices

Three new indices were created for this study. The pubic index was developed to illustrate the relationship between the pubic body width and the pubic length. The anterior/posterior sciatic notch index was conceived to assess the link between the anterior sciatic notch measurement and the posterior sciatic notch measurement. This index was developed to quantify the sciatic notch shape and as a means to assess symmetry. The sciatic notch width/iliac length index, was designed to establish an association with the width of the sciatic notch to the iliac length.

Additionally, established indices were also utilized for this study. The first, the sciatic notch index, was an index originally employed by Boucher (1955) to describe the relationship of the sciatic notch width to the depth. The second index, the ischio-pubic index, that reports the length of the pubis by the length of the ischium, was developed by Thomson (1899) and first used by Washburn (1948).

2.3.15 Measurement standardization

The measurements followed standardized, accepted methods when available; however, for many features, previous analysis was either conducted subjectively or in a non-standardized fashion. The sciatic notch measurements were based on the techniques presented by Vlak *et al.* (2008), Sutter (2003), and Day and Pitcher-Wilmott (1975), but not Schutkowski (1993), as he did not analyze features metrically. Moreover, posterior and anterior sciatic notch edges and notch apex were utilized to measure width and depth of the notch as per Vlak *et al.* (2008). This differs from Boucher's method (1957), as she used an arbitrary point of curvature within the sciatic notch to take the measurement, and from Weaver's method (1980), which only measured a small portion of the width of the sciatic notch.

Specific sciatic notch shape landmarks guidelines were provided in Rogers and Saunders (1994) and Taylor and Dibennardo (1984), and these were used for this current study. Researchers such as Wilson and Holcomb (2008) and Holcomb and Konigsberg (1995) used shape analysis software for an evaluation of the entire shape of the ilium, including the sciatic notch shape. These studies were not applicable in this current study's context.

2.4 INTRAOBSERVER RELIABILITY

Each metric measurement was scored twice for a minimum of 10% of each population to test for intraobserver reliability. These additional individuals were chosen at random with at least a week between the initial scoring and the subsequent scoring for the HTH and NMNH collections, to determine if intraobserver error, or the amount of variation found in repeating a measurement, was a factor. These measurements were compared to each other statistically, using reliability analysis, with an interclass correlation threshold of .80 or greater for the metric measurements.

2.5 PHOTOGRAPHS

Photographs were taken following the protocol of by Gonzalez and colleagues (2007) with a digital SLR camera set on macro with an 18-55 lens. The lens was placed parallel to the ilium, with the aid of a camera stand. Distance from each bone to the camera was determined for the bone assessed based on its size. It should be noted that it was necessary to change this distance to ensure consistency in how each bone fit within the camera lens, particularly with the HTH Collection, which consisted of bones aged infant through 16 years. Heights varied from 51.0 cm to 23.1 cm for this collection. For the NMNH Collection, the standard height of 25.5 cm from the camera stand base to the lens was used as most bones were similar in size. This height was replicated with the Trotter Collection. A scale was positioned in each photograph, with the museum’s specimen number noted for reference.

2.6 COMPUTER ANALYSIS

ImageJ 1.40g was used to measure lines and angles based on standardized landmark positions (Abramoff *et al*. 2004; Gonzalez *et al*. 2007; Wilson *et al*. 2008). This program, available for free through the National Institute of Health website (Rasband 1997-2011), is an image processing program designed for measuring lines and angles. Through this program, a scale was set for each photograph. The measurements taken on dry bone were also taken from the photographs using ImageJ. Initially a copy of the original photograph was created, the scale for that photograph was set, and then the available line and angle measurements were taken. Lines were drawn on the photograph using the appropriate tool and then saved to a separate file. The measurements obtained were entered into a spreadsheet for each photograph. Angles were appraised based on the sciatic notch points and subpubic angle points listed above. All elements for one individual were assessed at one sitting. When evaluating the ilium, the photograph was rotated to appraise each feature from the best orientation.

2.7 STATISTICAL ANALYSIS

2.7.1 Sample size analysis

Sample size calculations were determined using the following calculators: Raosoft, Inc., DSS Research, and DanielSoper.com (Raosoft 2004; Research 2009; Soper 2009). Sample size calculations were performed for p-value <0.05, with a power of 0.80. Initial analysis provided a sample size of 96 with a 95% confidence level, and 68 with a 90% confidence level, with additional power analysis providing a sample size of 97. Therefore, 97 individuals were considered the minimum number required for the primary collection. The Smithsonian collection, of 113 individuals, exceeded this calculated target sample size.

Table 2.2. Sample size calculations using three different sample size calculators for 95% and 90% p-values

	P-value	Effect size	Margin of error	Response distribution	Power level	Minimum sample
Soper.com	0.05	0.2	n/a	n/a	0.8	97
Soper.com	0.10	0.2	n/a	n/a	0.8	82
Raosoft.inc	0.05	n/a	0.1	50%	n/a	96
Raosoft.inc	0.10	n/a	0.1	50%	n/a	68
DSS Research	0.05	0.5	n/a	n/a	0.8	65

2.7.2 Paired bone analysis

While studies of skeletal material typically included one side of an individual, usually the left side (Albanese 2003; Bytheway 2003; Hunt 1990; Nagesh *et al*. 2007; Trotter and Peterson 1967), several subadult pelvic studies did not mention the side or sides analyzed (Boucher 1957; Bruzek 2002; Cardoso and Saunders 2008; Dibennardo and Taylor 1983; Patriquin *et al*. 2005; Schutkowski 1993; Sutter 2003; Weaver 1980). Therefore, it was necessary to test whether right and left sides could be interchanged. As a study by Ridley (2002) used the correlation method to examine right and left measurements from paired bones, this study tested if right and left sides measurements were considered to be from the same population. Right and left sides were analyzed for descriptive statistics independently, followed by paired t-tests and Pearson's correlation coefficient to determine how well the paired bones correlated. Paired t-tests were used as this test is more sensitive to correlations than the independent t-test (StatSoft 2010).

Even though the sample size for the NMNH sample was over 100 and the data were mainly normal, the assumption that both males and females have roughly equal variation needed to be considered, and therefore, both correlations and t-tests were conducted. In addition, histograms for each right/left pair were created to ensure that no unusual patterns were observed within the two datasets. Wilcoxon-Sign tests were conducted to determine if observations from the t-tests were similar, as this test determined if both right and left sides were from the same population. As this test was non-parametric, unlike t-tests, normality was not assumed (StatSoft 2010).

2.7.3 Statistical analysis

The statistical analysis was performed in several ways using the statistical program package PASW Statistics 16, Release Version 16.0.1 (SPSS 2007) and included descriptive statistics, t-tests, and correlation coefficient analysis of the measurements. Descriptive statistics were performed to assess the raw data, for both photographic and direct measurements for the three samples. Descriptive statistics were conducted and Q-Q plots were generated to evaluate normality. Independent t-tests were used to compare the means between males and females for each feature measurement. Paired t-tests were also used to compare the means of the photographic measurements and the direct measurements within the same samples. Graphs and histograms illustrated variation between ages, right and left sides, males and females, and statistically significant traits.

Correlations were conducted to determine if any traits correlated significantly statistically with sex in both photographic and direct measurements. Both Pearson's and Spearman's correlations were used, as Pearson's was utilized for the linear measurements and Spearman's was utilized for rank analyses, specifically for the auricular surface elevation. In order to account for missing values, pairwise deletion and mean substitution were utilized for testing correlations, with no differences in the correlations between the two different techniques.

For sex discrimination purposes, both logistic regression and discriminant function were performed using SAS software. Logistic regression is less restrictive in the assumptions that must be met, while the discriminant function can assess a combination of traits (Gapert *et al.* 2009b). Combining traits may predict sex better than a single trait alone, as was observed in other studies (Gapert *et al.* 2009b; Walker 2008). Logistic regression was used to determine if a model could be constructed to predict group membership – in this instance, biological sex; this method was chosen as it is useful when predicting a dichotomous outcome (Hosmer and Lemeshow 2000) and when using categorical variables (Field 2006; Lani 2011; Spicer 2005). Discriminant function analysis was conducted to determine if a model to classify the subadults by sex was probable. This method is particularly valuable in identifying patterns in dependent variables in order to predict group membership (StatSoft 2010). Both analyses were conducted on the NMNH sample and then tested on the HTH and Trotter samples. For these analyses, biological sex was the dependent variable.

3.0 RESULTS

3.1 SAMPLE DEMOGRAPHIC DATA

The demographic distribution for each of the three collections analyzed is discussed below. The raw measurements for each collection are compiled in Appendices C, D, and E. The Smithsonian and Trotter collections were similar in age composition, while the Cleveland sample represented large age differences. The Trotter and Cleveland collections were identical in size, while the Smithsonian sample was much larger and was therefore the primary focus of this study. Several individuals from each collection were omitted from this study as they either lacked the necessary elements or displayed damaged features. Additionally, at the time of data collection, several individuals were missing from each sample and were unavailable for examination. As a result of these discrepancies in either the quality or inability to locate individuals, the maximum numbers of individuals available from each sample was less than the total number listed in the collection records.

3.1.1 The Smithsonian Forensic Fetal Osteological Collection

Of the 271 individuals available from the Smithsonian Forensic Fetal Osteological Collection (NMNH), a subsample of 113 individuals was analyzed for this study. The number of males and females was nearly equal, with 56 males and 57 females analyzed. This group represented almost entirely newborn individuals, as 98 of the 113 (87%) individuals studied fell into the newborn category (Figure 3.1). The age range for this collection was from newborn (birth to one month) up to eight months of age. The age category was unclear or vague in the records (e.g., listing only the word *child*) for approximately 65 individuals. For these cases, long bone measurements were taken to establish more precise age parameters using fetal and infant age determination charts (Fazekas and Kósa 1978; Schaefer 2008). The raw measurements are listed in Appendix D.

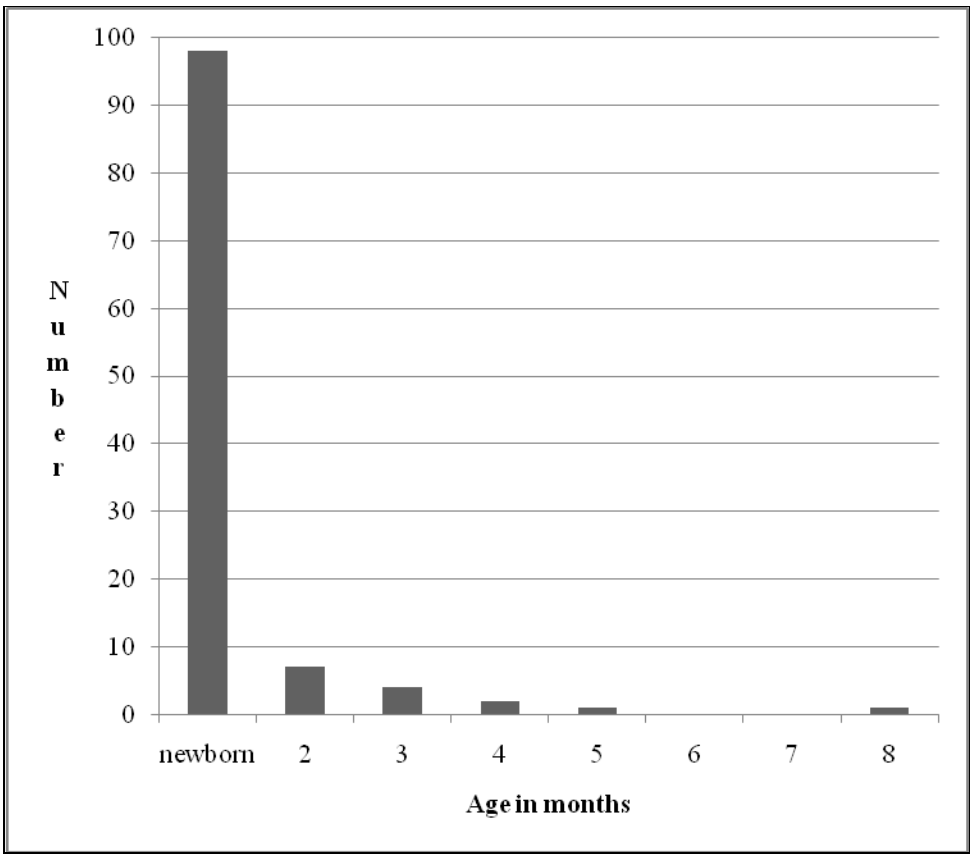


Figure 3.1. Number of individuals per age in the NMNH sample.

3.1.2 The Hamann-Todd Collection

For this study, only 37 out of 50 individuals within the subadult portion of the Hamann-Todd Collection (HTH) were suitable for examination. This subgroup consisted of 18 males and 19 females. The ages of these individuals ranged from one year to 16 years with the one year age category being the largest with nine individuals (Figure 3.2). The raw data for this collection are listed in Appendix E.

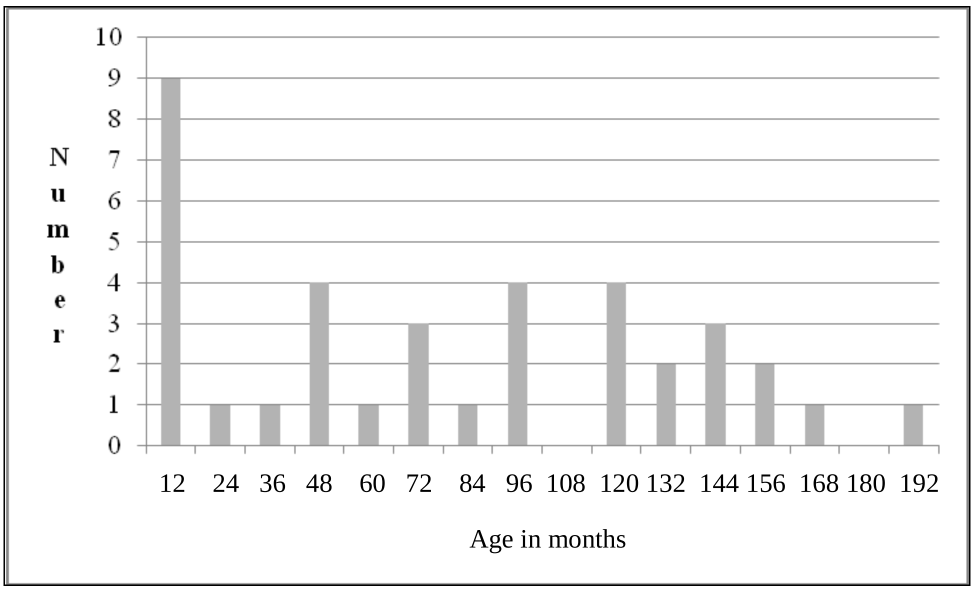


Figure 3.2. Number of individuals per age category in the HTH sample.

3.1.3 The Trotter Fetal Bone Collection

Of the 144 individuals available in the Trotter Fetal Bone Collection, 37 individuals were of an eligible age and condition for analysis. This sample consisted of 21 females and 16 males. Only those aged eight months *in utero* or older were considered for this study, as the bones of younger individuals were not developed enough for inclusion in this analysis. Age was confirmed through femoral length measurement to verify age with the exception of three individuals who lacked femora (Fazekas and Kósa 1978; Schaefer 2008). The ages for this group consisted of one month prenatal (eight months *in utero* to birth), newborn (birth to one month of age), and two months (Figure 3.3). The data collected for this sample is listed in Appendix F.

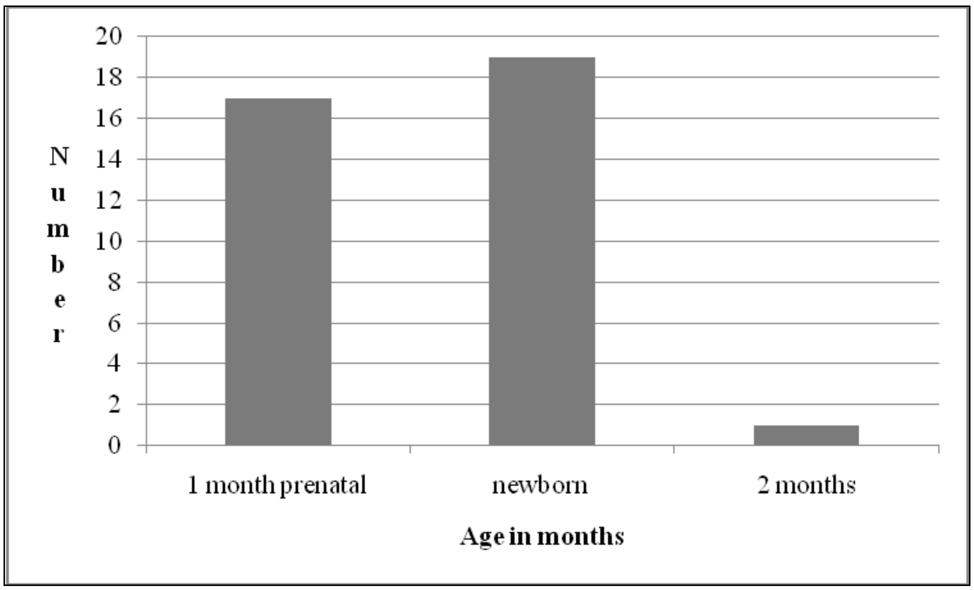


Figure 3.3. Number of individuals per age in the Trotter sample.

3.2 DESCRIPTIVE STATISTICS

The descriptive statistics for both males and females from the three samples were compiled for both direct and photographic measurements. Data for 13 measurements and five indices for both right and left sides were recorded for each individual (see Appendices C, D and E). Males and females were separated in the descriptive statistics to show differences in means and ranges between the sexes.

The data for all three samples were normally distributed ($p<0.05$). For the NMNH sample of 113 individuals, not all individuals were assessed for each measurement on both sides, so that some features displayed fewer than 226 results. The descriptive statistics are provided below in Tables 3.1 and 3.2. Both the HTH and the Trotter samples were composed of 37 individuals, and were evaluated for both right and left sides in the same fashion as the NMNH sample. Descriptive statistics followed a very similar pattern as the NMNH sample. The descriptive statistics are provided below in Tables 3.3 and 3.4 for the HTH sample and Tables 3.5 and 3.6 for the Trotter group.

When comparing the descriptive statistics for these samples, it should be noted that the measurements related to the length of an element or bone were much different in the HTH sample. This is a reflection of the sample make-up, as the HTH sample contains older children with much larger bones. Nevertheless, the angle measurements were very similar in range and did not vary much between the populations. Indices also showed similar ranges between collections. Overall, the sciatic notch and subpubic angles were larger in photographic measures than in direct measurements and lengths were longer for the direct method when compared to the photographic analysis for the three samples.

3.3 VISUAL ANALYSIS

Those features typically utilized in macroscopic analysis to determine sexual dimorphism, the sciatic notch angle, sciatic notch shape, and arch criterion, were evaluated utilizing Schutkowski's (1993) methodology. The auricular surface elevation was assessed using both Weaver's (1980) and Hunt's (1990) binary method as well as the ranked method developed by Mittler and Sheridan (1992) and used by Sutter (2003). For these analyses, both right and left sides were scored, potentially doubling the number of individual measurements obtained from each collection.

3.3.1 Sciatic notch angle

The sciatic notch angle represented the angle created from each of the two maximum breadth points of the sciatic notch to the apex of the notch. Those individuals with a 90° angle or less are considered to be male while those with a greater than 90° angle are deemed female.

For the NMNH material direct analysis, the majority of the sciatic notch angles fell into the over-90° category, as only 23% of males were assessed at 90° or below (Table 3.7). Sixteen individuals were evaluated at 90°, and of these 43.8% were confirmed to be male. Half of those observed at over 90° were male and many of these had angles greater than 110°. In total, only 51.4% of individuals were correctly identified for sex through this visual appraisal method and no clear sex determination pattern was detected.

Photographic analysis differed dramatically from what was seen in the dry bone evaluation, as no sciatic notch angles were measured at or below 90° (Table 3.8). The male measurement ranged from 99° to 144°, while females exhibited a slightly smaller range of 101° to 140°.

For the HTH material using the direct visual assessment, the binary categorization of this notch was no more clear-cut than in the NMNH population (Table 3.9). Only 42% of the sample was correctly sexed. While nearly 90% of the individuals had sciatic notch angles greater than 90°, only 45% of this group represented females. Five of the males (14%) were between 91° and 95°, but were still considered greater than 90°. Furthermore, those individuals with fused pelvic bones (n=5) displayed small sciatic notch angles, most less than 90°, and all were female. Therefore, the visual assessment with this group was problematic. Results similar to the NMNH photographic group were observed in the photographic analysis for the HTH sample, with no individuals at or below the 90° level (Table 3.10).

The pattern generated from the Trotter material differed from that seen in either the NMNH or HTH samples (Table 3.11). Approximately 56% of the Trotter group had sciatic notch angles of 90° or less. Using direct bone evaluation, 61% of males and 48% of females were correctly sexed, which was the highest percent correct for the three groups. Photographic study revealed a pattern similar to the other two photographic analyses (Table 3.12), as each individual was categorized as being over 90°.

Graphic representations of for the three samples (Figures 3.4, 3.5, and 3.6) showed the distribution of the angles between males and females. For the NMNH and Trotter samples, males show a wider distribution of angles than females, with the reverse for the HTH sample. The three samples exhibited an overlap between males and females, with no definitive segregation between males and females in any of the analyses.

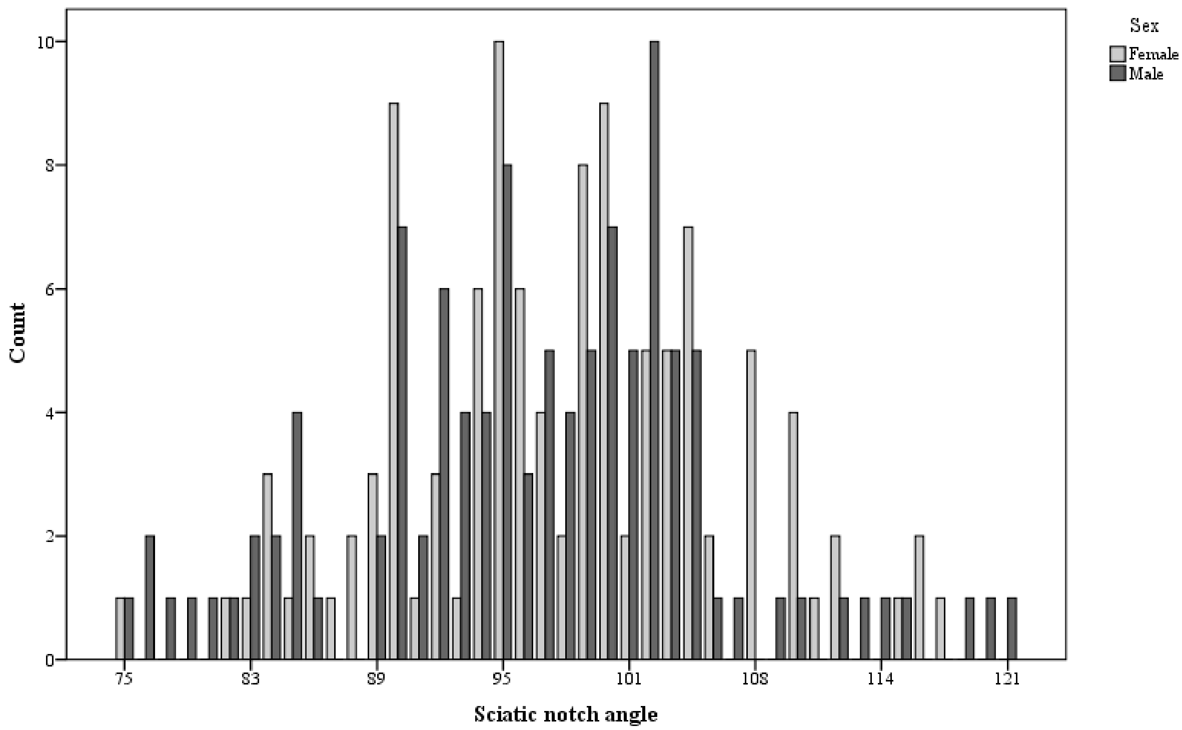


Figure 3.4. NMNH direct method sciatic notch angle widths in degrees for males and females

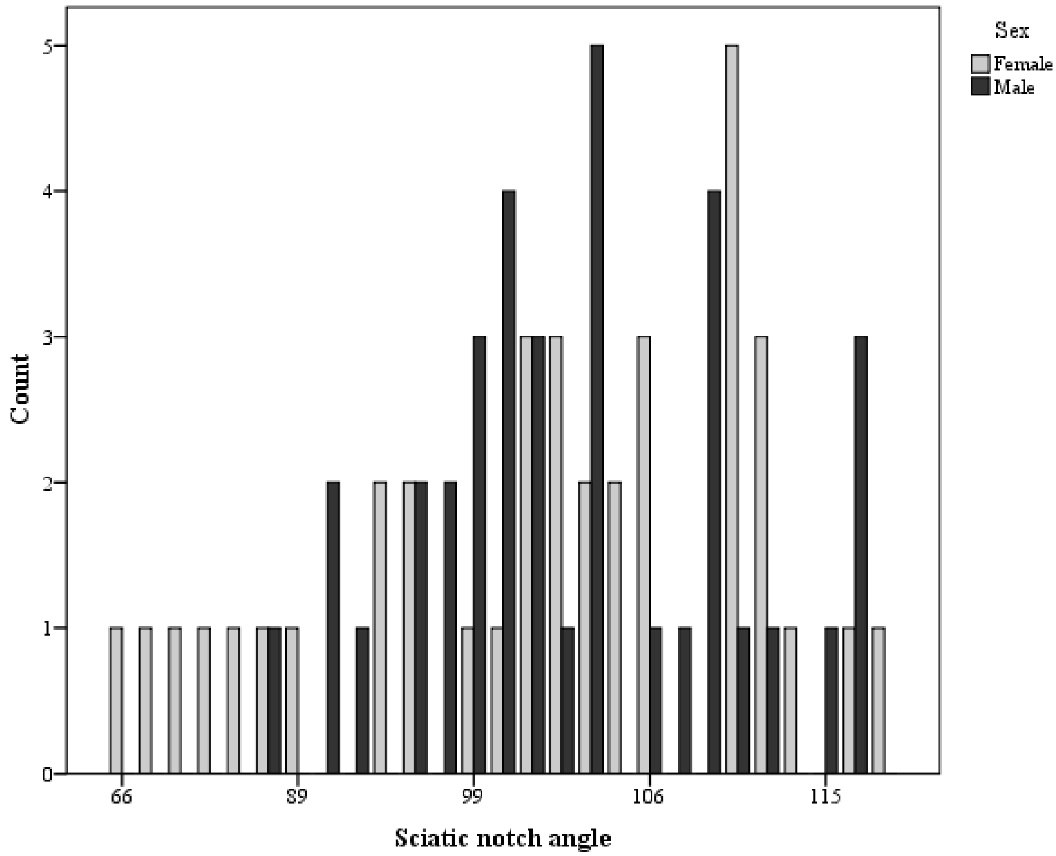


Figure 3.5. HTH direct method sciatic notch angle widths in degrees for males and females

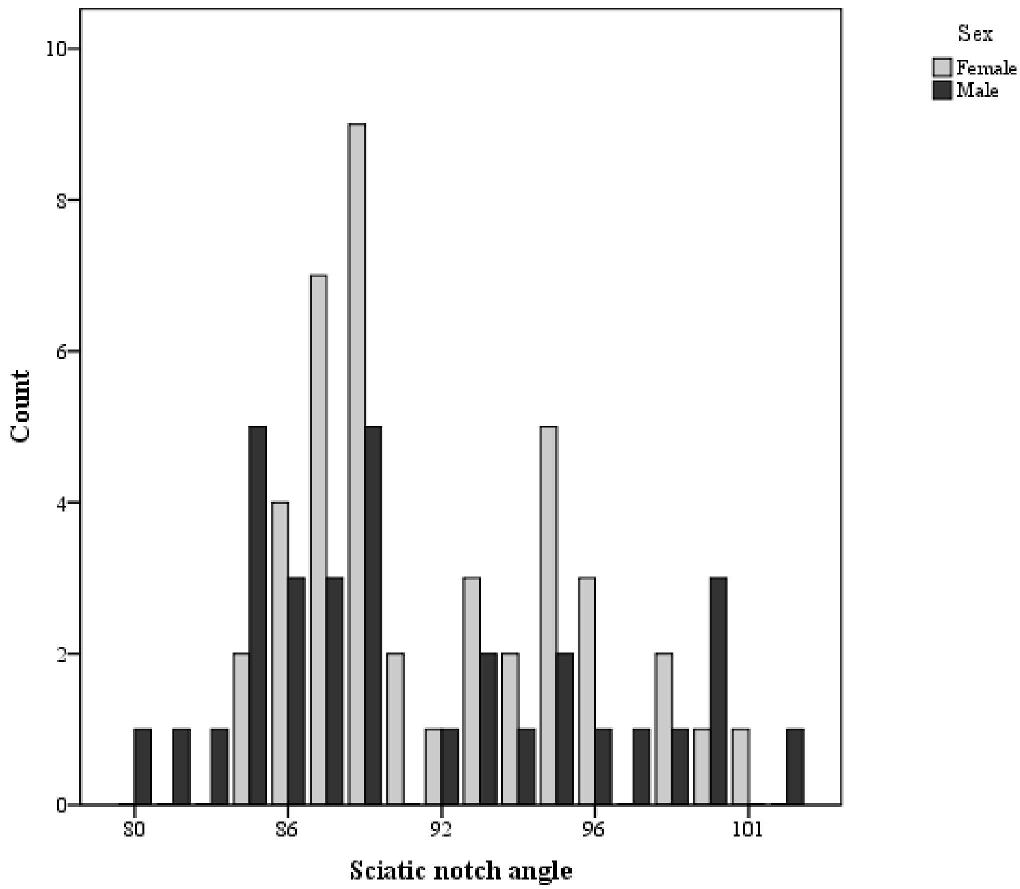


Figure 3.6. Trotter direct method sciatic notch angle widths for males and females

3.3.2 Sciatic notch shape

The shape of the sciatic notch was evaluated visually as either asymmetric or symmetric. The asymmetric form is argued to indicate male while the symmetric form indicated female. For the NMNH direct sample, 64% of individuals demonstrated the asymmetric form, but of these, only 47% of these were actually male (Table 3.13). In total, only 45% of individuals were correctly assigned to sex. Photographic analysis also showed a high number of individuals with the asymmetric form, with the majority (54%) being female (Table 3.14). Overall accuracy levels were found to be 44%, similar to what was obtained through direct evaluation of this feature. Within the NMNH sample, only 30% of males and 15% of females were correctly assigned for direct measures and 34% of males and 9% of females for photographic analysis.

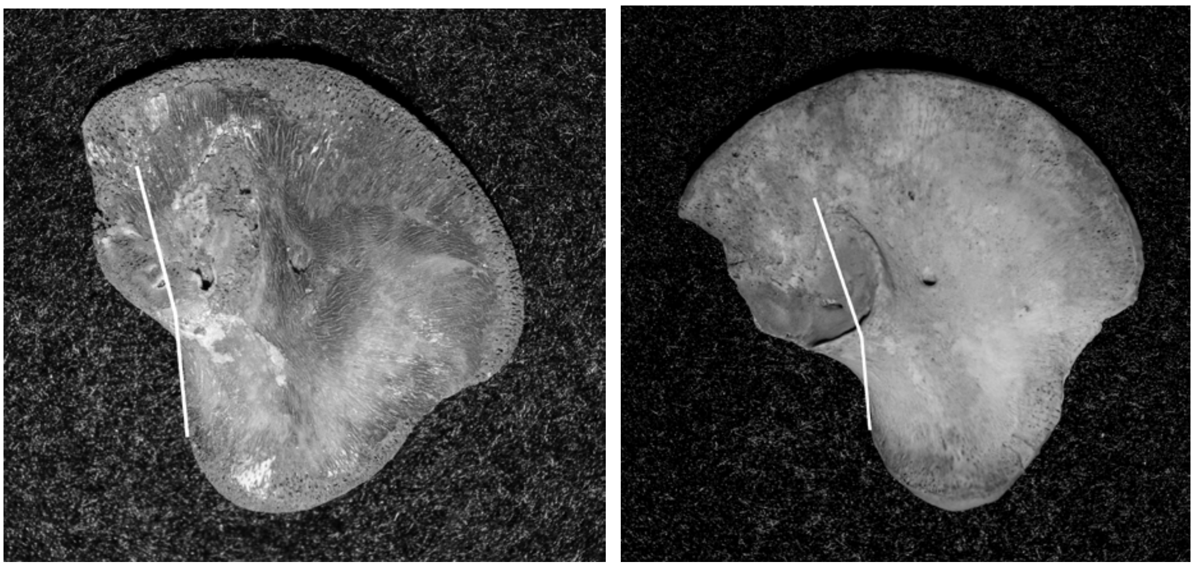
Direct and photographic analyses to determine symmetry for the HTH sample were identical to one another (Tables 3.15 and 4.16). The overall pattern was similar to that seen in the NMNH photographic examination, as the majority of those evaluated fell into the asymmetric category; however, the bulk of these individuals (54%) were in fact female. In the HTH direct and photographic assessments, the accuracy levels were 48% and 46% respectively. Only 35% of males and 10% of females in both direct and photographic measures were assigned to the correct sex.

The Trotter collection continued the trend observed in the other samples, with the majority of the individuals classified as asymmetric (Tables 3.17 and 3.18). A greater percentage of males in comparison to females were scored as symmetric for this trait in the direct analysis, which contrasts the current standards for sex determination for this trait (Rogers and Saunders 2003; Taylor and Dibennardo 1984). While males demonstrated an exceptionally high accuracy level (81%), females were correctly placed only 5% of the time. The photographic assessment varied diametrically with more individuals considered symmetric. More females were correctly assigned using the photographic method (65%), but male accuracy levels fell to 58%.

3.3.3 Arch criterion

The arch criterion evaluated an arch running along the anterior sciatic notch, following it onto or above the auricular surface of the ilium for female or male forms respectively. Much variation was found with this feature. As can be seen below, the arch can pass along the low end

(Figure 3.7A) or high end of the center portion of the auricular surface (Figure 3.7B) as well as the low end of the "top" of the auricular surface (Figure 3.7C) or well beyond the anterior rim of the auricular surface (Figure 3.7D). These four images represent the variation found in all three groups analyzed. This feature proved to be a poor tool for sex determination in this study.



3.7A Arch passes low "center" **3.7B** Arch passes high "center"

3.7C Arch passes low "top" **3.7D** Arch passes beyond "top"

Figure 3.7. Variation in arch criterion, as the arch crosses different places along the auricular surface

For the NMNH sample evaluated in the direct manner, 50% of those assessed as females were indeed female, while 49% of those judged as males were indeed male (Table 3.19). Results obtained using the NMNH photographic method differed from the direct approach, with 78% of individuals showing the female form despite the fact that males accounted for nearly half of the individuals (Table 3.20). This result shows a drastic shift from the more balanced distribution of this trait in direct analysis.

For the HTH sample, 50% of those assessed as female were actually female, while only 41% of those assessed as male were in fact males for direct measures (Table 3.21). Photographic techniques provided a higher percentage of accuracy for females (55%), but there was no change in the percentage for males (Table 3.22). Overall, individuals were designated as females the majority of the time, in both direct and photographic analysis.

For the Trotter sample, direct evaluation of the arch criterion revealed the majority of individuals to be in the male form, which differed from results of the other two samples (Table 3.23). Approximately 50% of the individuals were correctly assessed. The reverse was evident in the photographic analysis, as the bulk of the individuals (65%) exhibited the female form (Table 3.24). However, this reversal did not greatly change the outcome, as 52% were assigned correctly to sex.

3.3.4 Auricular surface elevation

Auricular surface elevation analysis was conducted in two manners. The first considered no elevation as indicating male and any elevation as female. The second method scored the state of each individual side based on the number of raised sides, so that zero and one were considered male, three and four were female, with two considered an indeterminate ranking. In analyzing the NMNH material, the first method produced 94 males (44%) and 70 females (33%) in the not raised category, with sex correctly assigned only 50% of the time. The second method's findings are outlined in Table 3.25. With this method, 58% of males and 45% of females were selected correctly, with 23% of individuals falling into the indeterminate range. Photographic analysis revealed a similar breakdown for males, however, females displayed a greater percentage of not raised individuals and much fewer in the raised category (Table 3.26). These individuals were less likely to be correctly sexed, as only 51% of males and 23% of females were assigned to the proper sex. However, fewer individuals fell into the indeterminate range (Figures 3.8 and 3.9). These findings were the opposite of what was expected for this trait based on previous studies (Sutter 2003; Weaver 1980).

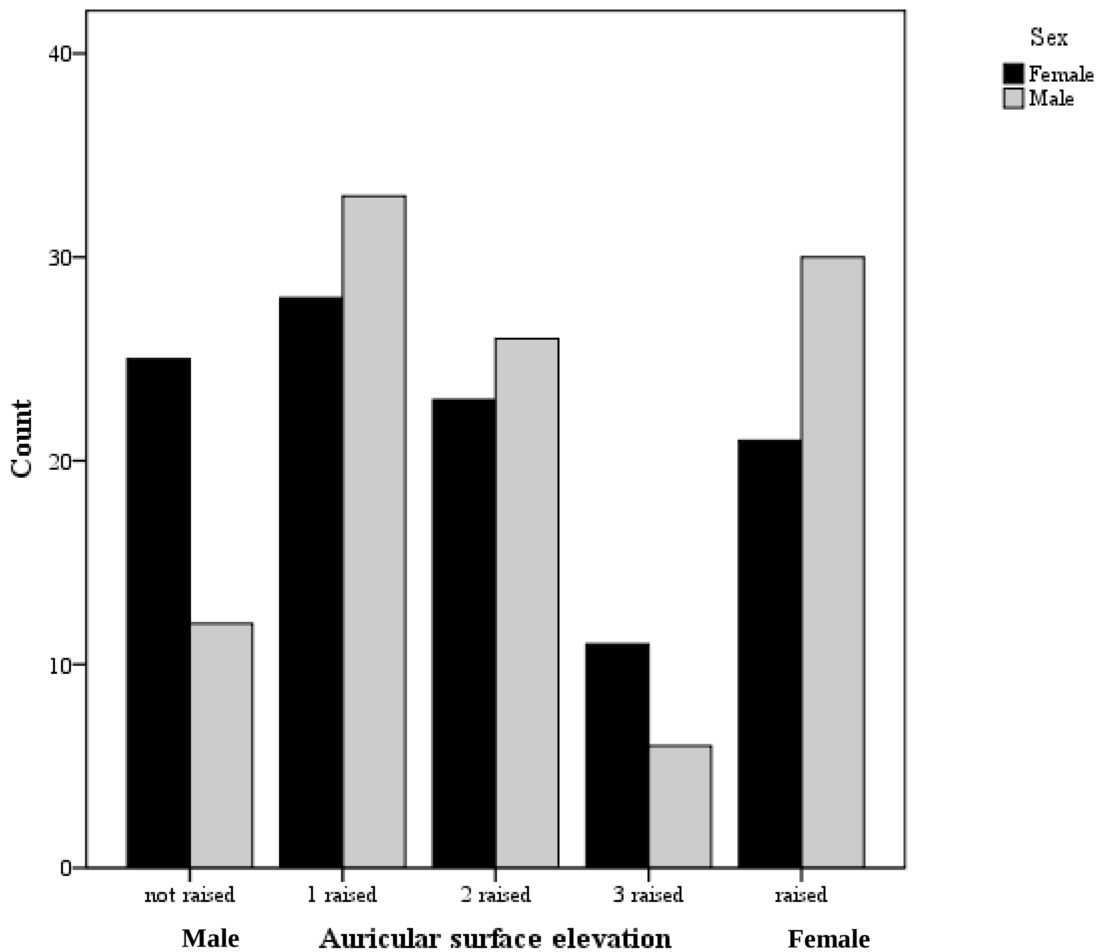


Figure 3.8. NMNH Direct auricular surface analysis based on method #2

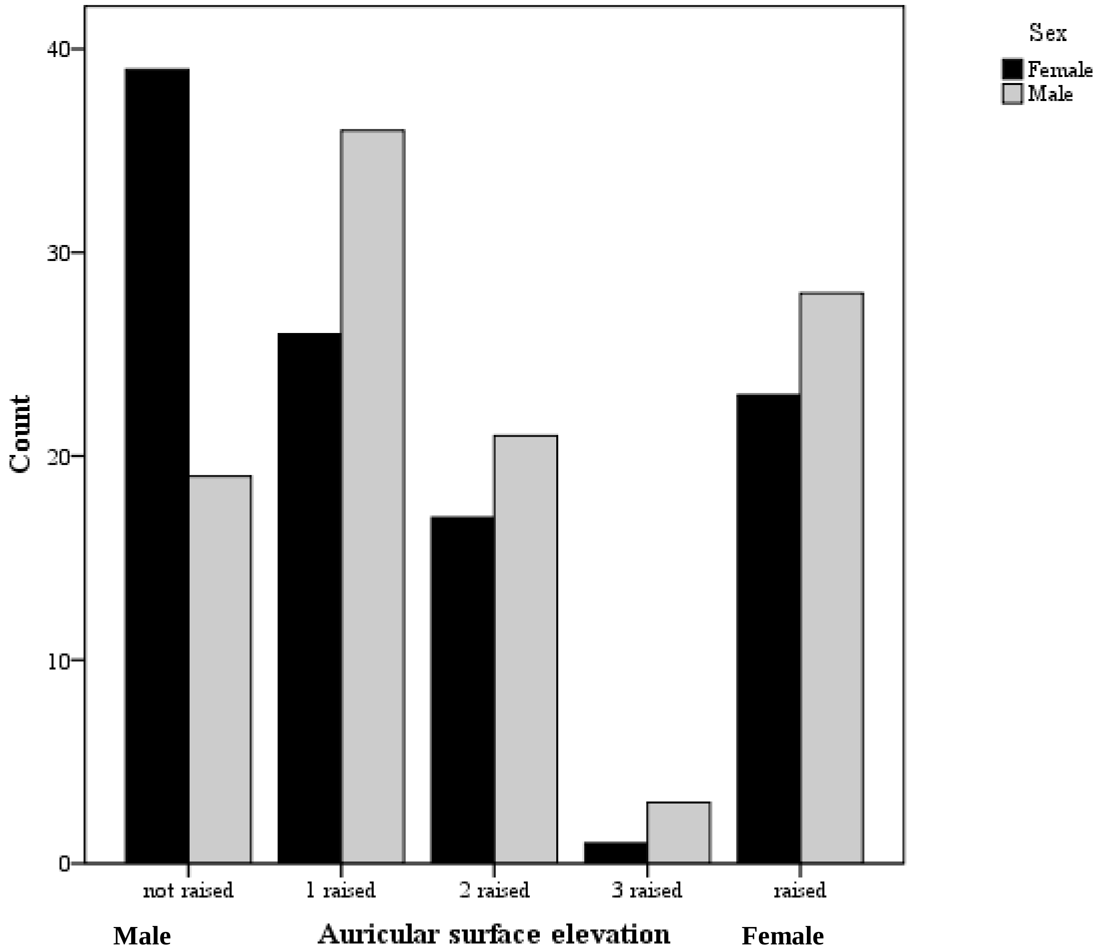


Figure 3.9. NMNH Photographic auricular surface analysis based on method #2

In analyzing the HTH material, males were more likely to not be raised in both direct and photographic analyses (Tables 3.27 and 3.28). Fewer females fell into the not raised category for the direct method, but not in the photographic analyses. Males were correctly identified 58% of the time in direct and 75% in photographic examinations. Females were less identifiable as 50% in direct and only 14% in photographic analyses were correctly assigned. The direct measurement method revealed far more individuals in the indeterminate range than was seen in the photographic evaluation. This distribution is illustrated in Figures 3.10 and 3.11.

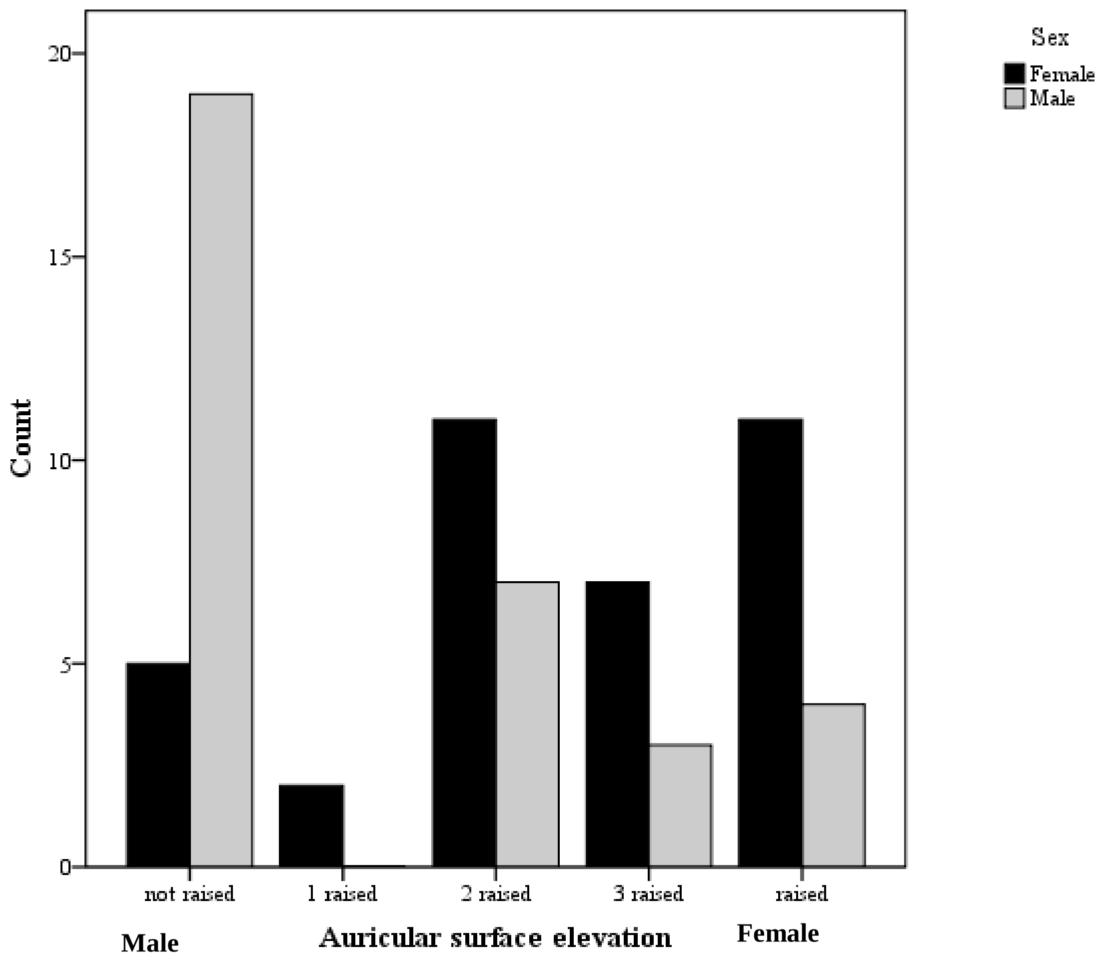


Figure 3.10. HTH Direct auricular surface analysis based on method #2

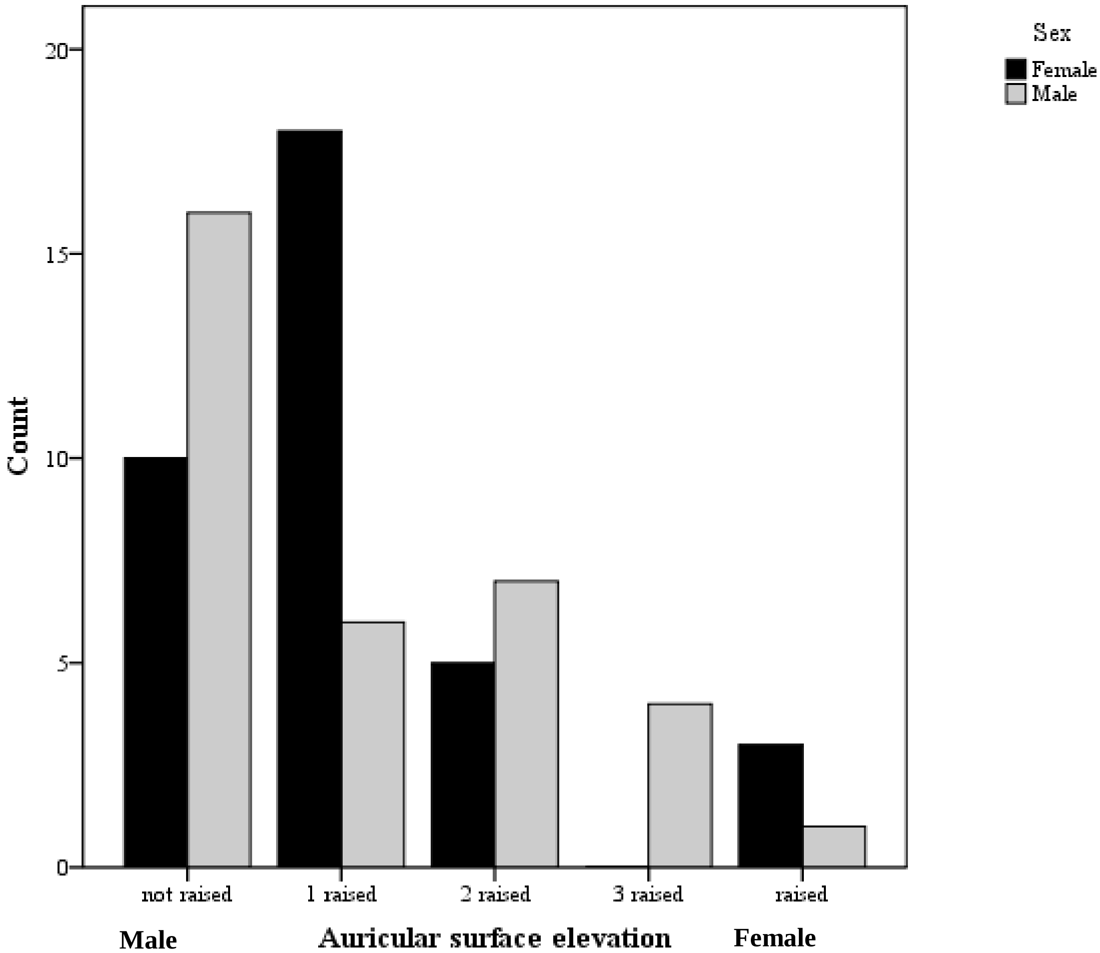


Figure 3.11. HTH photographic auricular surface analysis based on method #2

The results of the auricular surface analysis for the Trotter sample using the direct method differed from those of the previous two samples. Less than 10% of individuals displayed a raised auricular surface state, regardless of sex (Table 3.29). While 68% of males were correctly assigned, only 14% of females were accurately identified. In the photographic analysis, more individuals were found in a raised state, but this did not alter the overall accuracy of this result much (Table 3.30). While females are accuracy levels increased (48%), male accuracy dropped considerably (39%). No clear pattern of distribution was discerned from the corresponding graphs (Figures 3.12 and 3.13).

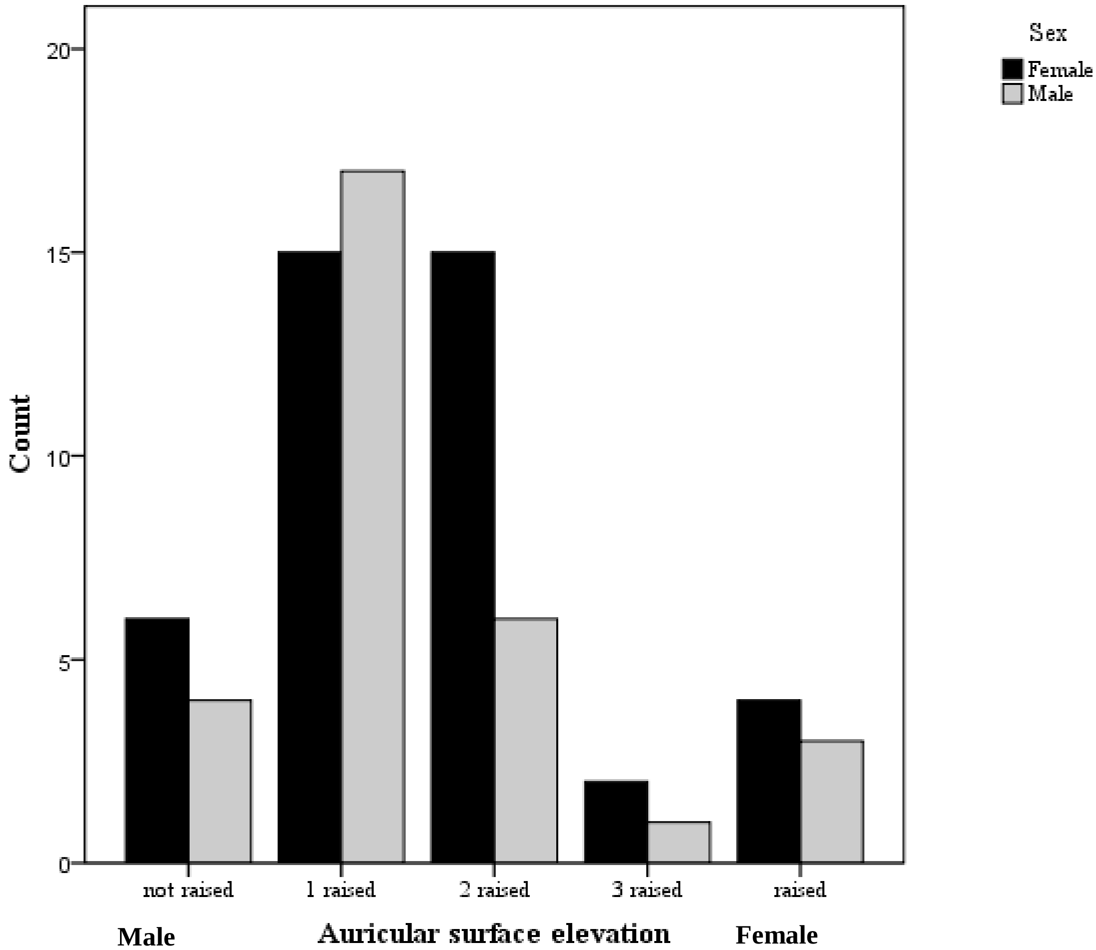


Figure 3.12. Trotter direct auricular surface analysis based on method #2

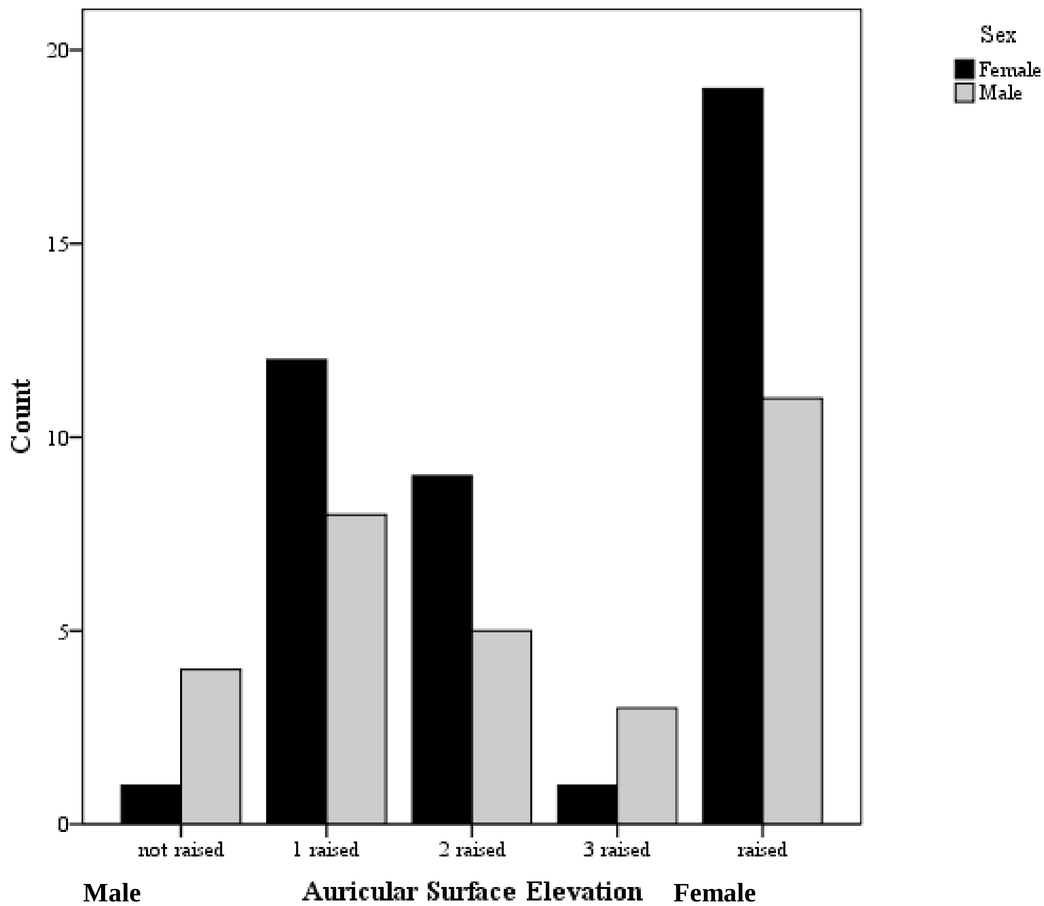


Figure 3.13. Trotter photographic auricular surface analysis based on method #2

3.4 PAIRED BONE ANALYSIS

For those variables whose means did not differ significantly, right and left sides were pooled and these results were analyzed. When the means did not suggest that the right and left sides were from the same population, these sides were not pooled for analysis. Paired t-tests, correlations, and Wilcoxon-Sign tests were conducted on the right and left pooled measurements and the results of each test were compared with one another.

The right and left side evaluations in the NMNH sample correlated at the .001 statistical significance level for both direct and photographic measures (Table 3.31). For both methods, scatterplot graphs showed a good line fit for most measurements, with the length measurements presenting a particularly good fit as is seen in the graph for the iliac length (Figure 3.14). Indices, on the other hand, showed a poor line fit. The ischio-pubic index is a good example of this (Figure 3.15). T-test results for the direct analysis method showed the following as non-significant: sciatic notch angle, sciatic notch width, iliac length, ischial length, and subpubic angle (Table 3.32). However, sciatic notch depth, pubic length, pubic width, anterior sciatic notch length, posterior sciatic notch length, sciatic notch index, pubic index, and ischio-pubic index were all statistically significant, suggesting that a difference between the mean values of the two samples. For photographic measures, only the sciatic notch angle and anterior sciatic notch differed at a statistically significant level, with all other measurement means indicating they were from the same population. Results from the Wilcoxon Sign tests for both direct and photographic measurements were similar to the t-tests.

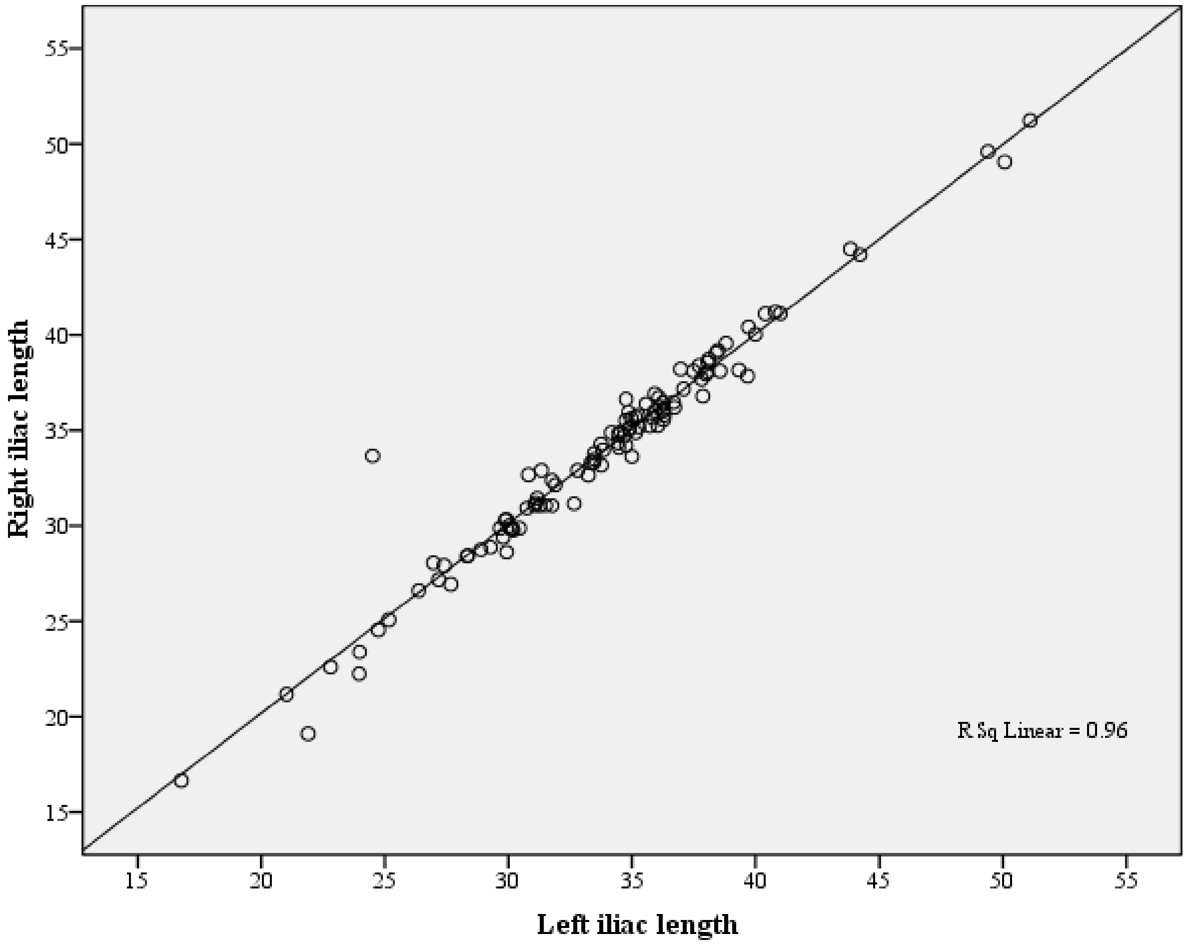


Figure 3.14. NMNH right and left direct iliac measurements in mm

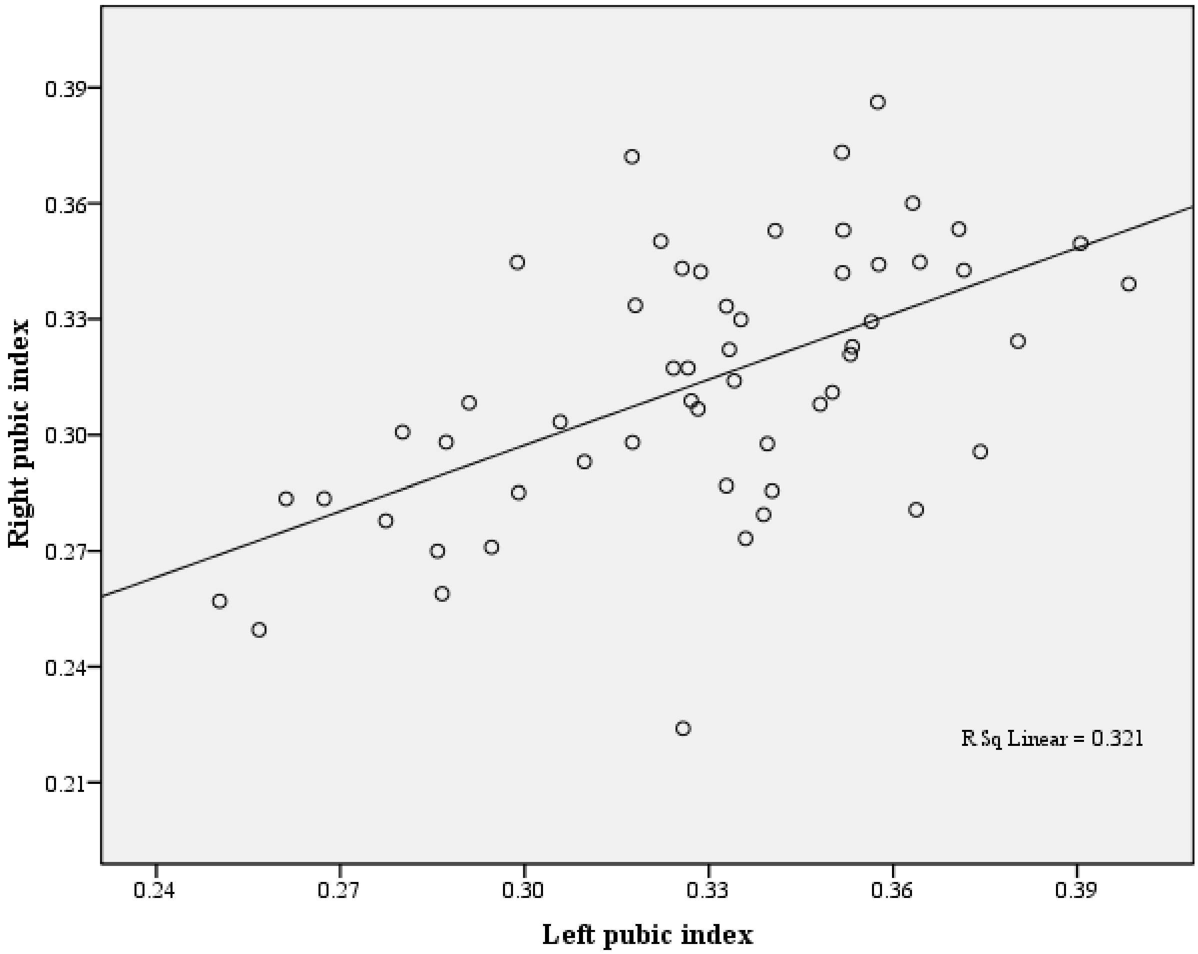


Figure 3.15. NMNH right and left direct pubic index measurements in mm

The right and left sides in the HTH sample correlated at the 0.001 statistical significance level for both direct and photographic measures (Table 3.33). Similar to the NMNH findings for both methods, scatterplot analyses revealed length measurements were a particularly good fit, but indices fitted poorly (Figures 3.16 and 3.17). T-test results for the direct method showed the following as not reaching a level of statistical significance: sciatic notch angle, sciatic notch width, sciatic notch depth, ischial length, subpubic angle, pubic body width, and anterior sciatic notch (Table 3.32). However, differences between the means for the two samples for the iliac length, and posterior sciatic notch length were all statistically significant. For photographic measures, only the anterior sciatic notch differed at a statistically significant level, with the other measurement means signifying that they were from the same population. The Wilcoxon Sign tests for both direct and photographic methods were identical to the t-tests.

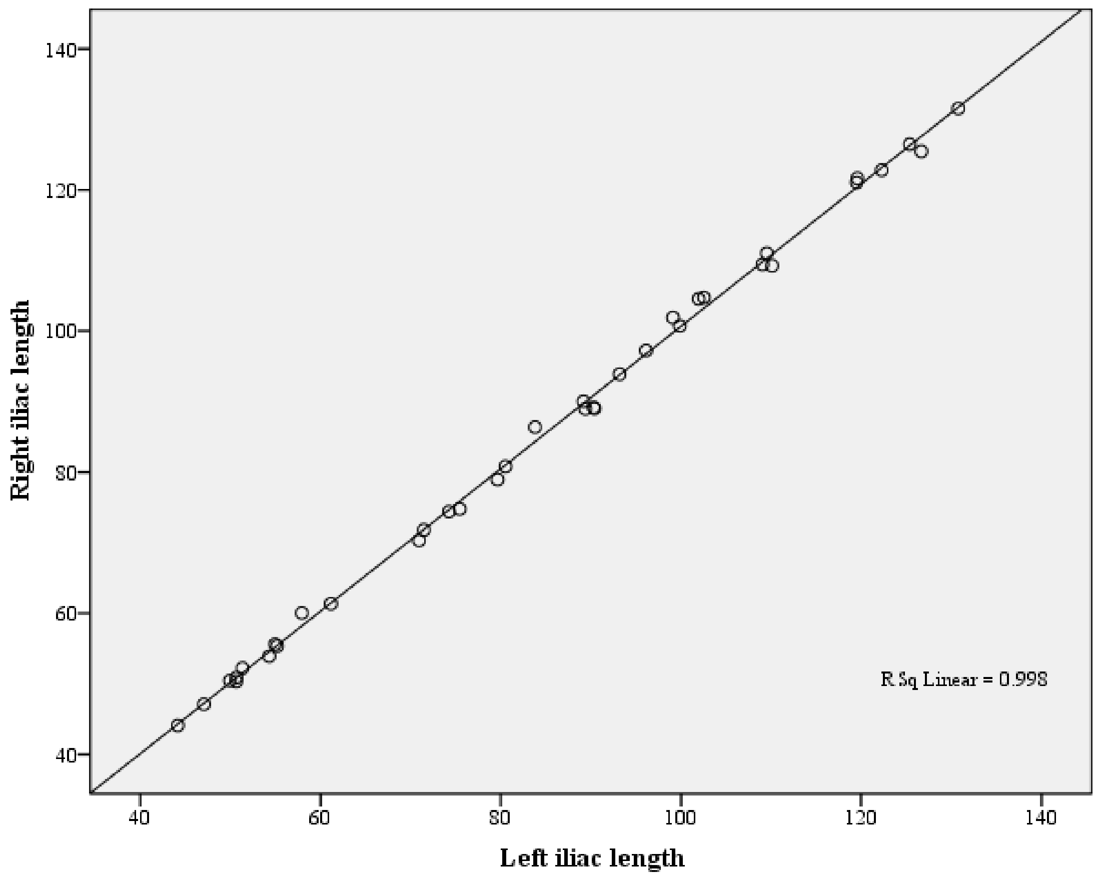


Figure 3.16. HTH right and left direct iliac measurements in mm

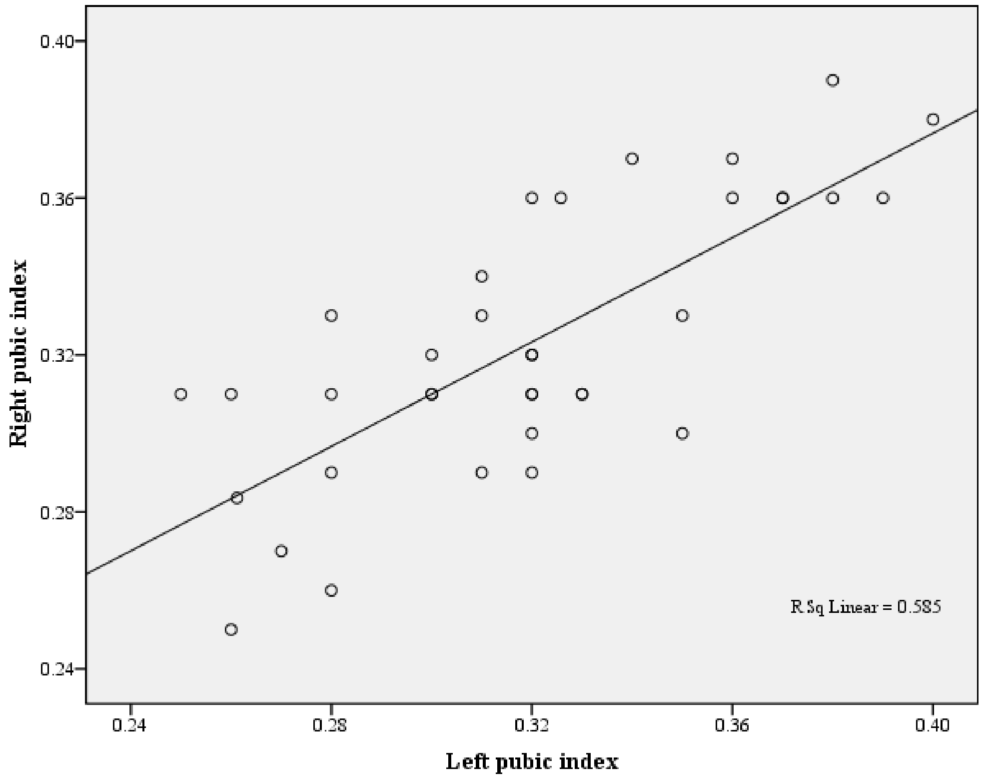


Figure 3.17. HTH right and left direct pubic index measurements in mm

For the Trotter collection, the direct and photographic measures were not at the 0.001 statistical significance levels as found in the previous studies, with the subpubic angle for both methods and the pubic index for direct method not reaching statistical significance (Table 3.34). When evaluated for paired t-tests for direct analysis, the sciatic notch angle, anterior sciatic notch length, subpubic angle, and pubic width were statistically significant (Table 3.32). The Wilcoxon Sign tests showed similar results as the t-test, except that the anterior sciatic notch did not reach a statistically significant level (0.088 and 0.884 respectively), but the posterior sciatic notch was found to be statistically significant at 0.001. Photographic analysis showed no differences between the sexes using a t-test (Table 3.32).

3.5 INTRAOBSERVER ERROR

Ten percent of each sample was selected at random to check for intraobserver error. Each measurement was re-taken independently and assessed using reliability analysis intraclass correlation. It should be noted that of the evaluations, the subpubic angle did not meet the .80 threshold for direct measurements. Due to the randomness of the selection process, fewer than half of those within the intraobserver sample were able to be appraised for this trait; therefore, too few individuals were available to adequately analyze this trait. The remaining measurements within the NMNH and HTH met the .80 threshold. The problem of sample size also affected the Trotter intraobserver group, but of those features with at least ten measurements available, the threshold of .80 was met.

3.6 GRAPHIC ANALYSIS

Graphs were created for several assessments. Primarily, boxplots were utilized to illustrate how closely measurements aligned. This can be seen in Figure 3.18, which compares the right and left sides of NMNH iliac lengths. Graphic analysis demonstrated clearly how many of the features were sexually dimorphic in nature, but that overlaps between the sexes occurred. This overlap presents an obstacle to developing functional sex determination methods from these traits. For example, the following graphs are from the HTH direct measurements and reflect the sciatic notch width, pubic body width, and iliac/sciatic notch index respectively (Figures 3.19, 3.20 and 3.21).

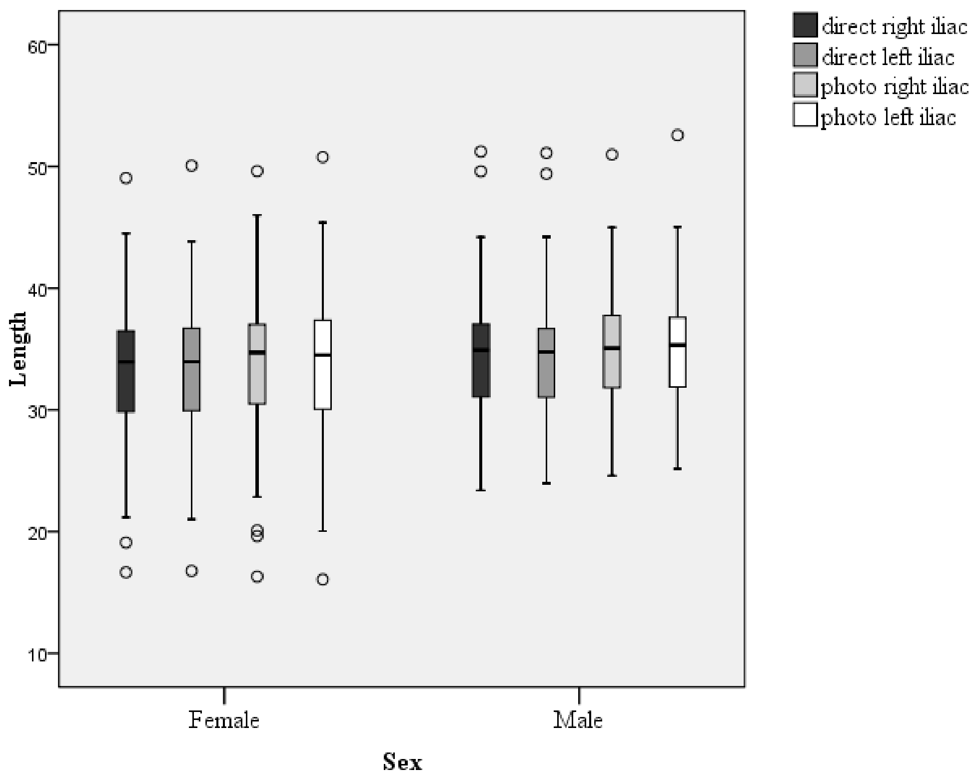


Figure 3.18. NMNH direct versus photographic measures of right and left iliac length (mm) for males and females.

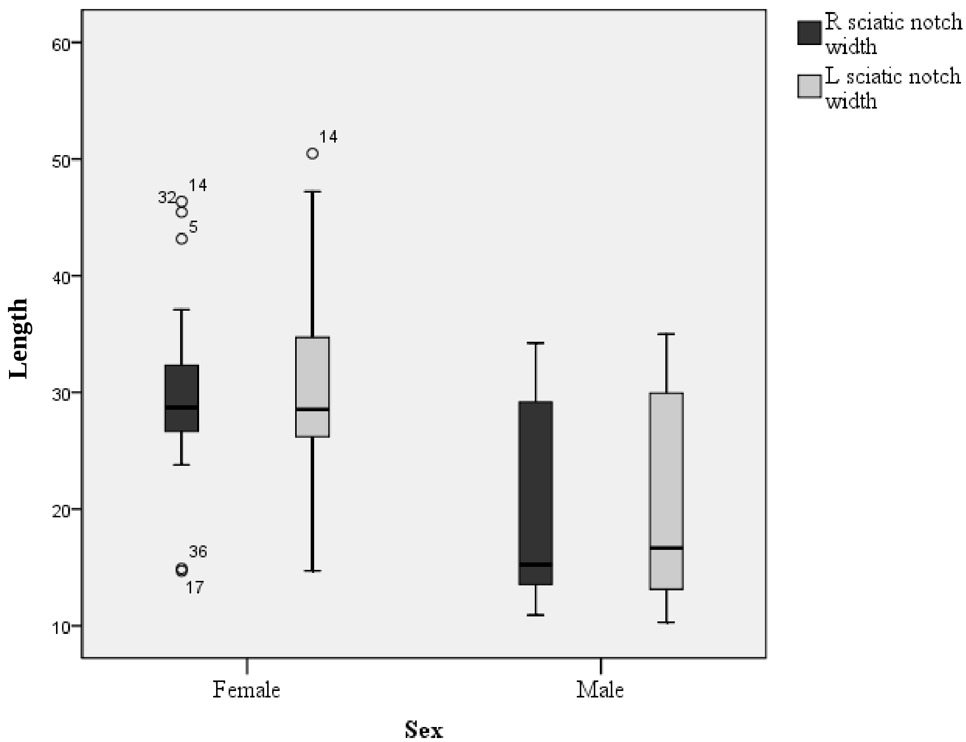


Figure 3.19. HTH right versus left sciatic notch width (mm) for males and females

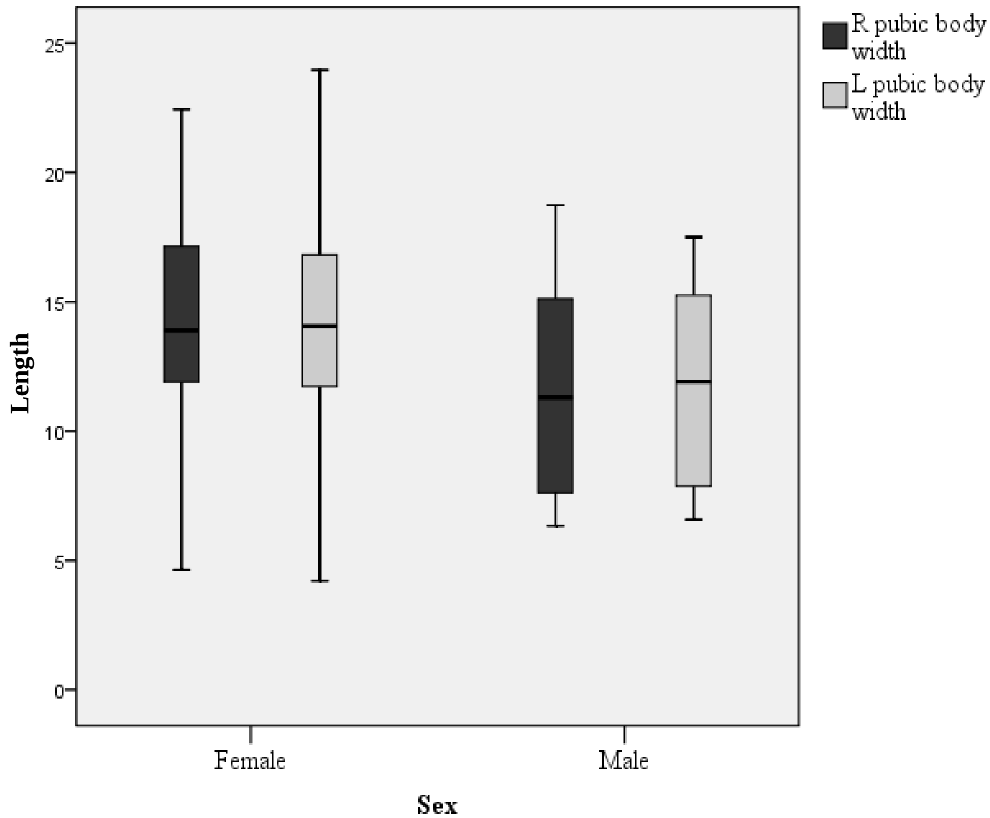


Figure 3.20. HTH right and left side pubic body width measurements (mm) for females and males

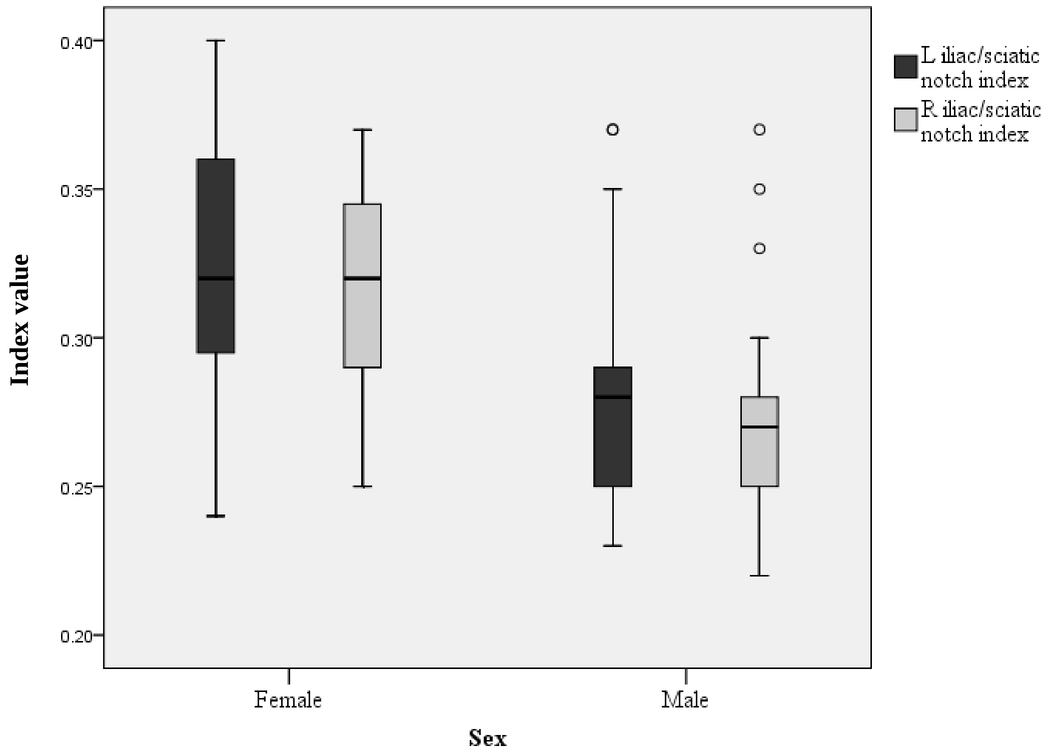


Figure 3.21. HTH iliac/sciatic notch index for right and left sides for females and males

Age differences were analyzed using scatterplots. The NMNH direct pooled comparisons of iliac, pubic, ischial lengths and pubic width with age were outlined in Figures 3.22 for females and Figure 3.23 for males. For the HTH sample, females were listed in Figure 3.24 and males in Figure 3.25, and for the Trotter sample, females were listed in Figure 3.26 and males in Figure 3.27. As expected, overall size of these bones does increase with an increase in age, with iliac length showing the greatest increase in size, and the pubic length showing the least amount of growth. This was consistent for the three samples. For the three samples, pubic body width, sciatic notch width, and sciatic notch depth were reviewed (Figures 3.28, 3.29, 3.30, 3.31, 3.32 and 3.33). No easily recognizable pattern was evident for the three groups. The Trotter group results showed smaller differences over the ages than the other two groups, but this was likely due to the small age range present.

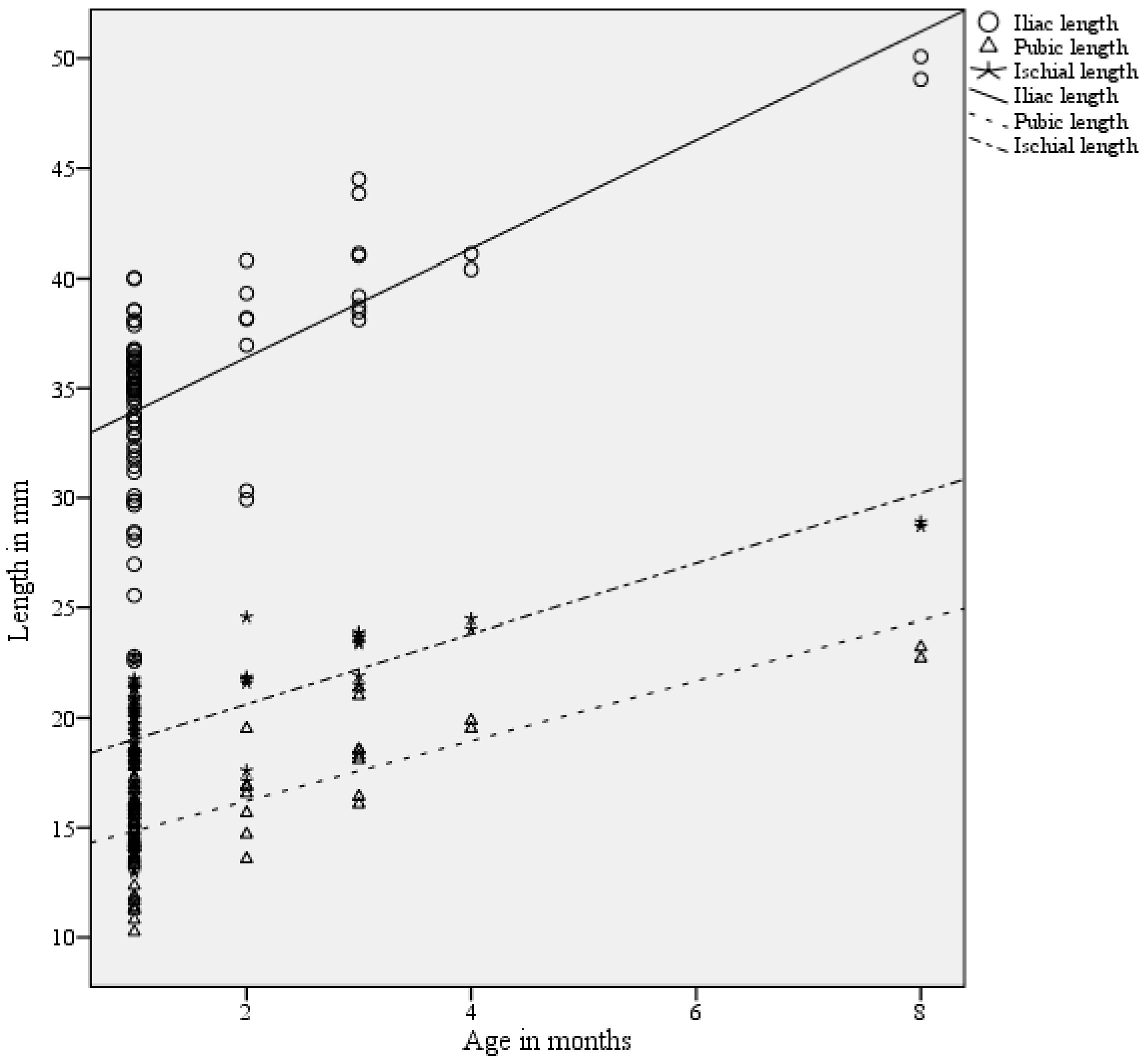


Figure 3.22. NMNH age compared to iliac, pubic and ischial lengths for females.

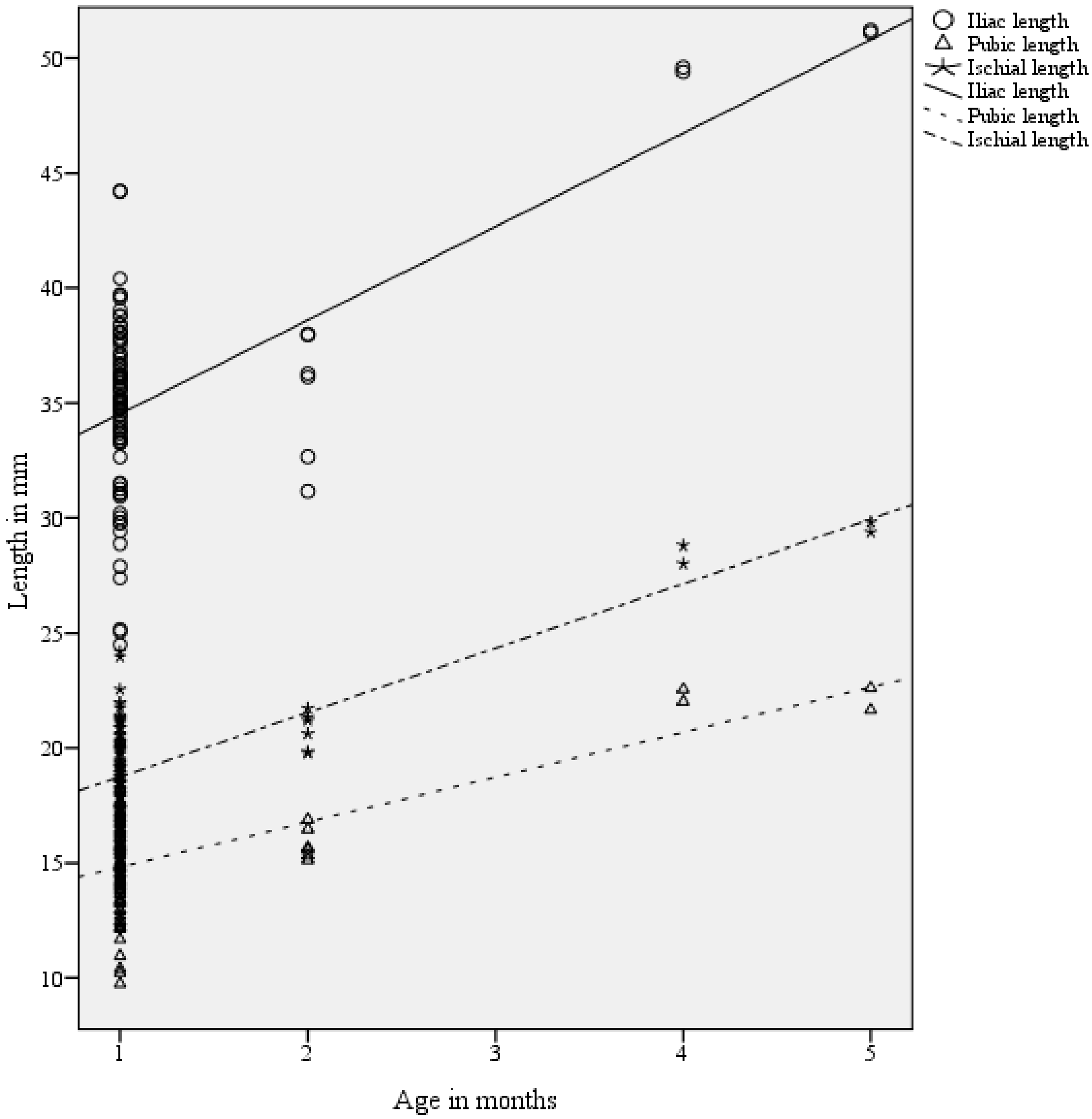


Figure 3.23. NMNH age compared to iliac, pubic and ischial lengths for males.

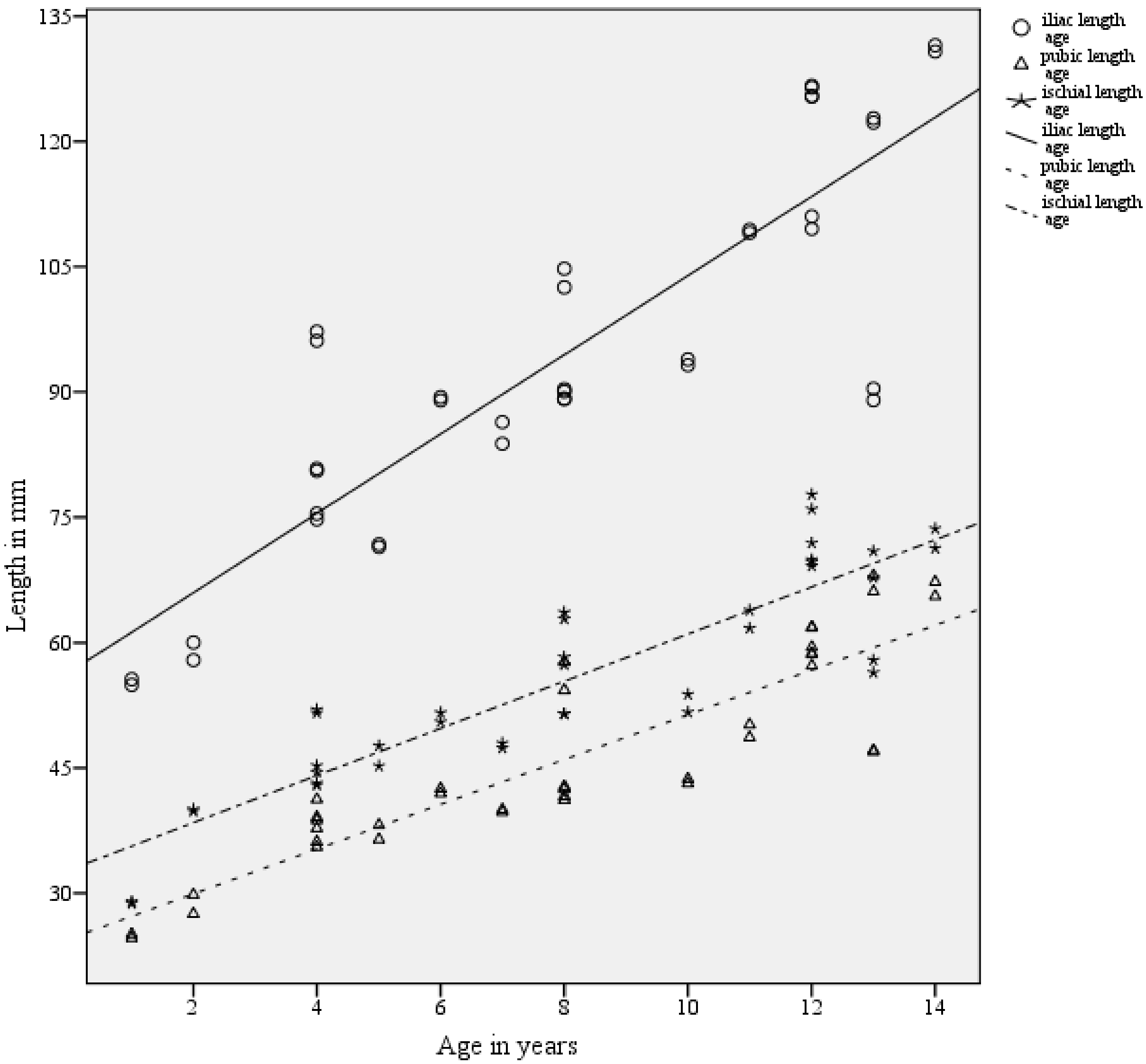


Figure 3.24. HTH age compared to iliac, pubic and ischial lengths for females.

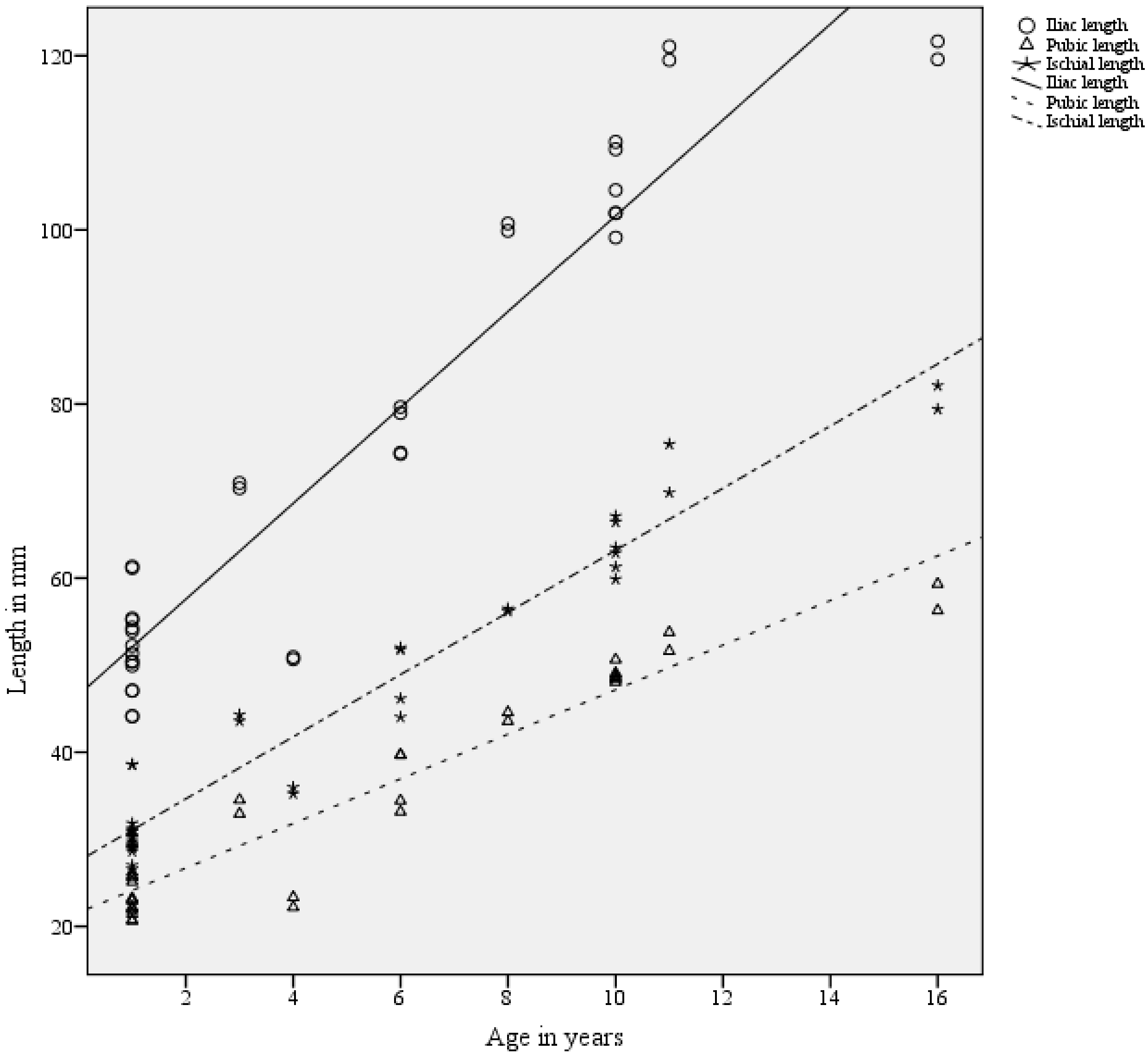


Figure 3.25. HTH age compared to iliac, pubic and ischial lengths for males.

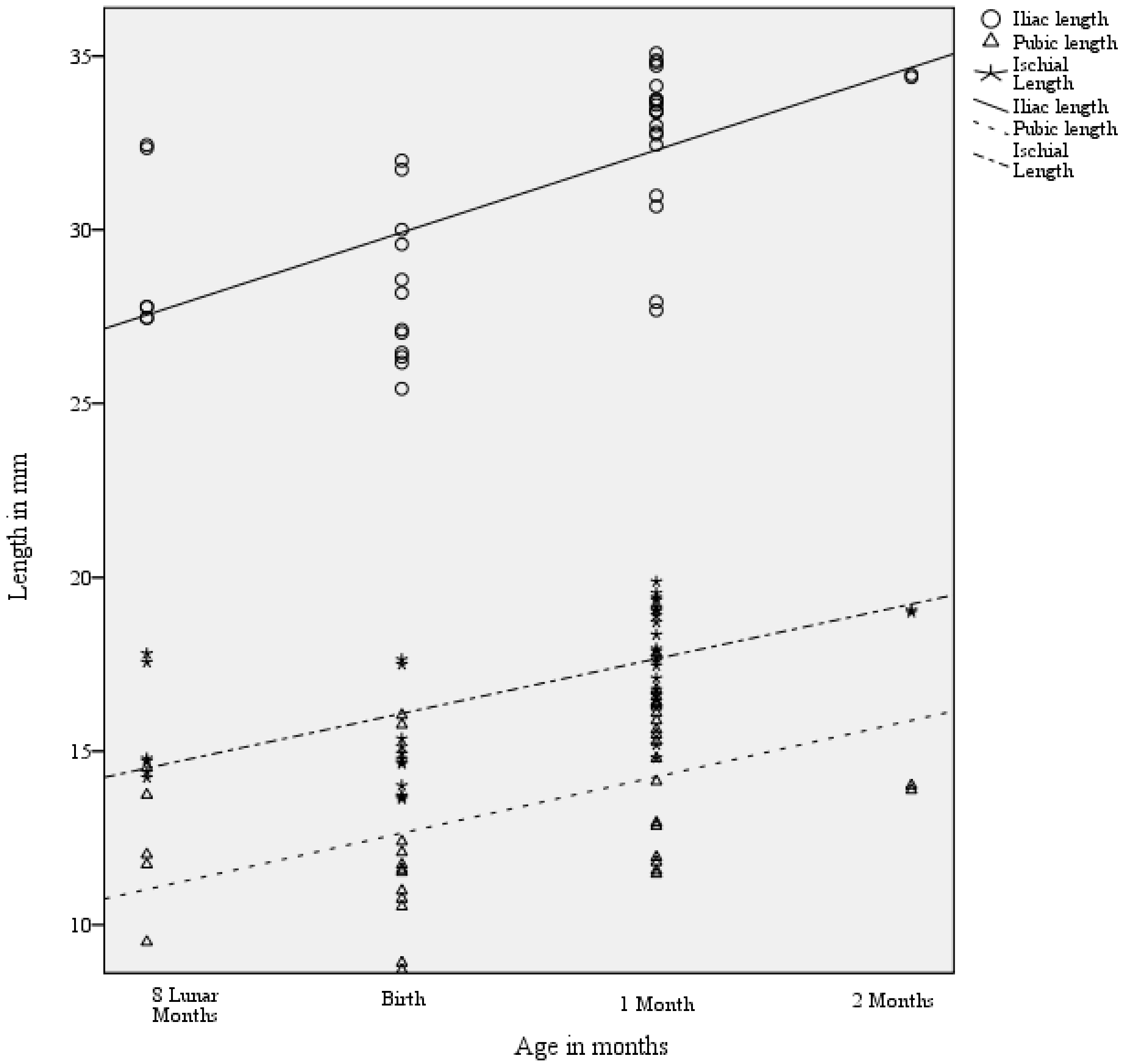


Figure 3.26. Trotter age compared to iliac, pubic and ischial lengths for females

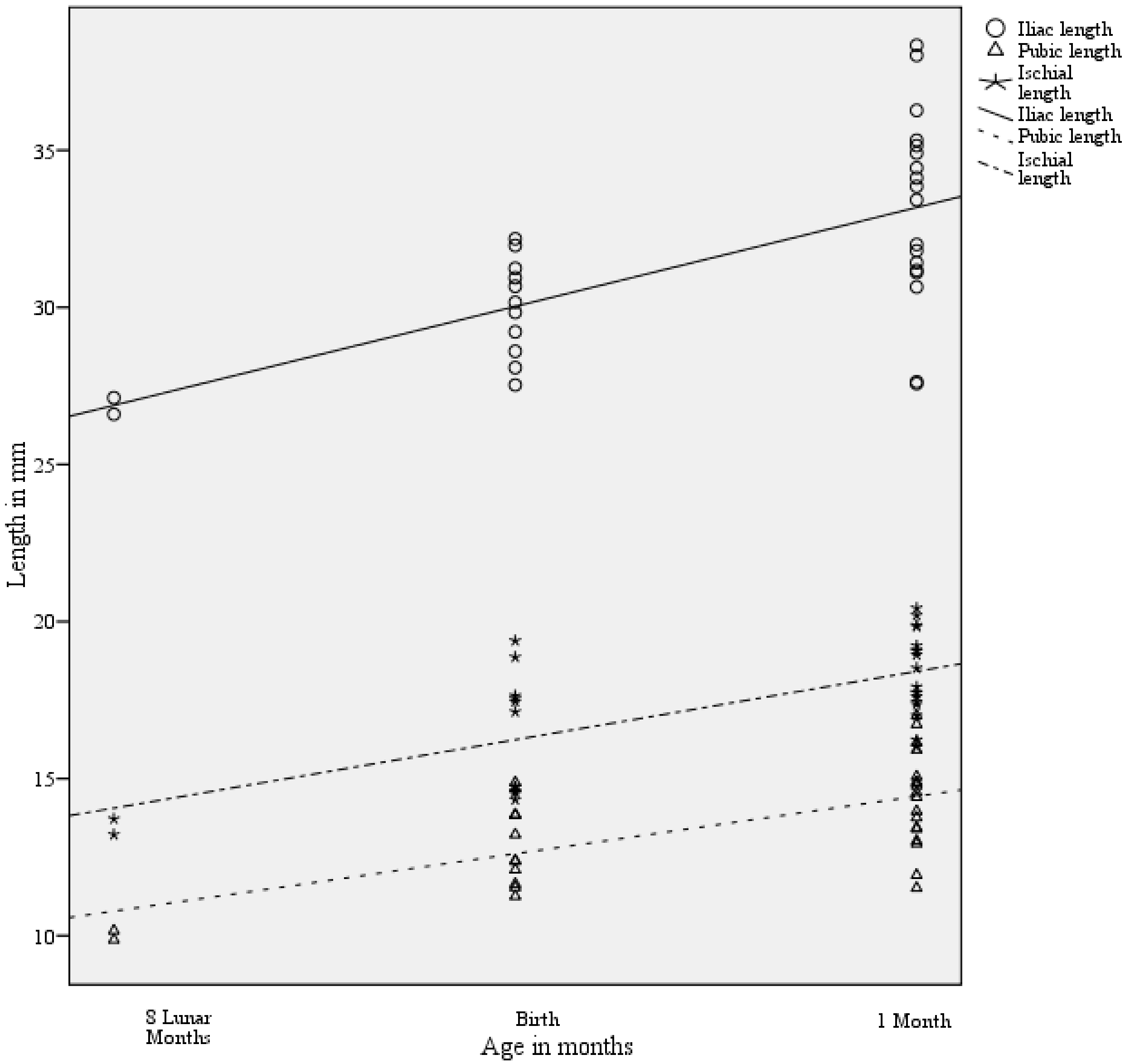


Figure 3.27. Trotter age compared to iliac, pubic and ischial lengths (mm) for males

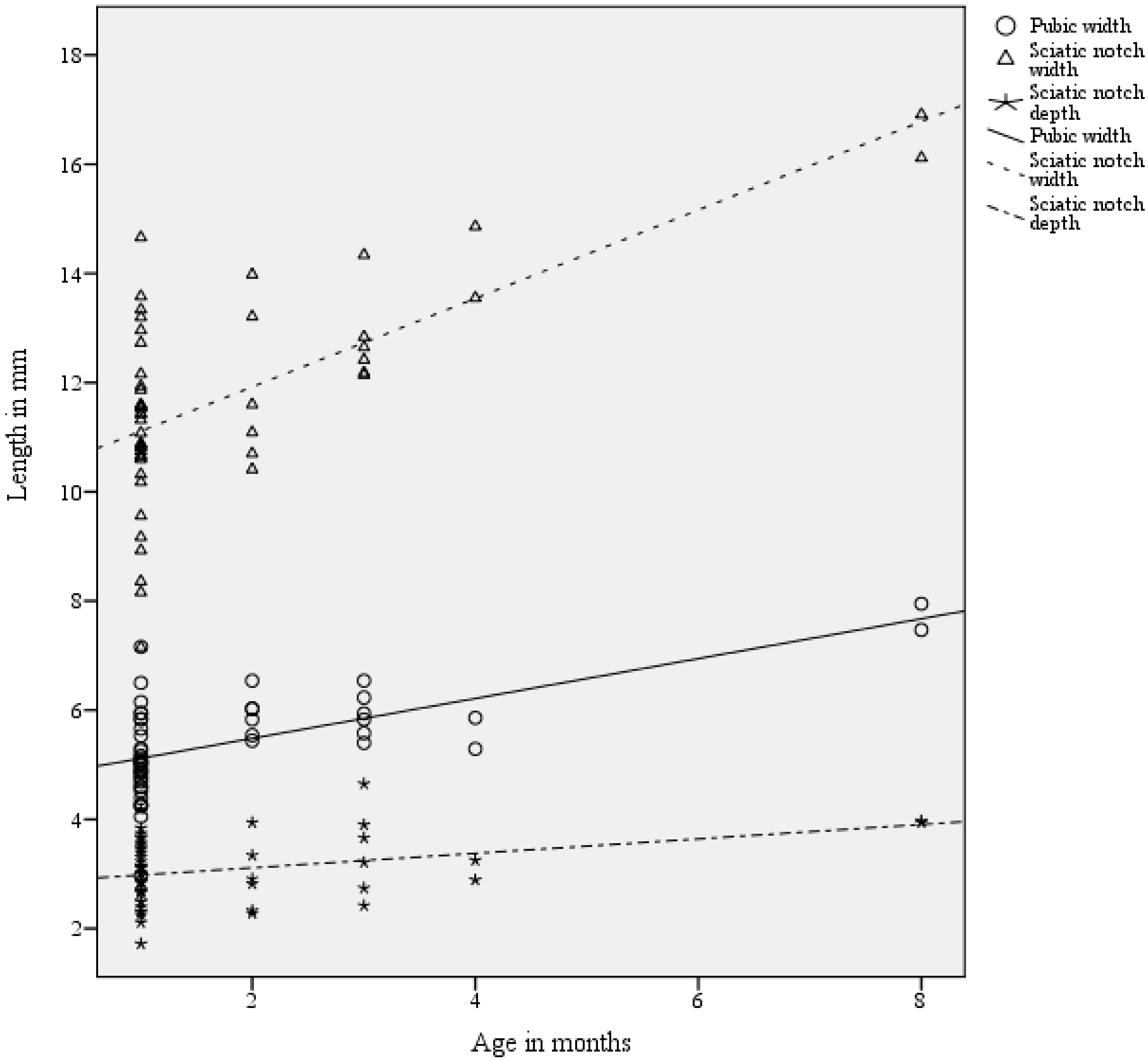


Figure 3.28. NMNH pubic body width, sciatic notch width and sciatic notch depth by age for females

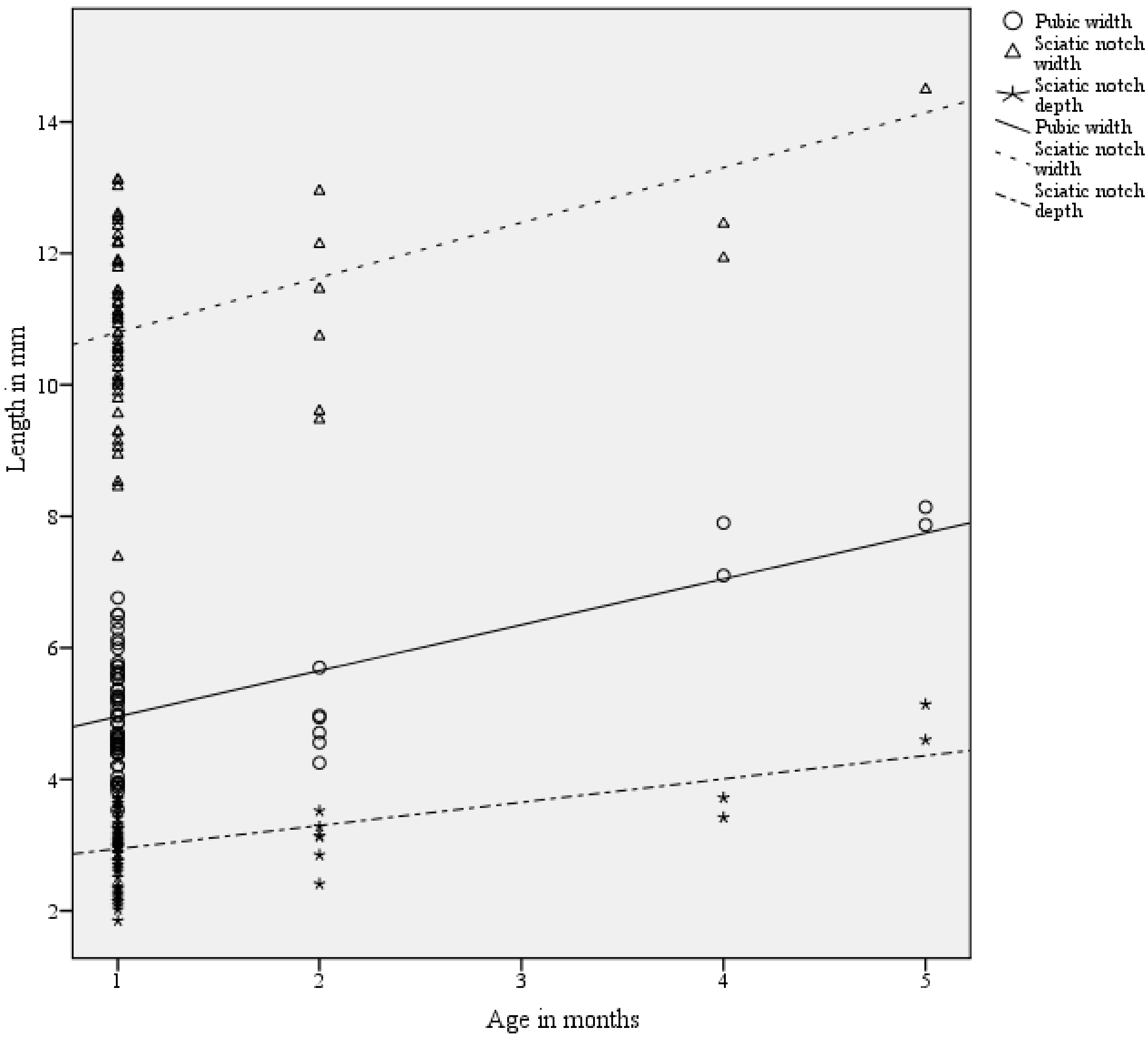


Figure 3.29. NMNH pubic body width, sciatic notch width and sciatic notch depth by age for males

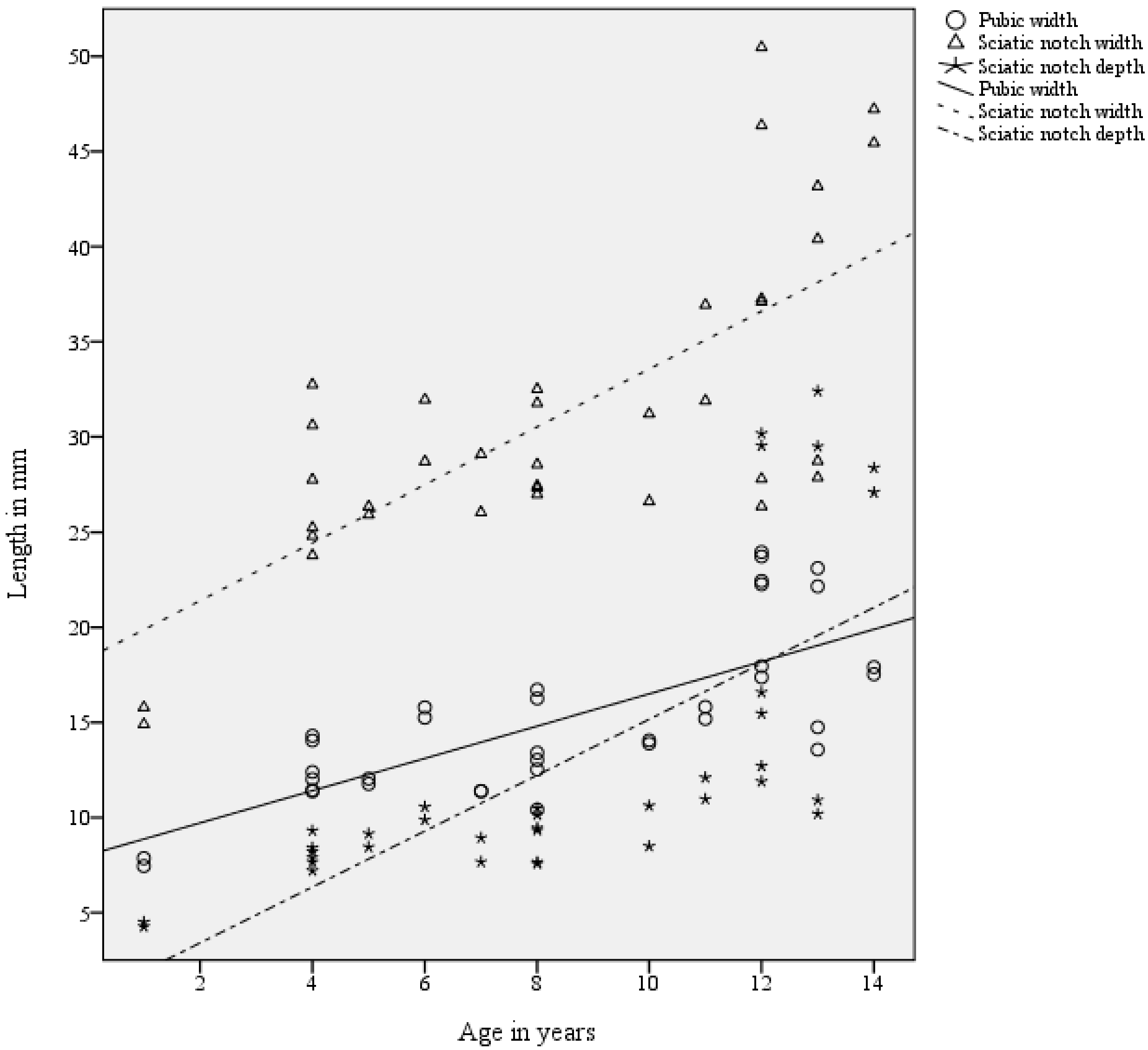


Figure 3.30. HTH pubic body width, sciatic notch width and sciatic notch depth by age for females

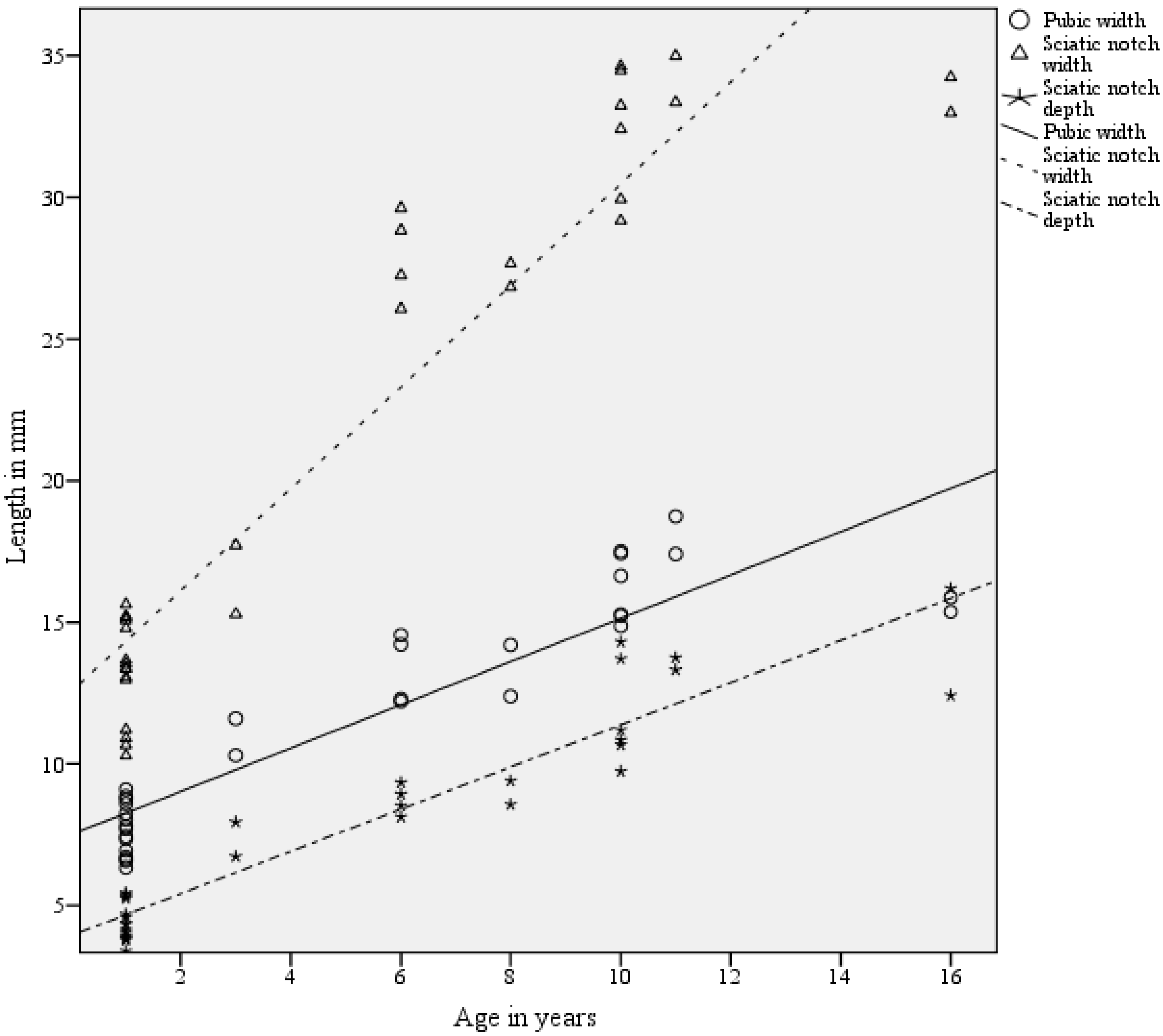


Figure 3.31. HTH pubic body width, sciatic notch width and sciatic notch depth by age for males

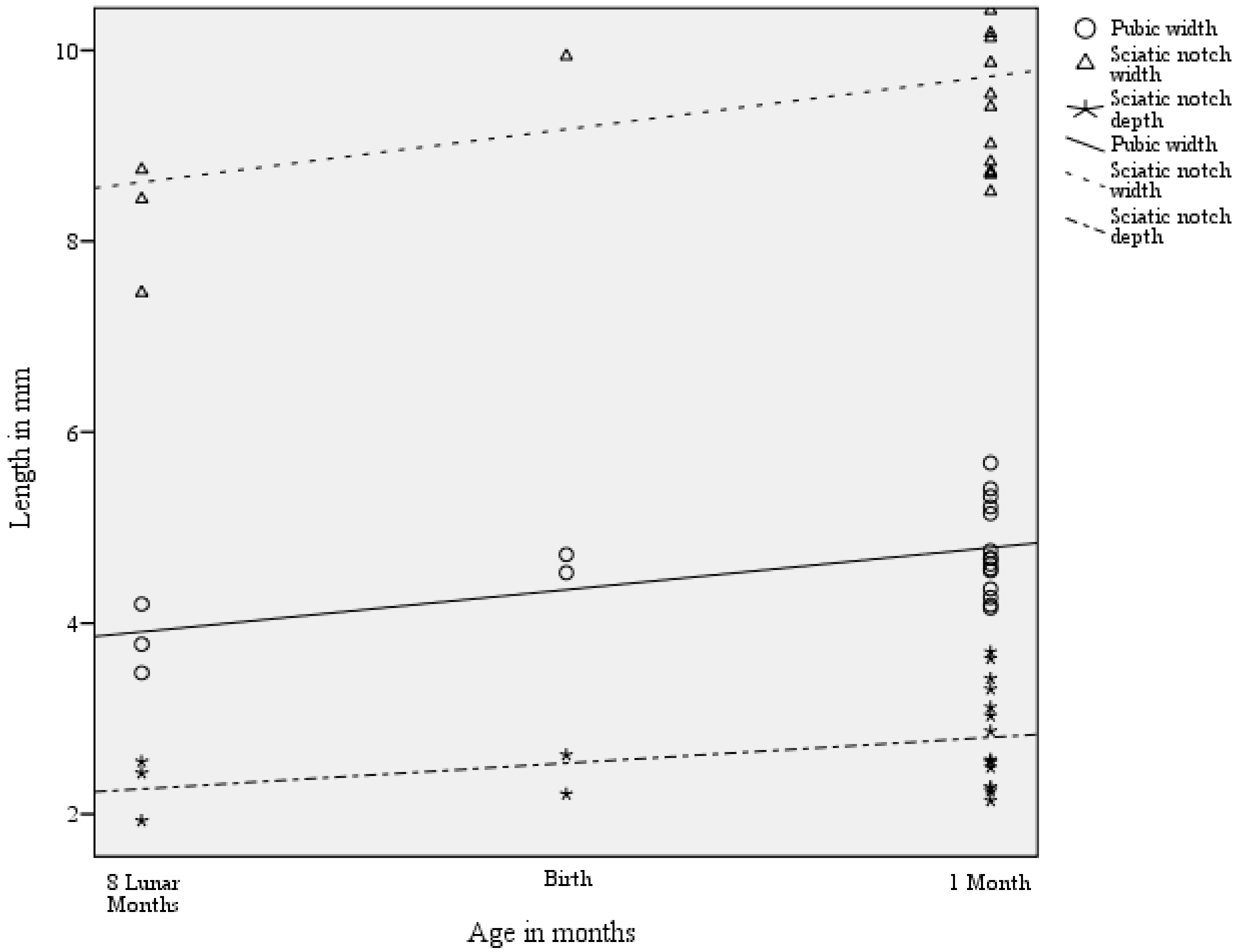


Figure 3.32. Trotter pubic body width, sciatic notch width and sciatic notch depth by age for females

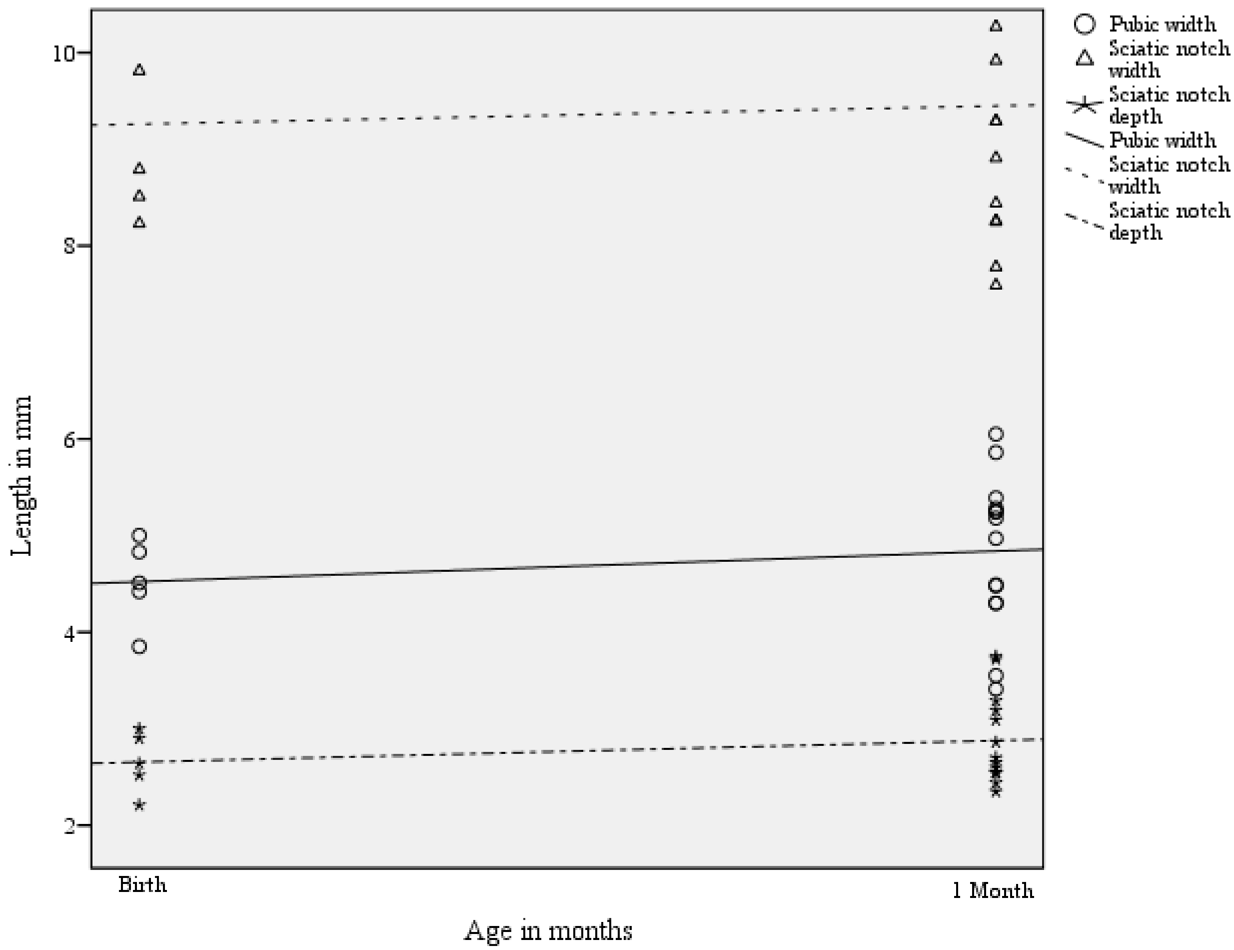


Figure 3.33. Trotter pubic body width, sciatic notch width and sciatic notch depth by age for males

3.7 SEXUALLY DIMORPHIC TRAITS

The differences between features which demonstrated statistical significance for sexual dimorphism between males and females are outlined below for each sample. As the Smithsonian sample was the largest, it was used to produce a discriminant function analysis model and will be discussed separately at the end of these results.

While no trait correlated at a statistically significant level to sex across the three samples for both direct and photographic methods, the sciatic notch depth and anterior sciatic notch in photographic measurements showed sexual differences for the three samples. Several features were correlated at a statistically significant level in two samples for direct measurements: the sciatic notch shape, anterior sciatic notch, and subpubic angle. The sciatic notch angle was not determined to be dimorphic for males and females in any direct analysis sample. The bulk of the features were revealed to be sexually dimorphic in one population only and have been outlined below for each sample.

3.7.1 NMNH sample sexually dimorphic traits

Independent t-tests were performed to test whether differences existed between the sexes in the means of males and females. For the NMNH sample, the results are listed below in Table 3.35. The differences between the two means for males versus females were statistically significant for subpubic angle and sciatic notch shape in direct measures; a statistically significant difference was observed for the sciatic notch depth and sciatic notch shape in photographs.

Correlation analyses were conducted on the NMNH sample for separated right and left sides as well as pooled sides for those measurements. For the right and left correlation analysis of the direct method testing, only the right sciatic notch shape correlated with sex at the .05 level (Table 3.36). Results from pooling left and right direct measurements indicated that the subpubic angle, sciatic notch shape, and pubic-iliac index were statistically significant at the .05 level (Table 3.37). For photographic correlation analysis, several features correlated at the .05 level, including the right anterior sciatic notch, left auricular surface, and right sciatic notch depth

(Table 3.36). When photographic measurements were pooled, sciatic notch depth, sciatic notch shape, sciatic notch index, pubic index, and auricular surface elevation were statistically significant at the .05 level, with anterior sciatic notch statistically significant at the .01 level (Table 3.37). Age was not correlated with sex.

For the photographic method, the sciatic notch depth, sciatic notch shape, sciatic notch index, pubic index and pubic-iliac index correlated with sex. None of the measurements correlated with the subpubic angle, although several of the indices did. This varied from the direct measurement analysis and indicated a difference in the overall angle differences between photographs and direct bone. Of the indices, the ischio-pubic index correlated with pubic length, but not with ischial length. The sciatic notch index correlated with the sciatic notch measures, which was anticipated. Pubic index correlated with pubic width but not pubic length. As expected, sciatic notch width to iliac length index did not correlate with sciatic notch depth.

3.7.2 Hamann-Todd sample sexually dimorphic traits

For the HTH sample, the results are listed below in Table 3.35. T-tests for HTH direct-only showed identical results as the right and left side study as statistically significant. This is nearly identical to what was seen in the correlations. The differences between the two means when comparing males versus females were statistically significant for nearly all direct measures, with the exception of right ischium, right and left sciatic notch angle, right and left arch criterion, and right and left sciatic notch shape. For photographic analysis, statistically significant differences were observed for right and left sciatic notch width, right and left sciatic notch depth, right and left iliac length, right and left pubic length, right and left pubic width, right and left anterior sciatic notch, and right and left posterior sciatic notch.

Correlations were conducted for the HTH direct material, on the right and left sides separately as well as pooled sides for those measurements. The majority of the features analyzed correlated with sex, with most features strongly correlated at the .01 statistical significance level (Table 3.36). Those that did not correlate for the right and left direct analysis were right and left sciatic notch angle, right ischium, right and left arch criterion, right and left sciatic notch shape, right pubic width, right and left sciatic notch index, and right and left pubic index. For the right and left photographic correlation, right and left sciatic notch depth, right and left iliac length, right and left pubic length, right and left anterior sciatic notch correlated at the .05, while sciatic notch width, pubic body width, posterior sciatic notch and ischio-pubic index correlated at the .01 level for both sides. When direct measures were pooled, only three traits and two indices were not found to be statistically significant: the sciatic notch angle, sciatic notch shape, shape, and arch criterion, with the anterior/posterior sciatic notch index and the pubic index (Table 3.37). When photographic measurements were pooled, sciatic notch angle, ischial length, arch criterion, and sciatic notch index were statistically significant at the .05 level, with sciatic notch depth, sciatic notch width, iliac length, pubic length, subpubic angle, pubic width, anterior and posterior sciatic notch, and ischio-pubic index statistically significant at the .01 level (Table 3.37).

3.7.3 Trotter fetal collection sexually dimorphic traits

For the Trotter collection, t-tests determined that only the left sciatic notch width and right anterior sciatic notch in photographic method analyses were statistically significant (Table 3.35). In correlations, no features were found as statistically significant when evaluating the direct measurements with right and left sides separated (Table 3.36). This pattern was also seen in the photographic analysis, with the exception of the left anterior sciatic notch length, which was statistically significant at .02. Pooled analyses showed that sciatic notch shape, anterior sciatic notch, and pubic index correlated to sex in direct method, with the sciatic notch depth and anterior sciatic notch correlating at a statistically significant level in the photographic method (Table 3.37).

3.8 DIRECT VERSUS INDIRECT MEASUREMENT

Many of the length measurements were similar or slightly larger in photographs. For the three samples, the photographic angle measures were larger than those taken directly. While the sciatic notch angle measurements were much larger in the photographs, with a higher mean, the standard deviation and variance were similar for both cases (Tables 3.1, 3.2, 3.3, 3.4, 3.5 and 3.6).

In the paired t-test analysis for the NMNH collection of direct versus photographic measurements, most of the traits were statistically significant at the .05 level, with many at the 0.001 level (Table 3.38). Only left sciatic notch width, left sciatic notch depth, and both anterior sciatic notch lengths did not reach statistical significance. The HTH sample followed a similar pattern to the NMNH group, with only the right iliac length, right ischial length, right and left sciatic notch depth, right anterior sciatic notch length, right and left posterior sciatic notch length, right and left subpubic angle, and left pubic body width at the statistically significant level. In the Trotter sample, only the right subpubic angle, right and left pubic width, right anterior sciatic notch length, and left posterior sciatic notch length were statistically significant at the .05 level and only three features, the right and left sciatic notch angles and right posterior sciatic notch length were statistically significant at the 0.001 level.

3.9 REGRESSION

The classification of individuals into the correct sex category for the NMNH sample was not promising using logistic regression. For the NMNH sample, the right side measurements proved to be best, with the right sciatic notch symmetry and right sciatic notch width/iliac length index the two most statistically significant variables (Table 3.39). When the regression was performed with these two variables, the predictive performance of these two was 0.683. Cross-validation was conducted to assess how accurately the model predicted sex by removing bias, and a lower result was obtained at 0.604. When the model was tested on the HTH and Trotter samples, results dropped, with predictive scores of 0.429 and 0.6111 respectively. When age was factored into the analysis, the results were similar for the NMNH group at 0.663 and with a cross-validation value of 0.5941; however, the HTH value increased when age was factored in, with a predictive value of .686. The Trotter sample predictive value dropped considerably to .444.

3.10 DISCRIMINANT FUNCTION ANALYSIS

The discriminant function investigation was conducted using the variables on the NMNH sample. When including the traits on the pubis and ischium, the eigenvalues and canonical correlations did show a strong relationship to sex (Table 3.40). In neither the ilium-only nor overall analysis were the Wilks' Lambda levels statistically significant (significance = .630). When the traits of the ilium were analyzed separately using discriminant function, they did not show a strong relationship to sex (Table 3.41). The eigenvalue was small and the canonical correlation does not exceed .5, which indicated a strong relationship.

This analysis was then conducted strictly on the traits found to be statistically significant. The highest predictive score was obtained using right sciatic notch shape, right ischio-pubic index, and right sciatic notch width/iliac length index (Table 3.42). Correct classification for sex was found to be 0.619, which is at a similar level to what was obtained when using cross-validation (0.6969). When compared to the HTH and Trotter samples, the HTH sample predictive rate was 0.6857, while the Trotter group provided a value of 0.5676. These results did not reach the required levels necessary for valid scientific methods (Bernstein 1994).

Adding age to the function did not substantially alter the findings, with the NMNH value at 0.631, and the cross-validation level at 0.6038. The only real difference noted when adding age to the function was found in the HTH group, which dropped to 0.5143. The Trotter samples did not change when age was added to the analysis.

3.11 AGE DIFFERENCES

Age differences were noted primarily in the HTH material, as this collection covered a wider age range than either the NMNH or the Trotter material, which were only within a few months of each other, with most individuals within the newborn age group (see Appendix D and F). The comparison of the sciatic notch angle and age should be acknowledged, as this relationship was noted in Vlak and colleagues (2008). Similar results were seen with the HTH material (Figure 3.34), which illustrated how when age increased, the width of the sciatic notch decreased. Note that female angles were lower at older ages than male sciatic notch angles. As the NMNH and Trotter material were biased toward the newborn age group, the age analysis for the sciatic notch angle did not demonstrate as wide a range of variation as found in the HTH sample.

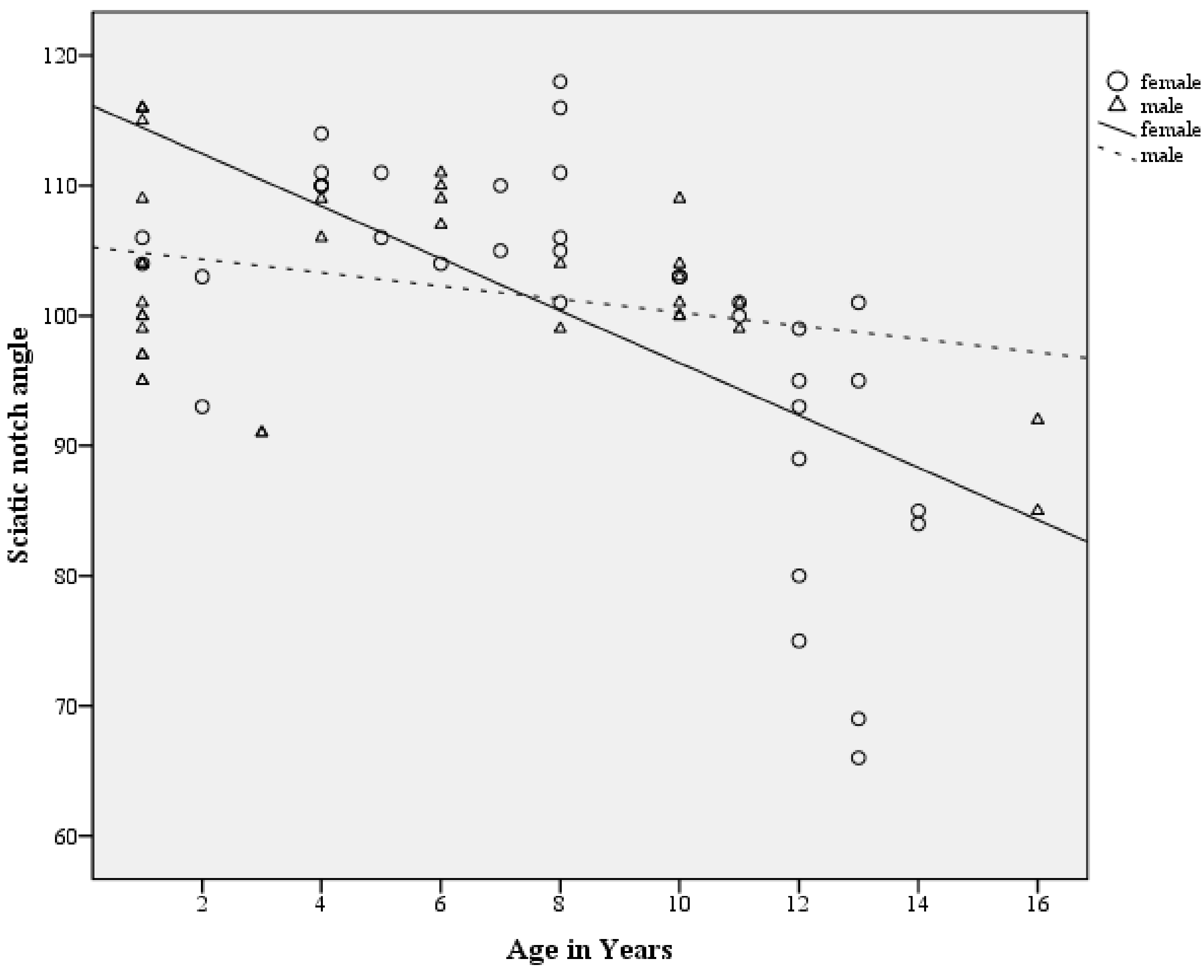


Figure 3.34. HTH sciatic notch angle in degrees for age in years for males and females

Table 3.1. NMNH unpaired direct measurements descriptive statistics

	Male					Female				
Measurement	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
R sciatic notch angle	56	77	120	97.11	8.909	56	82	116	98.02	7.738
L sciatic notch angle	53	75	121	96.26	9.578	55	75	118	98.00	8.724
R sciatic notch width	56	6.01	16.32	10.7941	1.63000	56	6.87	16.12	10.6832	2.00188
L sciatic notch width	53	7.02	14.49	10.7230	1.59351	54	5.92	16.91	10.6407	2.12746
R sciatic notch depth	56	1.33	5.14	3.0350	.64262	56	1.29	4.65	2.9289	.67853
L sciatic notch depth	53	1.12	4.60	2.7051	.63499	54	1.50	3.94	2.6172	.53054
R sciatic notch index	56	2.26	6.65	3.6723	.79481	56	2.74	5.43	3.7329	.61214
L sciatic notch index	53	2.44	6.27	4.1122	.81597	54	2.30	6.41	4.1468	.81620
R iliac length	56	23.39	51.22	34.5543	5.10736	57	16.66	49.05	33.0053	6.12086
L iliac length	53	23.98	51.11	34.4813	5.14417	55	16.77	50.07	33.1882	5.96925
R pubic length	48	10.41	22.61	15.2748	2.50852	39	10.80	23.23	15.5933	2.64622
L pubic length	46	9.74	22.04	15.2322	2.42143	42	10.25	22.73	15.5560	2.62070
R ischium length	53	12.79	29.38	18.8908	3.11426	50	7.13	28.70	18.6054	3.83547
L ischium length	51	11.95	29.82	18.8882	3.34045	53	6.60	28.90	18.6621	3.87433
R anterior/posterior sciatic notch index	56	.31	.99	.5966	.15764	55	.30	.92	.5727	.14920
L anterior/posterior sciatic notch index	53	.36	1.12	.6798	.16772	54	.34	1.08	.6346	.16781
R iliac/sciatic notch index	56	.23	.52	.3149	.04499	56	.25	.52	.3276	.05169
L iliac/sciatic notch index	53	.24	.53	.3138	.04669	54	.25	.51	.3228	.04809
R subpubic angle	29	17	41	26.79	5.697	20	22	36	28.80	4.384
L subpubic angle	29	15	41	27.72	5.345	22	21	43	30.50	6.209
R arch criterion	56	1	2	1.52	.504	56	1	2	1.54	.503
L arch criterion	53	1	2	1.53	.504	55	1	2	1.58	.498
R auricular surface	55	0	4	1.98	1.434	55	0	4	1.76	1.465
L auricular surface	52	0	4	2.19	1.358	53	0	4	1.77	1.396
R pubic body width	33	3.53	8.14	5.0852	1.06648	25	2.97	7.95	5.2756	.93108
L pubic body width	31	3.88	7.87	5.2971	.94379	26	2.94	7.47	5.4169	.98945
R pubic index	33	.22	.39	.3152	.03827	25	.25	.40	.3176	.03250
L pubic index	31	.25	.40	.3322	.03547	26	.26	.39	.3249	.03542
R sciatic notch shape	56	1	2	1.57	.499	56	1	2	1.77	.426
L sciatic notch shape	53	1	2	1.57	.500	55	1	2	1.64	.485
R anterior sciatic notch	56	2.81	6.41	4.7345	.87165	55	2.65	7.27	4.5580	.99491
L anterior sciatic notch	53	2.99	6.79	5.0268	.87722	54	3.13	8.00	4.7793	1.09268
R posterior sciatic notch	56	4.53	12.63	8.2318	1.60315	55	3.74	13.43	8.2929	1.92152
L posterior sciatic notch	53	4.06	11.42	7.6766	1.63380	54	3.79	13.06	7.8172	1.79106
R ischio-pubic index	47	.64	.89	.7912	.05816	38	.64	.91	.7847	.06456
L ischio-pubic index	44	.66	.90	.7843	.05390	42	.62	.89	.7862	.06552
Valid N (listwise)	24					19				

Table 3.2. NMNH unpaired photographic measurements descriptive statistics

	Male					Female				
Measurement	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
R sciatic notch angle	56	99.3	144.0	121.149	8.9069	57	104.4	140.5	122.441	7.2045
L sciatic notch angle	53	104.1	143.8	122.339	8.8019	54	101.1	138.3	123.741	7.9916
R sciatic notch width	55	6.140	13.760	10.384	1.939429	57	5.120	16.34	10.0902	2.537819
L sciatic notch width	53	6.58	14.36	10.504	1.69840	55	5.05	17.27	10.4864	2.60455
R sciatic notch depth	55	.92	4.29	2.6909	.64752	57	1.06	4.07	2.4640	.65413
L sciatic notch depth	53	1.06	4.60	2.7242	.68874	55	1.07	4.48	2.5489	.64589
R sciatic notch index	55	2.64	6.91	3.9653	.72501	57	2.72	6.22	4.1618	.68173
L sciatic notch index	53	2.31	7.03	4.0092	.78123	55	3.08	5.55	4.1705	.65477
R iliac length	55	24.60	50.98	34.9545	4.82977	56	16.31	49.62	33.5136	6.23397
L iliac length	52	25.18	52.57	35.1498	4.76362	54	16.08	50.76	33.6948	6.19506
R pubic length	45	10.73	22.67	15.5278	2.51442	38	10.74	23.49	15.9750	2.68145
L pubic length	46	10.26	22.20	15.4207	2.50915	42	10.80	23.54	15.8690	2.76648
R ischium length	52	12.77	29.93	19.2256	3.17832	51	6.48	29.19	19.0686	3.95079
L ischium length	51	11.66	30.79	19.3692	3.49803	52	6.30	29.87	19.0735	4.00398
R anterior/posterior sciatic notch index	54	.35	1.18	.7228	.20063	57	.38	1.15	.7154	.15319
L anterior/posterior sciatic notch index	53	.37	1.07	.7283	.16215	54	.43	1.33	.7365	.17299
R iliac sciatic notch index	54	.20	.40	.2957	.04250	56	.18	.41	.3007	.04732
L iliac sciatic notch index	52	.23	.38	.3015	.03707	54	.21	.40	.3098	.04672
R subpubic angle	26	20	53	33.37	7.407	16	25	47	31.96	5.260
L subpubic angle	28	21	56	35.22	7.368	18	27	49	34.64	5.936
R arch criterion	55	1	2	1.24	.429	56	1	2	1.20	.401
L arch criterion	52	1	2	1.27	.448	53	1	2	1.17	.379
R auricular surface	55		4	1.85	1.496	55		4	1.62	1.545
L auricular surface	52		4	1.87	1.428	51		4	1.29	1.501
R pubic width	26	3.74	6.44	4.7973	.65369	16	2.62	6.67	4.7244	.93583
L pubic width	27	3.58	7.22	4.9037	.75386	17	4.04	7.01	4.9435	.75753
R pubic index	26	.24	.33	.2904	.02341	16	.22	.35	.2800	.03246
L pubic index	27	.25	.35	.2963	.02619	17	.24	.32	.2835	.02262
R sciatic notch shape	56	1	2	1.66	.478	57	1	2	1.77	.423
L sciatic notch shape	54	1	2	1.72	.452	55	1	2	1.85	.356
R anterior sciatic notch	55	1.84	7.51	4.9056	1.08444	57	2.38	8.67	4.4591	1.23106
L anterior sciatic notch	54	2.04	7.36	4.9628	.97143	55	2.41	7.90	4.7835	1.28964
R posterior sciatic notch	54	3.27	9.94	6.7352	1.33464	57	2.70	12.56	6.6972	1.89292
L posterior sciatic notch	52	4.31	10.16	6.8181	1.33421	55	2.96	12.79	6.8291	1.88550
R ischio-pubic index	44	.64	.93	.7836	.06096	38	.63	.90	.7874	.05994
L ischio-pubic index	44	.64	.90	.7773	.06048	42	.68	.90	.7843	.05657
Valid N (listwise)	20					15				

Table 3.3. HTH unpaired direct measurements descriptive statistics

	Male					Female				
Measurement	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
R sciatic notch angle	18	91	116	102.83	7.414	18	66	118	100.22	13.384
L sciatic notch angle	18	85	116	102.67	7.784	19	69	116	99.89	12.261
R sciatic notch width	18	10.91	34.24	21.1056	8.97396	19	14.71	46.37	30.1042	8.54724
L sciatic notch width	18	10.30	34.99	21.5517	9.48005	19	14.71	50.48	30.5526	9.00575
R sciatic notch depth	18	3.82	13.71	7.5172	3.46449	19	4.27	32.40	12.5737	8.05774
L sciatic notch depth	18	3.40	16.19	7.7422	4.03425	19	4.50	30.17	12.5000	7.87133
R sciatic notch index	18	2.27	3.67	2.8706	.39714	19	1.33	3.57	2.7579	.67862
L sciatic notch index	18	2.04	3.84	2.9128	.52828	19	1.37	3.72	2.7995	.69904
R iliac length	18	44.11	121.65	74.9228	27.46468	19	55.63	131.53	95.2200	22.00300
L iliac length	18	44.15	119.57	74.4094	26.87038	19	54.95	130.77	94.6774	22.07846
R pubic length	18	20.75	59.34	34.6783	12.85832	19	24.62	68.05	45.9874	12.30032
L pubic length	17	20.62	56.27	35.2729	12.42612	19	25.09	67.29	46.6011	12.00188
R ischium length	18	26.59	82.11	46.0406	17.72865	19	29.00	75.96	55.6205	12.54536
L ischium length	18	27.01	79.40	45.3022	16.85710	19	28.77	77.71	55.7747	12.92666
R anterior/posterior sciatic notch index	18	.41	.91	.6661	.14213	19	.46	1.38	.7458	.24638
L anterior/posterior sciatic notch index	18	.42	.80	.6483	.10728	19	.41	1.29	.6616	.24907
R iliac/sciatic notch index	18	.22	.37	.2783	.03823	19	.25	.37	.3137	.03876
L iliac/sciatic notch index	18	.23	.37	.2828	.04336	19	.24	.40	.3211	.04215
R subpubic angle	18	15	45	28.50	7.081	19	21	45	35.53	6.947
L subpubic angle	17	21	41	27.47	6.001	19	23	49	35.84	7.705
R arch criterion	17	1	2	1.41	.507	18	1	2	1.50	.514
L arch criterion	17	1	2	1.41	.507	18	1	2	1.50	.514
R auricular surface	17		4	1.35	1.579	18		4	2.39	1.420
L auricular surface	16		4	1.00	1.461	18		4	2.56	1.338
R pubic body width	17	6.34	18.74	11.5165	4.20808	19	4.63	22.44	14.5242	4.65908
L pubic body width	16	6.58	17.51	11.5925	3.94637	19	4.21	23.96	14.7132	5.15344
R pubic index	17	.25	.39	.3282	.03861	18	.27	.38	.3211	.03046
L pubic index	16	.26	.38	.3238	.03964	18	.25	.40	.3200	.04044
R sciatic notch	17	1	2	1.76	.437	18	1	2	1.83	.383
L sciatic notch	17	1	2	1.71	.470	18	1	2	1.78	.428
R anterior sciatic notch	18	4.98	21.43	11.1956	5.89093	19	7.14	46.56	18.2421	11.60404
L anterior sciatic notch	18	4.29	19.78	11.1550	5.46733	19	6.59	45.11	16.9111	10.77188
R posterior sciatic notch	18	8.25	28.86	16.2994	6.70506	19	10.44	37.31	23.1937	6.97046
L posterior sciatic notch	18	8.93	29.91	16.9161	7.46174	19	12.28	36.24	24.4800	7.03321
R ischio-pubic index	18	.63	.84	.7556	.04540	19	.69	1.00	.8205	.06671
L ischio-pubic index	17	.65	.85	.7659	.04611	19	.74	.93	.8321	.05029
Valid N (listwise)	16					17				

Table 3.4. HTH unpaired photographic measurements descriptive statistics

	Male					Female				
Measurement	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
R sciatic notch angle	17	99	137	114.44	9.140	18	69	121	106.04	15.234
L sciatic notch angle	16	93	133	114.66	11.154	18	70	125	107.93	15.512
R sciatic notch width	17	12.32	47.39	25.7476	10.59999	18	15.90	49.51	34.3133	8.55133
L sciatic notch width	17	12.25	37.75	25.6100	9.50434	18	16.86	52.73	35.3583	8.97074
R sciatic notch depth	17	3.22	16.33	7.8182	3.98879	18	4.32	33.33	13.2133	8.28074
L sciatic notch depth	17	3.24	15.96	8.2906	4.42168	18	4.05	31.99	13.2739	8.13707
R sciatic notch index	17	2.58	5.44	3.5112	.69378	18	1.42	3.84	3.0122	.75925
L sciatic notch index	17	2.30	4.94	3.3929	.73772	18	1.41	4.36	3.0828	.82879
R iliac length	17	44.78	128.15	78.9512	29.17160	18	56.17	141.68	100.6678	22.38873
L iliac length	17	45.80	124.76	78.3000	28.31389	18	56.18	140.54	100.7122	22.46428
R pubic length	17	20.84	63.12	36.9688	14.00281	18	24.20	75.48	48.9161	12.89402
L pubic length	16	21.56	60.86	37.8650	13.84090	18	24.57	78.75	49.3489	13.85652
R ischium length	17	27.41	81.56	48.3247	18.80773	18	30.17	77.29	58.4033	12.97740
L ischium length	17	28.04	82.39	48.6494	18.55498	18	30.23	80.52	58.4506	13.29857
R anterior/posterior sciatic notch	17	.46	.98	.6865	.14832	18	.51	1.14	.7417	.18706
L anterior/posterior sciatic notch	17	.58	.99	.8088	.11472	18	.45	1.09	.7911	.19378
R iliac sciatic notch index	17	.26	.43	.3241	.04836	18	.24	.41	.3411	.04457
L iliac sciatic notch index	17	.27	.43	.3271	.04780	18	.22	.48	.3533	.05750
R subpubic angle	17	24	43	31.49	5.582	17	25	49	34.53	7.535
L subpubic angle	17	22	43	30.77	5.610	18	26	57	35.00	8.001
R arch criterion	17	1	2	1.29	.470	18	1	2	1.56	.511
L arch criterion	17	1	2	1.29	.470	18	1	2	1.56	.511
R auricular surface	17		3	.94	1.144	18		4	1.28	1.127
L auricular surface	17		4	1.18	1.286	18		4	.94	1.056
R pubic body width	17	4.86	16.21	10.2194	3.65054	18	7.81	19.64	14.1000	3.29150
L pubic body width	17	5.61	16.97	10.3171	3.76220	17	8.35	19.87	14.2265	3.25791
R pubic index	17	.23	.34	.2788	.03276	18	.23	.32	.2911	.02610
L pubic index	17	.25	.33	.2845	.02431	18	.00	.35	.2772	.07591
R sciatic notch	17	1	2	1.88	.332	18	1	2	1.78	.428
L sciatic notch	17	1	2	1.88	.332	17	1	2	1.82	.393
R anterior sciatic notch	17	4.96	20.65	12.1153	5.48517	18	7.40	43.98	19.0783	10.33113
L anterior sciatic notch	17	5.70	25.65	13.7800	6.20015	18	7.54	45.09	20.2528	10.44485
R posterior sciatic notch	17	8.98	38.10	17.6841	7.74740	18	10.67	38.52	24.7933	7.35715
L posterior sciatic notch	17	8.03	29.01	17.0841	7.27736	18	11.13	41.20	24.9817	8.04796
R ischio-pubic index	17	.71	.86	.7676	.03914	18	.73	1.05	.8344	.07755
L ischio-pubic index	17	.71	.87	.7669	.04105	18	.69	1.05	.8394	.08447
Valid N (listwise)	15					16				

Table 3.5. Trotter unpaired direct measurements descriptive statistics

Measurement	Male					Female				
	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
R sciatic notch angle	15	80	100	88.73	6.017	21	85	96	90.71	3.212
L sciatic notch angle	16	84	104	91.88	5.655	21	85	101	92.29	4.981
R sciatic notch width	15	7.78	11.86	9.6893	1.21436	21	7.46	10.82	9.5767	1.00523
L sciatic notch width	16	7.59	11.89	9.7938	1.32610	21	7.60	11.22	9.5690	.87590
R sciatic notch depth	15	2.15	3.72	2.7600	.42763	21	1.93	3.70	2.6676	.46336
L sciatic notch depth	16	2.21	3.76	2.8725	.50154	21	1.59	3.42	2.5686	.41385
R sciatic notch index	15	2.72	4.56	3.5627	.55283	21	2.87	4.65	3.6533	.50070
L sciatic notch index	16	3.04	4.31	3.4450	.36628	21	2.88	6.31	3.8267	.79439
R iliac length	15	27.12	38.34	31.7633	3.24099	21	26.17	34.88	30.8881	3.08002
L iliac length	16	26.60	38.02	31.5563	3.16725	21	25.42	35.08	30.8414	3.09712
R pubic length	16	10.16	17.01	13.4906	1.80990	20	7.99	17.82	13.3715	2.68782
L pubic length	16	9.87	16.73	13.5013	1.85312	20	8.91	16.77	13.3725	2.50153
R ischium length	16	13.72	20.20	17.1806	1.98301	21	13.68	19.88	16.7481	2.06323
L ischium length	16	13.22	20.43	17.3519	2.19207	21	13.63	19.55	16.6438	2.03162
R anterior/posterior sciatic notch index	15	.51	1.03	.6713	.14456	21	.42	.81	.6057	.10623
L anterior/posterior sciatic notch index	16	.52	1.21	.8019	.17830	21	.39	.97	.6533	.15809
R iliac sciatic notch index	15	.24	.36	.3060	.03869	21	.25	.39	.3114	.03692
L iliac sciatic notch index	16	.26	.37	.3113	.03862	21	.27	.39	.3129	.03703
R subpubic angle	5	13	30	19.80	6.611	6	15	27	21.17	3.920
L subpubic angle	4	20	27	24.00	3.162	4	23	37	29.00	7.118
R arch criterion	15	1	2	1.80	.414	21	1	2	1.76	.436
L arch criterion	16	1	2	1.81	.403	21	1	2	1.67	.483
R auricular surface	15		4	1.27	1.033	21		4	1.57	.926
L auricular surface	16		4	1.56	1.153	21		4	1.62	1.284
R pubic width	10	3.55	5.28	4.4770	.53541	11	3.48	5.15	4.4236	.47124
L pubic width	9	3.41	6.05	5.0656	.78589	9	4.19	5.68	4.8533	.56771
R pubic index	10	.29	.36	.3150	.02224	11	.26	.36	.2945	.02806
L pubic index	9	.29	.39	.3500	.02828	9	.28	.36	.3211	.03296
R sciatic notch shape	15	1	2	1.80	.414	21	1	2	1.95	.218
L sciatic notch shape	16	1	2	1.81	.403	21	1	2	1.95	.218
R anterior sciatic notch	15	3.68	6.80	4.6600	.89302	21	3.44	5.41	4.3095	.55437
L anterior sciatic notch	16	2.73	6.70	4.9613	1.14852	21	3.39	5.48	4.4495	.62482
R posterior sciatic notch	15	5.71	8.90	7.1300	.97324	21	5.81	9.11	7.1705	.91410
L posterior sciatic notch	16	4.84	8.23	6.6844	1.06916	21	5.14	8.39	6.6538	.95062
R ischio-pubic index	16	.72	.86	.7850	.04147	20	.55	.94	.7890	.09662
L ischio-pubic index	16	.71	.88	.7800	.04546	20	.65	.96	.7945	.08256
Valid N (listwise)	4					4				

Table 3.6. Trotter unpaired photographic measurements descriptive statistics

	Male					Female				
Measurement	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
R sciatic notch angle	16	107	131	119.60	6.820	21	113	131	121.75	5.591
L sciatic notch angle	15	114	133	122.22	5.696	21	107	135	122.36	7.650
R sciatic notch width	16	6.69	12.14	9.9456	1.45733	21	7.79	11.96	9.7448	1.05980
L sciatic notch width	15	8.26	12.42	10.5540	1.26934	21	7.52	11.77	9.7776	.99987
R sciatic notch depth	16	2.09	3.48	2.7025	.39999	21	1.91	3.36	2.5324	.43519
L sciatic notch depth	15	2.28	3.41	2.7353	.37777	21	2.00	3.16	2.5262	.33708
R sciatic notch index	16	2.78	4.54	3.7056	.46027	21	3.12	4.75	3.9100	.50689
L sciatic notch index	15	3.15	4.69	3.8913	.48009	21	2.89	5.04	3.9205	.55545
R iliac length	16	27.22	38.21	31.7050	3.12427	21	26.16	35.38	31.0429	3.21452
L iliac length	16	11.55	38.12	30.4338	5.92369	21	25.53	35.96	30.9943	3.19658
R pubic length	16	9.82	16.07	13.3250	1.74882	21	7.96	16.51	12.9662	2.58647
L pubic length	16	10.10	16.42	13.5788	1.71655	20	9.17	16.44	13.3095	2.33420
R ischium length	16	13.79	20.45	17.4575	2.03288	21	13.75	20.25	16.9667	2.19058
L ischium length	15	13.57	20.77	17.8753	2.12817	21	13.78	19.88	16.9138	2.19047
R anterior/posterior sciatic notch index	15	.58	1.16	.8447	.17521	21	.59	1.07	.7786	.13264
L anterior/posterior sciatic notch index	16	.65	1.29	.8619	.15892	21	.56	1.33	.7962	.17119
R iliac/sciatic notch index	16	.22	.41	.3150	.04619	21	.25	.38	.3157	.03558
L iliac/sciatic notch index	15	.26	.40	.3340	.04205	21	.22	.40	.3176	.03961
R subpubic angle	7	31	46	36.83	4.753	9	21	44	35.06	7.379
L subpubic angle	7	28	44	36.13	6.508	8	29	45	38.21	5.390
R arch criterion	15	1	2	1.33	.488	21	1	2	1.33	.483
L arch criterion	16	1	2	1.31	.479	21	1	2	1.33	.483
R auricular surface	15		4	2.20	1.474	21	1	4	2.86	1.389
L auricular surface	16		4	2.38	1.586	21		4	2.33	1.354
R pubic width	8	2.51	4.97	3.4463	.80385	10	3.27	4.69	3.8970	.41031
L pubic width	8	2.46	4.97	3.7775	.74375	8	2.81	4.58	3.9013	.60565
R pubic index	8	.18	.33	.2425	.05285	10	.23	.30	.2610	.02079
L pubic index	8	.20	.35	.2638	.05097	8	.21	.29	.2550	.02563
R sciatic notch shape	15	1	2	1.53	.516	21	1	2	1.86	.359
L sciatic notch shape	16	1	2	1.56	.512	21	1	2	1.67	.483
R anterior sciatic notch	15	3.79	6.29	4.9887	.84155	21	3.54	6.16	4.7100	.74536
L anterior sciatic notch	16	4.23	7.45	5.4300	.87895	21	3.58	6.07	4.7867	.59700
R posterior sciatic notch	15	4.14	7.58	6.0293	1.02322	21	4.72	7.54	6.0962	.75057
L posterior sciatic notch	16	5.04	7.68	6.3663	.79713	21	4.56	7.97	6.1357	.86582
R ischio-pubic index	16	.68	.84	.7644	.04926	21	.55	.88	.7600	.09165
L ischio-pubic index	15	.65	.82	.7573	.05120	20	.66	.94	.7800	.07384
Valid N (listwise)	7					7				

Table 3.7. NMNH direct sciatic notch angle

	Male		Female		Total	
Sciatic notch angle	N	%	N	%	N	%
<90° (Male form)	18	16.7%	15	13.4%	33	15.0%
90° (Male form)	7	6.5%	9	8.0%	16	7.3%
>90° (Female form)	83	76.9%	88	78.6%	171	77.7%
Total	108	100.0%	112	100.0%	220	100.0%

Table 3.8. NMNH photographic sciatic notch angle

	Male		Female		Total	
Sciatic notch angle	N	%	N	%	N	%
<90° (Male form)	0	0.0%	0	0.0%	0	0.0%
90° (Male form)	0	0.0%	0	0.0%	0	0.0%
>90° (Female form)	109	100.0%	111	100.0%	220	100.0%
Total	109	100.0%	111	100.0%	220	100.0%

Table 3.9. HTH direct sciatic notch angle

	Male		Female		Total	
Sciatic notch angle	N	%	N	%	N	%
<90° (Male form)	1	2.8%	7	19.4%	8	11.1%
90° (Male form)	0	0.0%	0	0.0%	0	0.0%
>90° (Female form)	35	97.2%	29	80.6%	64	88.9%
Total	36	100.0%	36	100.0%	72	100.0%

Table 3.10. HTH photographic sciatic notch angle

	Male		Female		Total	
Sciatic notch angle	N	%	N	%	N	%
<90° (Male form)	0	0.0%	6	16.7%	6	8.7%
90° (Male form)	0	0.0%	0	0.0%	0	0.0%
>90° (Female form)	33	100.0%	30	83.3%	63	91.3%
Total	33	100.0%	36	100.0%	69	100.0%

Table 3.11. Trotter direct sciatic notch angle

Sciatic notch angle	Male		Female		Total	
	N	%	N	%	N	%
<90° (Male form)	14	45.2%	13	31.0%	27	37.0%
90° (Male form)	5	16.1%	9	21.4%	14	19.2%
>90° (Female form)	12	38.7%	20	47.6%	32	43.8%
Total	31	100.0%	42	100.0%	73	100.0%

Table 3.12. Trotter photographic sciatic notch angle

Sciatic notch angle	Male		Female		Total	
	N	%	N	%	N	%
<90° (Male form)	0	0.0%	0	0.0%	0	0.0%
90° (Male form)	0	0.0%	0	0.0%	0	0.0%
>90° (Female form)	31	100.0%	42	100.0%	73	100.0%
Total	31	100.0%	42	100.0%	73	100.0%

Table 3.13. NMNH sciatic notch direct symmetry vs. asymmetry

Sciatic notch symmetry	Male		Female		Total	
	N	%	N	%	N	%
Symmetric (Female form)	46	41.1%	34	31.5%	80	36.4%
Asymmetric (Male form)	66	58.9%	74	68.5%	140	63.6%
Total	112	100.0%	108	100.0%	220	100.0%

Table 3.14. NMNH sciatic notch photographic symmetry vs. asymmetry

Sciatic notch symmetry	Male		Female		Total	
	N	%	N	%	N	%
Symmetric (Female form)	34	30.9%	21	18.8%	55	24.8%
Asymmetric (Male form)	76	69.1%	91	81.3%	167	75.2%
Total	110	100.0%	112	100.0%	222	100.0%

Table 3.15. HTH sciatic notch direct symmetry vs. asymmetry

Sciatic notch symmetry	Male		Female		Total	
	N	%	N	%	N	%
Symmetric (Female form)	9	26.5%	7	19.4%	16	22.9%
Asymmetric (Male form)	25	73.5%	29	80.6%	54	77.1%
Total	34	100.0%	36	100.0%	70	100.0%

Table 3.16. HTH sciatic notch photographic symmetry vs. asymmetry

Sciatic notch symmetry	Male		Female		Total	
	N	%	N	%	N	%
Symmetric (Female form)	9	26.5%	7	19.4%	16	22.9%
Asymmetric (Male form)	25	73.5%	29	80.6%	54	77.1%
Total	34	100.0%	36	100.0%	70	100.0%

Table 3.17. Trotter sciatic notch direct symmetry vs. asymmetry

Sciatic notch symmetry	Male		Female		Total	
	N	%	N	%	N	%
Symmetric (Female form)	6	19.4%	2	4.8%	8	11.0%
Asymmetric (Male form)	25	80.6%	40	95.2%	65	89.0%
Total	31	100.0%	42	100.0%	73	100.0%

Table 3.18. Trotter sciatic notch photographic symmetry vs. asymmetry

Sciatic notch symmetry	Male		Female		Total	
	N	%	N	%	N	%
Symmetric (Female form)	17	54.8%	32	76.2%	49	67.1%
Asymmetric (Male form)	14	45.2%	10	23.8%	24	32.9%
Total	31	100.0%	42	100.0%	73	100.0%

Table 3.19. NMNH direct arch criterion

Arch criterion	Male		Female		Total	
	N	%	N	%	N	%
Across center (Female form)	52	47.7%	52	46.8%	104	47.3%
Across top (Male form)	57	52.3%	59	53.2%	116	52.7%
Total	109	100.0%	111	100.0%	220	100.0%

Table 3.20. NMNH photographic arch criterion

Arch criterion	Male		Female		Total	
	N	%	N	%	N	%
Across center (Female form)	80	74.8%	89	81.7%	169	78.2%
Across top (Male form)	27	25.2%	20	18.3%	47	21.8%
Total	107	100.0%	109	100.0%	216	100.0%

Table 3.21. HTH direct arch criterion

Arch criterion	Male		Female		Total	
	N	%	N	%	N	%
Across center (Female form)	20	58.8%	18	50.0%	38	54.3%
Across top (Male form)	14	41.2%	18	50.0%	32	45.7%
Total	34	100.0%	36	100.0%	70	100.0%

Table 3.22. HTH photographic arch criterion

Arch criterion	Male		Female		Total	
	N	%	N	%	N	%
Across center (Female form)	19	59.4%	21	55.3%	40	57.1%
Across top (Male form)	13	40.6%	17	44.7%	30	42.9%
Total	32	100.0%	38	100.0%	70	100.0%

Table 3.23. Trotter direct arch criterion

Arch criterion	Male		Female		Total	
	N	%	N	%	N	%
Across center (Female form)	6	19.4%	12	28.6%	18	24.7%
Across top (Male form)	25	80.6%	30	71.4%	55	75.3%
Total	31	100.0%	42	100.0%	73	100.0%

Table 3.24. Trotter photographic arch criterion

Arch criterion	Male		Female		Total	
	N	%	N	%	N	%
Across center (Female form)	21	67.7%	28	66.7%	49	65.1%
Across top (Male form)	10	32.3%	14	33.3%	24	32.9%
Total	31	100.0%	42	100.0%	73	100.0%

Table 3.25. NMNH direct auricular surface analysis

Auricular surface dlevation	Male		Female		Total	
	N	%	N	%	N	%
Not raised (Male form)	22	20.6%	15	13.9%	37	17.2%
1 side raised (Male form)	40	37.4%	21	19.4%	61	28.4%
2 sides raised (Indeterminate)	26	24.3%	23	21.3%	49	22.8%
3 sides raised (Female form)	6	5.6%	11	10.2%	17	7.9%
Raised (Female form)	23	21.5%	38	35.2%	61	28.4%
Total	107	100.0%	108	100.0%	215	100.0%

Table 3.26. NMNH photographic auricular surface analysis

Auricular surface elevation	Male		Female		Total	
	N	%	N	%	N	%
Not raised (Male form)	19	17.8%	39	36.8%	58	27.2%
1 side raised (Male form)	36	33.6%	26	24.5%	62	29.1%
2 sides raised (Indeterminate)	21	19.6%	17	16.0%	38	17.8%
3 sides raised (Female form)	3	2.8%	1	0.9%	4	1.9%
Raised (Female form)	28	26.2%	23	21.7%	51	23.9%
Total	107	100.0%	106	100.0%	213	100.0%

Table 3.27. HTH direct auricular surface analysis

Auricular surface elevation	Male		Female		Total	
	N	%	N	%	N	%
Not raised (Male form)	19	57.6%	5	13.9%	24	34.8%
1 side raised (Male form)	0	0.0%	2	5.6%	2	2.9%
2 sides raised (Indeterminate)	7	21.2%	11	30.6%	18	26.1%
3 sides raised (Female form)	3	9.1%	7	19.4%	10	14.5%
Raised (Female form)	4	12.1%	11	30.6%	15	21.7%
Total	33	100.0%	36	100.0%	69	100.0%

Table 3.28. HTH photographic auricular surface analysis

Auricular surface elevation	Male		Female		Total	
	N	%	N	%	N	%
Not raised (Male form)	16	50.0%	10	27.8%	26	38.2%
1 side raised (Male form)	8	25.0%	16	44.4%	24	35.3%
2 sides raised (Indeterminate)	6	18.8%	5	13.9%	11	16.2%
3 sides raised (Female form)	2	6.3%	2	5.6%	4	5.9%
Raised (Female form)	0	0.0%	3	8.3%	3	4.4%
Total	32	100.0%	36	100.0%	68	100.0%

Table 3.29. Trotter direct auricular surface analysis

Auricular surface elevation	Male		Female		Total	
	N	%	N	%	N	%
Not raised (Male form)	4	12.9%	6	14.3%	10	13.7%
1 side raised (Male form)	17	54.8%	15	35.7%	32	43.8%
2 sides raised (Indeterminate)	6	19.4%	15	35.7%	21	28.8%
3 sides raised (Female form)	1	3.2%	2	4.8%	3	4.1%
Raised (Female form)	3	9.7%	4	9.5%	7	9.6%
Total	31	100.0%	42	100.0%	73	100.0%

Table 3.30. Trotter photographic auricular surface analysis

Auricular surface elevation	Male		Female		Total	
	N	%	N	%	N	%
Not raised (Male form)	4	12.9%	1	2.4%	5	6.8%
1 side raised (Male form)	8	25.8%	12	28.6%	20	27.4%
2 sides raised (Indeterminate)	5	16.1%	9	21.4%	14	19.2%
3 sides raised (Female form)	3	9.7%	1	2.4%	4	5.5%
Raised (Female form)	11	35.5%	19	45.2%	30	41.1%
Total	31	100.0%	42	100.0%	73	100.0%

Table 3.31. NMNH paired correlations for direct measurements

Feature analyzed	Direct measurements			Photographic measurements		
	N	Correlation	Sig.	N	Correlation	Sig.
Measurements						
R iliac length & L iliac length	108	.980	.000	106	.991	.000
R pubic length & L pubic length	84	.978	.000	82	.978	.000
R ischial length & L ischial length	99	.989	.000	100	.993	.000
R sciatic notch angle & L sciatic notch angle	107	.884	.000	107	.908	.000
R sciatic notch width & L sciatic notch width	107	.872	.000	107	.875	.000
R sciatic notch depth & L sciatic notch depth	107	.813	.000	107	.836	.000
R sciatic notch shape & L sciatic notch shape	107	.541	.000	109	.655	.000
R anterior sciatic notch & L anterior sciatic notch	106	.760	.000	108	.781	.000
R posterior sciatic notch & L posterior sciatic notch	106	.871	.000	106	.890	.000
R arch criterion & L arch criterion	107	.832	.000	103	.552	.000
R auricular surface & L auricular surface	104	.699	.000	101	.709	.000
R subpubic angle & L subpubic angle	49	.641	.000	42	.812	.000
R pubic body width & L pubic body width	55	.884	.000	41	.872	.000
Indices						
R sciatic notch index & L sciatic notch index	107	.666	.000	107	.834	.000
R anterior/posterior sciatic notch index & L anterior/posterior sciatic notch index	106	.744	.000	106	.696	.000
R iliac/sciatic notch index & L iliac/sciatic notch index	107	.730	.000	105	.666	.000
R pubic index & L pubic index	55	.567	.000	41	.595	.000
R ischio-pubic index & L ischio-pubic index	80	.859	.000	79	.858	.000

Table 3.32. Paired t-test p-values for right and left measurements for the three samples for direct and photographic metric measurements

	NMNH		HTH		Trotter	
Features tested	Direct	Photo	Direct	Photo	Direct	Photo
Measurements						
R iliac length - L iliac length	.375	.534	.006**	.305	.407	.253
R pubic length - L pubic length	.012*	.521	.673	.455	.954	.061
R ischial length - L ischial length	.338	.203	.291	.543	.840	.517
R sciatic notch angle - L sciatic notch angle	.057	.001**	.674	.235	.001**	.089
R sciatic notch width - L sciatic notch width	.125	.077	.167	.417	.967	.084
R sciatic notch depth - L sciatic notch depth	.000**	.203	.705	.240	.757	.679
R anterior sciatic notch - L anterior sciatic notch	.001**	.010**	.061	.005**	.000**	.126
R posterior sciatic notch - L posterior sciatic notch	.000**	.430	.004**	.675	.883	.139
R subpubic angle - L subpubic angle	.122	.059	.624	.847	.034*	.792
R pubic body width - L pubic body width	.005**	.176	.858	.638	.000**	.233

* - indicates statistically significant findings at .05; ** indicates statistically significant at .01 level, for 2-tailed significance

Table 3.33. HTH paired correlations for direct and photographic measurements

Feature analyzed	Direct measurements			Photographic measurements		
	N	Correlation	Sig.	N	Correlation	Sig.
Measurements						
R iliac length & L iliac length	37	.999	.000	35	.998	.000
R pubic length & L pubic length	37	.993	.000	34	.990	.000
R ischial length & L ischial length	37	.995	.000	35	.994	.000
R sciatic notch angle & L sciatic notch angle	36	.884	.000	34	.941	.000
R sciatic notch width & L sciatic notch width	37	.982	.000	25	.947	.000
R sciatic notch depth & L sciatic notch depth	37	.985	.000	35	.983	.000
R sciatic notch shape & L sciatic notch shape	35	.850	.000	34	.647	.000
R anterior sciatic notch & L anterior sciatic notch	37	.976	.000	35	.953	.000
R posterior sciatic notch & L posterior sciatic notch	37	.973	.000	35	.948	.000
R arch criterion & L arch criterion	34	.825	.000	35	.767	.000
R auricular surface & L auricular surface	37	.892	.000	35	.733	.000
R subpubic angle & L subpubic angle	36	.979	.000	34	.789	.000
R pubic body width & L pubic body width	35	.982	.000	34	.978	.000
Indices						
R sciatic notch index & L sciatic notch index	37	.921	.000	35	.853	.000
R anterior/posterior sciatic notch index & L anterior/posterior sciatic notch index	37	.811	.000	35	.624	.000
R iliac/sciatic notch index & L iliac/sciatic notch index	37	.896	.000	35	.721	.000
R pubic index & L pubic index	34	.763	.000	34	.647	.000
R ischio-pubic index & L ischio-pubic index	36	.889	.000	35	.890	.000

Table 3.34. Trotter paired correlations for direct and photographic measurements

Features tested	Direct measurements			Photographic measurements		
	N	Correlation	Sig.	N	Correlation	Sig.
Measurement						
R iliac length & L iliac length	36	.989	.000	37	.743	.000
R pubic length & L pubic length	36	.971	.000	36	.962	.000
R ischial length & L ischial length	37	.978	.000	36	.971	.000
R sciatic notch angle & L sciatic notch angle	36	.743	.000	36	.643	.000
R sciatic notch width & L sciatic notch width	36	.753	.000	36	.542	.001
R sciatic notch depth & L sciatic notch depth	36	.670	.000	36	.807	.000
R sciatic notch shape & L sciatic notch shape	36	.700	.000	36	.567	.016
R anterior sciatic notch & L anterior sciatic notch	36	.767	.000	36	.489	.002
R posterior sciatic notch & L posterior sciatic notch	36	.896	.000	36	.753	.000
R arch criterion & L arch criterion	36	.862	.000	36	.875	.000
R auricular surface elevation & L auricular surface elevation	36	.472	.004	36	.545	.001
R subpubic angle & L subpubic angle	8	.583	.129	14	.492	.074
R pubic body width - L pubic body width	18	.838	.000	16	.761	.001
Indices						
R sciatic notch index & L sciatic notch index	36	.360	.031	36	.660	.000
R anterior/posterior sciatic notch index & L anterior/posterior sciatic notch index	36	.691	.000	36	.576	.000
R iliac/sciatic notch index & L iliac/sciatic notch index	36	.778	.000	36	.587	.000
R pubic index & L pubic index	18	.413	.088	16	.590	.016
R ischio-pubic index & L ischio-pubic index	80	.859	.000	35	.867	.000

Table 3.35. Independent t-test p-values for male versus female measurements for the three samples using direct and photographic metric measurements

Features tested	NMNH		HTH		Trotter	
	Direct	Photo	Direct	Photo	Direct	Photo
R iliac length	.147	.177	.018*	.018*	.416	.534
R pubic length	.567	.436	.010**	.013*	.880	.636
R ischial length	.679	.824	.065	.073	.525	.491
R sciatic notch angle	.565	.398	.474	.058	.209	.301
R sciatic notch width	.748	.494	.004**	.013*	.763	.630
R sciatic notch depth	.398	.068	.019*	.021*	.547	.231
R anterior sciatic notch	.322	.044*	.027*	.019*	.155	.302
R posterior sciatic notch	.856	.903	.004**	.009**	.899	.822
R subpubic angle	.191	.512	.004**	.191	.680	.592
R pubic body width	.480	.768	.051	.002**	.811	.141
L iliac length	.231	.179	.017*	.014*	.495	.714
L pubic length	.548	.427	.005**	.022*	.865	.703
L ischial length	.751	.691	.040*	.080	.317	.198
L sciatic notch angle	.327	.390	.420	.161	.816	.953
L sciatic notch width	.822	.967	.005**	.004**	.539	.048*
L sciatic notch depth	.439	.175	.028*	.033*	.051	.090
L anterior sciatic notch	.200	.415	.050*	.034*	.091	.012*
L posterior sciatic notch	.672	.972	.003**	.005**	.927	.412
L subpubic angle	.093	.779	.001**	.081	.247	.509
L pubic body width	.642	.866	.033*	.003**	.521	.721

* - indicates statistically significant findings at .05; ** indicates statistically significant at .01 level, for 2-tailed significance

Table 3.36. Correlations to sex for each sample by trait, right and left side direct measurements.

	Right measurements						Left measurements					
Feature	NMNH		HTH		Trotter		NMNH		HTH		Trotter	
Age[1]	0.238		0.045	*	0.681							
Measurement												
Iliac length	0.147		0.018	*	0.416		0.231		0.017	*	0.495	
Pubic length	0.567		0.010	**	0.880		0.548		0.009	**	0.865	
Ischium length	0.679		0.065		0.525		0.751		0.040	*	0.317	
Sciatic notch angle	0.565		0.474		0.209		0.327		0.420		0.816	
Sciatic notch width	0.748		0.004	**	0.763		0.882		0.005	**	0.539	
Sciatic notch depth	0.398		0.019	*	0.547		0.439		0.028	*	0.051	
Sciatic notch shape	0.027	*	0.624		0.160		0.460		0.639		0.184	
Anterior sciatic notch	0.322		0.027	*	0.155		0.200		0.050	*	0.091	
Posterior sciatic notch	0.856		0.004	**	0.899		0.672		0.003	**	0.927	
Arch criterion	0.852		0.613		0.794		0.580		0.613		0.336	
Auricular surface[2]	0.365		0.054		0.157		0.114		0.003	**	0.937	
Subpubic angle	0.191		0.004	**	0.680		0.093		0.001	**	0.247	
Pubic body width	0.480		0.051		0.811		0.642		0.056		0.521	
Indices												
Sciatic notch index	0.652		0.545		0.611		0.827		0.583		0.084	
Anterior/posterior sciatic notch index	0.414		.001	**	0.125		0.167		0.028	*	0.011	*
Iliac/sciatic notch index	0.169		0.008	**	0.672		0.325		0.010	**	0.899	
Pubic index	0.796		0.547		0.082		0.444		0.787		0.063	
Ischio-pubic index	0.629		0.002	**	0.878		0.881		0.000	**	0.533	

[1] This reports age to sex, and is not split by right and left sides
[2]Spearman's rho Correlation, with the remainder analyzed with Pearson Correlation
* - indicates statistically significant findings at .05; ** indicates statistically significant at .01 level, for 2-tailed significance

Table 3.37. Correlations to sex for each sample by trait, right and left side pooled.

Feature	Direct measurements						Photographic measurements					
	NMNH		HTH		Trotter		NMNH		HTH		Trotter	
Measurement												
Iliac length	0.060		0.001	**	0.283		0.056		0.001	**	.956	
Pubic length	0.405		0.000	**	0.818		0.265		0.001	**	.533	
Ischium length	0.605		0.005	**	0.237		0.658		0.011	*	.156	
Sciatic notch angle	0.266		0.273		0.484		0.226		0.018	*	.445	
Sciatic notch width	0.697		0.000	**	0.507		0.600		0.000	**	.092	
Sciatic notch depth	0.257		0.001	**	0.064		0.024	*	0.001	**	.041	*
Sciatic notch shape	0.039	*	0.491		0.049	*	0.036	*	0.358		.056	
Anterior sciatic notch	0.112		0.006	**	0.025	*	0.004	**	0.005	**	.012	*
Posterior sciatic notch	0.688		0.000	**	0.959		0.950		0.000	**	.666	
Arch criterion	0.598		0.466		0.373		0.222		0.027	*	.924	
Auricular surface[1]	0.091		0.000	**	0.338		0.020	*	0.642		.348	
Subpubic angle	0.030	*	0.000	**	0.356		0.524		0.008	**	.977	
Pubic body width	0.389		0.003	**	0.499		0.933		0.000	**	.198	
Indices												
Sciatic notch index	0.640		0.008	**	0.090		0.062		0.027	*	.318	
Anterior/posterior sciatic notch index	0.001	**	0.833		0.086		0.015	*	0.079		.080	
Iliac sciatic notch index	0.083		0.000	**	0.698		0.190		0.071		.435	
Pubic index	0.754		0.538		0.018	*	0.046	*	0.086		.699	
Ischio-pubic index	0.835		0.000	**	0.590		0.564		0.000	**	.603	

[1] Spearman's rho Correlation, the remainder were analyzed with Pearson Correlation

* - indicates statistically significant findings at .05; ** indicates statistically significant at .01 level, for 2-tailed significance

Table 3.38. T-test significance values for the three samples, right and left direct measurements, photographic versus direct method

Features tested	NMNH		HTH		Trotter	
R iliac length	0.000	**	0.054		.957	
R pubic length	0.007	**	0.039	*	.523	
R ischial length	0.000	**	0.074		.626	
R sciatic notch angle	0.000	**	0.000	**	.000	**
R sciatic notch width	0.000	**	0.000	**	.384	
R sciatic notch depth	0.000	**	0.326		.266	
R anterior sciatic notch	0.559		0.350		.021	*
R posterior sciatic notch	0.000	**	0.054		.000	**
R subpubic angle	0.000	**	0.190		.042	*
R pubic body width	0.000	**	0.015	*	.001	**
L iliac length	0.000	**	0.030	*	.665	
L pubic length	0.000	**	0.019	*	.903	
L ischial length	0.000	**	0.029	*	.483	
L sciatic notch angle	0.000	**	0.000	**	.000	**
L sciatic notch width	0.205		0.000	**	.099	
L sciatic notch depth	0.622		0.077		.371	
L anterior sciatic notch	0.885		0.000	**	.074	
L posterior sciatic notch	0.000	**	0.741		.020	*
L subpubic angle	0.000	**	0.148		.248	
L pubic body width	0.000	**	0.056		.014	*

* - indicates statistically significant findings at .05; ** indicates statistically significant at .01 level, for 2-tailed significance

Table 3.39. Logistic regression summary of stepwise selection, statistically significant variables

Step	Variable	Chi square	df	P-value
1	Right sciatic notch shape	7.2416	1	0.0071
2	Right sciatic notch width/iliac length index	4.3081	1	0.0379

Table 3.40. Discriminant function analysis for all traits

Function	Eigenvalue	% of variance	Cumulative %	Canonical correlation
1	0.9	100	100	0.688

Table 3.41. Discriminant function analysis for traits on the ilium only

Function	Eigenvalue	% of variance	Cumulative %	Canonical correlation
1	0.157	100	100	0.369

Table 3.42. Discriminant function table for three statistically significant variables

Variable	Coefficient
Right sciatic notch shape	-1.4489
Right ischio-pubic index	-0.3548
Right sciatic notch width/iliac length index	10.1326
Constant	-2.4613
Below .5 is female, above .5 is male	

4.0 DISCUSSION

4.1 INTRODUCTION

4.1.1 Hypotheses and goals

The multiple hypotheses for this study required the collection of 13 skeletal measurements from three different pelvic samples. Making comparisons with previous studies has been challenging as prior studies by other researchers were conducted in unique or sometimes contradictory ways for each trait and feature under analysis. This study was developed in part to bridge the differences found in these previous studies. This section discusses the general results for each sample examined and then compares these results to recognize how these results differ from or confirm the previous findings. Issues with the various analyses will be discussed as well as recommendations for further research and clearer analysis techniques.

4.1.2 Populational differences

As one of the goals of this study was to recognize how sexual dimorphism varied from sample to sample, it was necessary to appreciate how the samples differed from one another. The most profound difference was in sample size available for research. The NMNH collection consisted of 113 individuals, with a balanced ratio between the sexes (56 males, 57 females), while both the HTH and Trotter collections were much smaller, both with only 37 individuals in each. The HTH sample was nearly equally divided at 18 males and 19 females, while the Trotter sample included 16 males and 21 females. Small sample sizes may have affected results, especially as the HTH collection distribution was spread over a much wider age range. This was a concern I kept in mind throughout my analysis and will discuss some of the limitations placed on interpretations later in this chapter. One further issue concerning the HTH collection was the variation in body size that accompanied the differences in ages. While the majority of the NMNH and Trotter skeletal remains were quite similar in size and condition, the HTH sample varied widely in size and stage of fusion of the pelvic epiphyses. This was considered during the analysis by comparing patterns found within each sample instead of comparing length measurements and adjusting the manner in which photographs were taken to account for bone shape differences. In addition, by using the NMNH sample as the primary sample, the two smaller collections were not used for any model development.

4.1.3 Paired bone differences

While the left side was commonly used in prior analyses, comparative studies did not consistently state which side or sides were evaluated. The analysis of right versus left sides was valuable to determine if statistically significant differences existed between the two sides of the body on one individual. As recovery of only one side may occur, knowing whether the two sides can be used interchangeably was necessary. In addition, if the two sides were considered the same, the data from each side was pooled for analysis.

Comparisons of right and left sides for paired measurements revealed that the NMNH sample had the highest number of features at a statistically significant level at nine measurements and indices. The Trotter sample, which contained bones of similar size to the NMNH sample, had fewer than the NMNH sample, with only seven statistically significant measurements and indices, but this was still more than the HTH sample at only four features at a statistically significant level. This may be due to the size of the bones and the small measurement values, as many features measured less than 10 millimeters. Previous findings showed that the length of a measurement reflected its reliability as smaller measures had poorer reliability than larger measures (Jamison and Ward 1993). While measurement size was not the only possible reason why statistical significance levels varied, it clearly played a role. Fewer features displayed statistically significant levels in the photographic analyses for the three samples. This may be the result of measuring photographs on a computer screen, which compensates for small measurement bias in some way.

It should be noted that the sciatic notch shape evaluation differed between the right and left sides in the Trotter collection, as many right sides were scored as symmetric while the left sides were assessed as asymmetric. Perhaps the photographic technique detected asymmetry in the sides that was not observable in direct measurements, but sample size may play a role as this result was not evident in the other two samples. Further analysis, with tests for intra- and inter-observer error, should be conducted to better understand why right and left sides should differ within a sample.

4.1.4 Issues

In the fetal and infant material, particularly the fetal material, the pubic width and subpubic angle were not always evaluated. In the very young, these elements were not sufficiently complete to take an accurate measurement, as the pubis is the last bone to develop of the three components (Hill 1939; McAuley and Uhthoff 1990). As seen in Figure 4.1, the pubic symphyseal surface was well-formed, with a clearly developing ramus beneath, which allowed for measurement of both the subpubic angle and pubic body width. The pubic bone on Figure 4.2, on the other hand, exhibited an underdeveloped symphysis with no ramus formation below it. Also, this area commonly was found deteriorated and varied widely in condition, both in the NMNH and Trotter material. Many individuals lacked this feature, which compromised the ability to accurate measure and evaluate these two traits via statistical analysis.

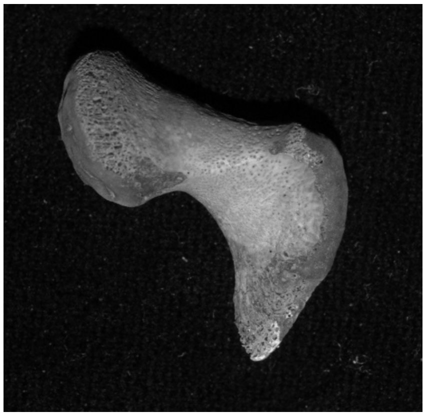


Figure 4.1. Right pubis, NMNH 249599

Figure 4.2. Right pubis, NMNH 228827

4.2 GENERAL SEXUAL DIMORPHISM ANALYSIS

Although many traits correlated with sex in each of the populations, this did not lead to an apparent means of determining the sex of an individual. Many of the traits that were statistically significant in other studies, such as visual assessment of the sciatic notch angle or arch criterion, did not reveal the same patterns in this study. While several metric traits were found to be statistically significant, these features were not without issue. In particular, the sciatic notch and its measurements showed an immense degree of variation both within each sample population and between the collections.

No single trait was associated with biological sex across the three samples. The ones that were found to be so in at least two populations were the subpubic angle and sciatic notch shape for direct measurements, and the sciatic notch depth and anterior sciatic notch for photographs. It was anticipated that the Trotter and NMNH samples would be most similar, as they contained individuals of roughly the same age. But for sciatic notch angle, arch criterion, auricular surface, and sciatic notch shape visual analysis, the two populations were no more similar to one another than with the HTH sample with older individuals. This underscores the variation seen during this analysis and also may provide an explanation as to why we do not see similar results in previous studies which have compared differing populations. Ambiguous feature shapes were observed both within and between the samples; one example was the sciatic notch shape, as a wide variety of shapes were found, far more than discussed by previous authors. Figures 4.3- 4.6 illustrate this point.

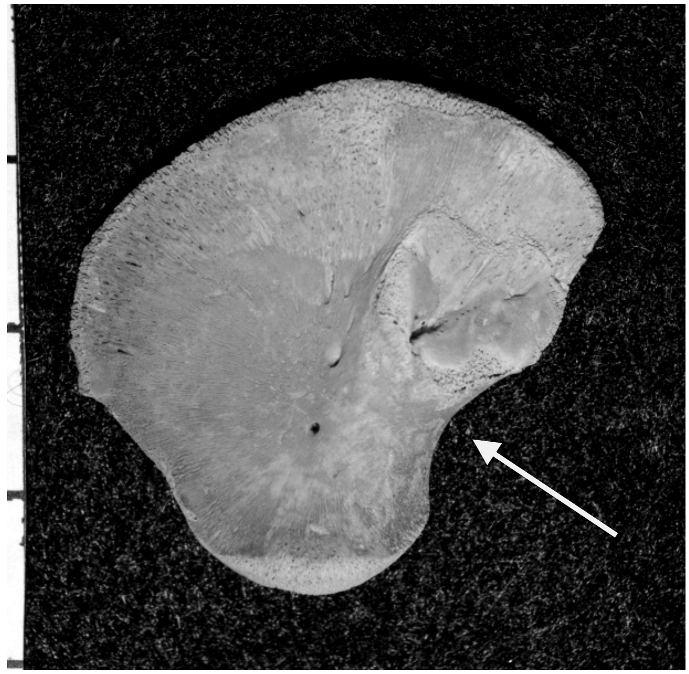


Figure 4.3. Male wide notch, NMNH224872

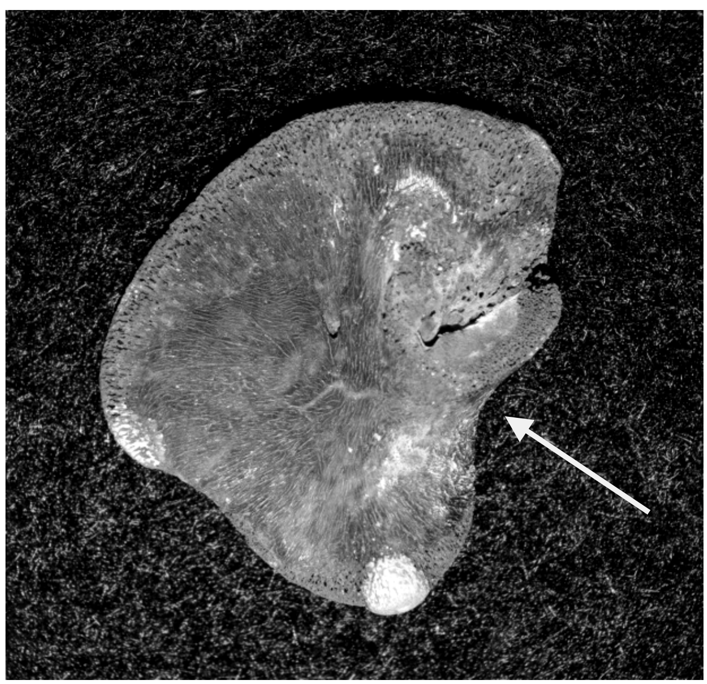


Figure 4.4. Female wide notch, NMNH253844

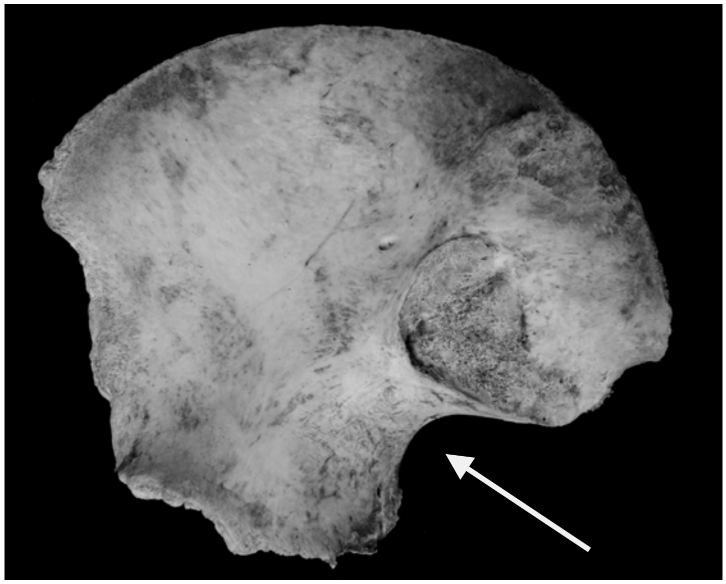


Figure 4.5. Male narrow notch, HTH0404

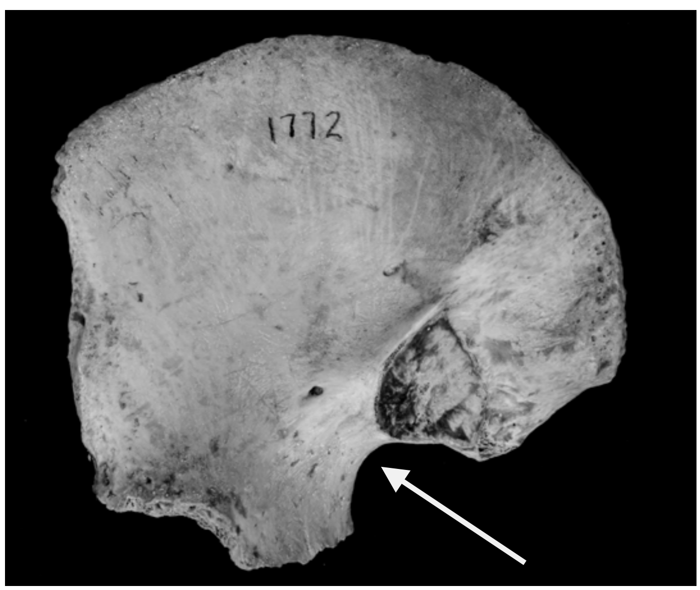


Figure 4.6. Female narrow notch, HTH1772

Few features between males and females in the NMNH sample were considered to be sexually dimorphic, with only one out of 13 at a statistically significant level for direct assessment and none in the photographic analysis. Conversely, most features correlated to sex in the HTH sample at a statistically significant level, with half of the features correlating to sex in the direct analysis, and the pubic body width approaching statistical significance. For the photographic analysis, nine traits were statistically significant, with the pubic body width again approaching statistical significance. Interestingly, even though the sciatic notch shape was useful to distinguish shape in the NMNH testing, both correlations and t-tests, this feature was absent for any statistically significant findings in the HTH sample. No correlations were found in either of the evaluative methods for the Trotter material. When the right and left sides were pooled, the analysis changed slightly, as more traits were found to be at a statistically significant level than in the right/left separated group. About half of the traits that rose to a statistically significant level in the pooled analysis were approaching statistical significance in the separated analysis. While sexually dimorphic traits were evident in each population, no trait was consistently dimorphic between the sexes in the three samples.

Differences observed in the means between direct and photographic measurements in the NMNH population may point to a difference in the ability to take the measurement, especially for features such as angles or the sciatic notch depth, which can be awkward to directly measure from the bone. While the majority of traits in the HTH population correlated with sex, differences existed in the sciatic notch angle correlations between photographic and direct measurements. As age was statistically significant in correlations, it must play some role in the development of the traits.

Even when obvious sexual dimorphism was found for an element, it was evident from graphic analysis, for instance the box plots in the results section (Figures 3.18, 3.20, and 3.21), that a great deal of overlap occurred between the measurements of the two sexes. Only traits with minimal overlap are beneficial in the development of sex determination methods. The feature that most closely met this requirement was the HTH direct measurements of the sciatic notch width (Figure 4.7). This graphic clearly illustrated that the means were different between the sexes, and while some overlap existed, it was less than what was exhibited in other features.

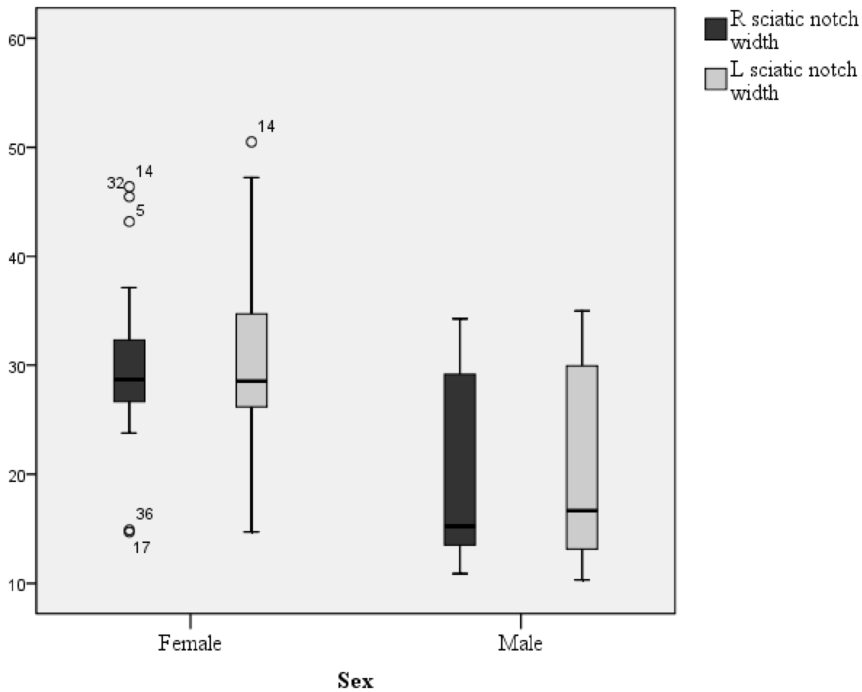


Figure 4.7. HTH direct measurement right versus left sciatic notch width for males and females

4.3 FEATURE ANALYSIS

4.3.1 Iliac length

The iliac length varied between sample populations, as the NMNH population did not show any sexual dimorphism for this trait, but the HTH sample did. In the HTH sample, the iliac length also correlated to age, at the 0.001 statistical significance level. Iliac length means were similar between males and females in both the NMNH and Trotter studies, similar to the Thomson (1899) study. However, the HTH sample means varied greatly between males and females. This feature may be heavily age dependent, reflecting not just differences between different age groups, but rates of growth between males and females. A larger sample distribution is needed to truly understand the differences seen here, especially as the HTH sample's small size may have affected this outcome. The anterior and posterior iliac spines are required for the standardized iliac length measurement as seen in previous evaluations (Fazekas and Kósa 1978; Schaefer *et al.* 2009). However, this study did not find these endpoints easy to define. The development of the spines varied from absent to clearly discernable in both the NMNH and Trotter samples. This reflects Thomson's (1899) assessment of the width of the sciatic notch, in which he observed that the posterior inferior iliac spine varied considerably. To counteract this variation, the largest length measurement was used, as distinct spines were not always evident.

4.3.2 Pubic length

Means for male and female pubic length in the NMNH and Trotter samples were similar to one another, as seen in other fetal evaluations (Reynolds 1945; Thomson 1899) (Tables 3.1 and 3.5). The underdeveloped state or poor condition of some of the pubic bones for the very young individuals in both the Trotter and NMNH samples may partly explain this similarity. Of the three bones, the pubic bone had the fewest number available for study in these two samples.

The mean in the HTH sample differed between the sexes, with females larger than males, reflecting previous studies of older subadult individuals (Reynolds 1947; Washburn 1948). Males in this sample were primarily found in the under-eight year category while females were mainly over-eight years. Regardless, when ages were separated out, female means continued to be larger than male means (Table 4.1), reflecting results from Washburn (1948) who stated that female pubic bones increase in size beginning at age seven. Differences in growth rates existed between the ilium and the pubis, which was related to differential growth in the pubis. As the Trotter and NMNH samples did not share the HTH results, pubic bone growth must be reviewed further with a larger population.

Table 4.1. Mean of pubic bone length for the HTH sample

	Male	Female
Under 8 years	27.01	35.91
Over 8 years	50.24	53.85

4.3.3 Ischial length

The means of the ischium were similar in males and females with males larger than females in the NMNH and Trotter studies, which followed other studies (Rissech *et al.* 2003; Thomson 1899) (Tables 4.1 and 4.5). The HTH ischial length means were larger in the females than in males, but this may reflect sample age distributions as males in this group were primarily under age eight and females over age eight. When separated into over and under eight years, females displayed smaller means than males in the older category (Table 4.2), a result more in line with previous results (Reynolds 1947; Washburn 1948). An unusual finding in this study was the longer ischial length in the female individuals in the younger evaluation. While Reynolds (1945) first study of infant pelvic material showed that females means for ischial length were longer than males, this current study found longer means for males than in females for the NMNH and Trotter groups, both were similar in age to Reynolds' study. Older individuals from the HTH sample did show sexually dimorphic ischial lengths at statistically significant levels.

Table 4.2. Mean of ischial lengths for HTH sample

	Male	Female
Under 8 years	35.15	44.22
Over 8 years	66.71	64.04

4.3.4 Sciatic notch shape, width, depth, and angle

The sciatic notch has been evaluated previously in several different ways, including visual assessment, direct measurements, and morphometric analysis of the shape through digitizing methods. These studies have evaluated one or more of the notch's traits, including the width and depth of the notch, the angle of the notch and the overall morphology of the notch. It was difficult to parse out separate aspects of sciatic notch analysis. Due to this overlap, four of these traits will be discussed in this section.

Sciatic notch shape: Sciatic notch shape was correlated to sex in the NMNH population but not in the HTH population, suggesting that age influenced this feature. As earlier studies mentioned this feature as being sexually dimorphic in fetal samples (Boucher 1955; Thomson 1899), it was anticipated that this feature would be statistically significant across age groups. What was not anticipated was that the feature did not remain dimorphic for males and females throughout childhood. Further analysis of older children is needed to determine if this was only an issue of the size and sample age distribution of the HTH sample. Populational differences may explain these differences found in previous studies, such as between British and Portuguese populations (Cardoso and Saunders 2008; Vlak *et al.* 2008).

When examining the symmetric/asymmetric condition of the sciatic notch, a notch was considered symmetric when both the anterior and posterior sides of the notch were fairly equal in distance and the apex was fairly centered within the notch. Some notches were unproblematic and simple to assess, but many were difficult, as when the angle was obtuse and the notch had no easily discernable apex. Some of the notches showed an apex just slightly off-center, enough to require a categorization of asymmetric. The overall shape of this notch varied quite widely, with projections or anterior or posterior edges that made end point analysis more problematic (Figures 4.8 - 4.13). Future studies should attempt to use more quantitative features for this trait, and not rely on a binary assessment.

Figure 4.8. Right ilium, female, with clear apex and measurement points

Figure 4.9. Right ilium, female, with auricular surface within sciatic notch and unclear posterior measurement point

Figure 4.10. Right ilium, male, with auricular surface within sciatic notch and unclear posterior measurement point

Figure 4.11. Left ilium, male, with a low placement of the auricular surface in relation to sciatic notch and posterior iliac spine

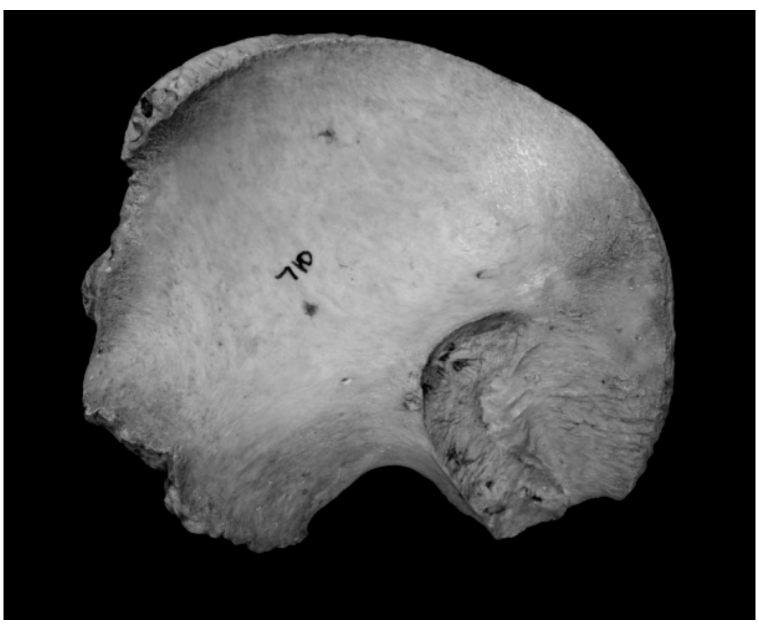


Figure 4.12. Right ilium, male, with clear apex and measurement points

Figure 4.13. Right ilium, male, with less well-defined apex

Overall, few individuals were correctly assigned to sex in any of the samples studied for sciatic notch shape. The three samples followed a similar trend, with the vast majority of individuals being scored as asymmetric. This result did not follow previous studies where the sciatic notch shape more clearly indicated male or female (Schutkowski 1993; Thomson 1899).

Sciatic notch width, depth, and angle: These three features needed to be discussed together as they have typically been evaluated in the same studies. While it may appear obvious that an individual with a sciatic notch width in the narrow range for that sample has a narrow angle, this was not always the case. Many individuals with quite narrow widths for the population had larger than expected angles in that sample, and those with narrow angles often had wider widths. However, when the means of the two groups were compared, they correlated to each other. Depth also correlated to the width and angle in analyses, so that these three features should be summarized as one subject area.

Wilson and colleagues (2008) evaluated a group of subadults from the Spitalfields collection and determined that the sciatic notch angles range was wider for females and was more condensed for males. In this study, the HTH was the only sample to follow this pattern (Figures 4.14 and 4.15), and the opposite was seen in the NMNH and Trotter samples (Figures 3.4 and 3.6). As Wilson examined individuals between ages one to eight years old, and the HTH sample covered the age ranges, this similarity may explain these results. This feature may broaden with age in females but not in males. In addition, the HTH sample displayed several females with sciatic notches much smaller than the males from that group. Males were expected to have lower sciatic notch angles than females, but clearly this was not the case. In addition, the overlap seen in these three groups between males and females indicated that this feature was not helpful in determining biological sex.

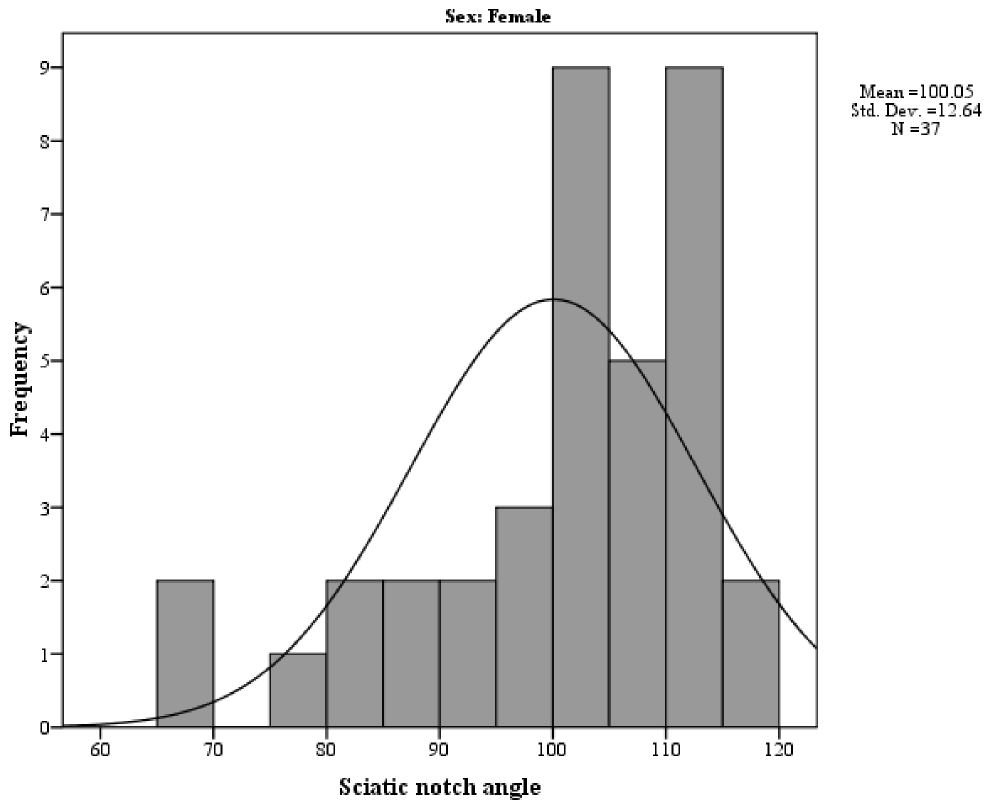


Figure 4.14. HTH sciatic notch angle measurements in degrees for females

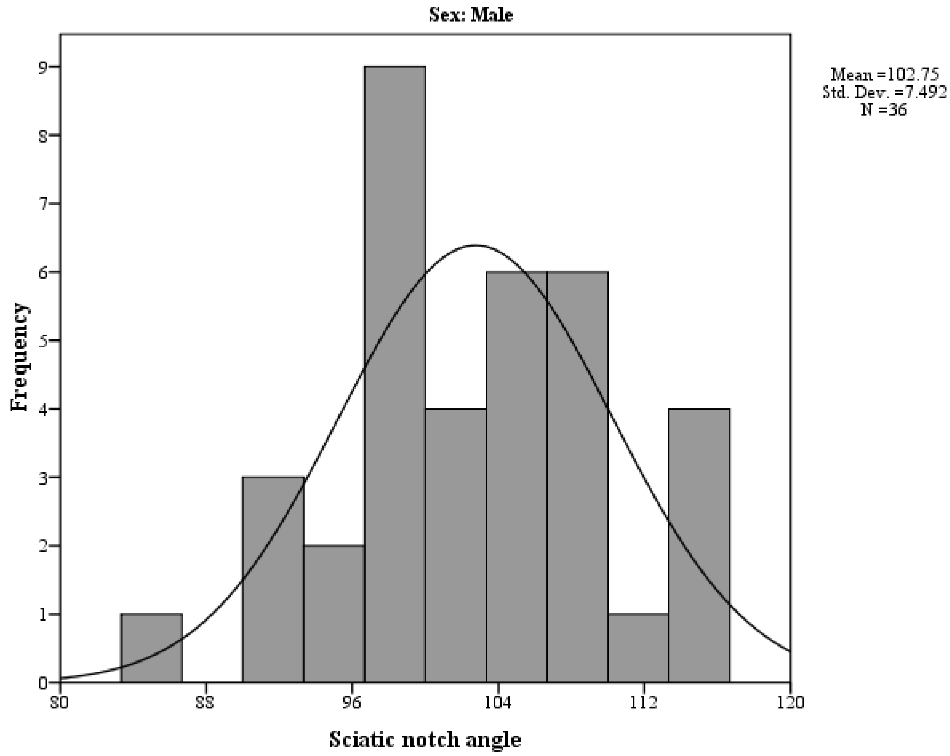


Figure 4.15. HTH sciatic notch angle measurements in degrees for male

Schutkowski (1993) determined that males were assessed at a 95% reliability level, and females at 71.4% in his sciatic notch research. This study of the NMNH and HTH samples found a surprisingly different pattern to Schutkowski's study as few sciatic notches were at or less than 90°. While many females were over 90°, the classification of males in this category was common too, as few were assessed at 90° or less. Of the males over 90°, many had extremely wide notches, which represented the female form. This assessment method did not provide an accurate means to determine sex in these individuals as nearly half of those over 90° were male. These findings correspond to the sciatic notch depth also discussed by Schutkowski as individuals with large angles had extremely wide and shallow sciatic notches. A majority of the NMNH males were assessed as female according to this method.

Schutkowski's study also found that males were more often correctly assigned than females, but this study found the opposite, as males were less often assigned to the correct category in both the NMNH and HTH samples (23% and 3% respectively). The HTH female group showed the highest correct assignment at 89%, which is nearly accurate enough for the *Daubert* standards of 90-95%. However, as the males in this group were more likely to be assigned to the female category, this trait revealed poor overall results. As can be seen in Table 4.3, males displayed a narrower range of notch values, with means similar to, but in fact, higher than females (male mean 102.75, female mean 100.05). For the Trotter collection, males fared better at 61% being correctly categorized as male. The distribution in the Trotter material differed from the other two populations as far more individuals were scored 90° or below. But surprisingly, nearly half of these were females. Only 61% of males and 48% of females were correctly assigned to sex using Schutkowski's methodology. In the photographic analysis, males fell into the over-90° category. This suggested Schutkowski's method cannot be applied to photographic analysis.

In addition, a group of three mid-to-late teenaged females from the HTH sample occurred in the male form utilizing Schutkowski's method. When using adult sciatic notch methods, these three individuals were categorized as female. Clearly, some change occurs during pubertal remodeling that makes standards of 90° for males or great-than 90° for females no longer applicable. This suggested that adult methods should be applied for these individuals and the infant and child assessment methods of Schutkowski do not apply to older subadults.

Comparisons of sciatic notch angle results with the Vlak and colleagues (2008) study, who found that sciatic notch angles decreased as age increased, showed mixed results. In the NMNH sample, the angle size decreased for males but not females with increasing age. In the

HTH material, the sciatic notch angle size was smaller in older individuals in both males and females, although at differing rates (Figure 3.34). The Trotter sample showed a completely different result as male sciatic notch angle size increased while female sciatic notch angle size decreased with age. As the makeup of the NMNH and Trotter samples were most similar, it was anticipated that these two would show similar results. Since they did not, this trait may be more population specific than age related in nature. This confirms and explains the inconsistencies found between the British and Portuguese findings of Schutkowski (1993) and Vlak and colleagues (2008) respectively.

In a study by Nakao (1998), greater sciatic notch width was sexually dimorphic in those fetuses with a greater than 40 cm in fetal length, usually those older than eight lunar months. In this study, sciatic notch width was not statistically significantly dimorphic between males and females in the two young samples containing fetal and newborn material over eight lunar months. In both the NMNH and HTH samples, this trait was statistically significantly correlated with age as well. This trait was sexually dimorphic in the HTH material at a statistically significant level. Nakao also evaluated sciatic notch height (depth) and did not find any statistically significant association with sex. This current study found mixed results, with NMNH photographic and both HTH direct and photographic methods correlating to sex. The NMNH and HTH direct and photographic measures also correlated to age. Therefore, it is suggested that although sexual differences occurred in sciatic notch width and height, there was also an association with age. While sexual differences can be identified, further analysis is required to fully understand the factors acting on these traits.

4.3.5 Subpubic angle

In the NMNH sample, the subpubic angle correlated to pubic length and pubic body width, suggesting a connection in the growth of the pubic body to overall somatic growth, especially at this early age. When this trait was available for analysis, angle measurement was straightforward; however, those individuals with unformed, under-formed, or deteriorated pubic bones were omitted for this feature. This data was missing in 55% of the NMNH sample and 52% of the Trotter material. This was expected for the age of the individuals contained in these collections. In the HTH material, only one individual was missing data for this feature, with a recorded age of one year old.

In the first study of this trait, Thomson (1899) determined that the subpubic angle was easy to assess and was smaller in males than in females, on average 50.5° in males and 67.7° in females. Measured with the pubic symphyses united, the measurement reflects the entire subpubic angle. If the means for the right and left sides from this current study were added together, the entire subpubic angle region was replicated. In the NMNH group, males averaged 54.5° and females averaged 59.3°, with the left side larger than the right side. For the HTH direct sample, males averaged 56.0° while females averaged 71.4°, and in the Trotter collection, males averaged 43.8° and females 50.2°. These results were similar to Thomson's smaller subpubic angles in males. While the NMNH sample showed a small range, the HTH had a range larger than seen in Thomson's study. Differences may relate to the growth and development of the pubic bone. The Trotter measurements were smaller overall than in the other two samples, but males continued to have smaller angles than females. Clearly the subpubic angle means were sexually dimorphic in the three samples and were consistent with Thomson's early study.

Thomson (1899) also analyzed the subpubic angle via photographs as he found this to be easier and more accurate technique. However, this was not replicated with the photographic analysis for this study. In the NMNH photographic method, males averaged larger subpubic angles than females, at 68.6° and 66.6° respectively. The HTH photographic sample followed the results of Thomson, with males averaging 62.3° and females at 69.5°. Males and females showed virtually no difference in the Trotter photographic assessment, with 73.0° and 73.23° respectively.

4.3.6 Pubic body width

Pubic body width assessment was not conducted previously on subadult material. Few adult studies are known, and in these studies, the ventral arc and pubic body width were primarily evaluated visually, with the metric analysis virtually untested. However, discussions with Judy Suchey, known for pubic symphysis analysis, regarding tests she conducted on the pubic body width led me to question this feature's usefulness for subadults. To date, there have been no publications regarding this metric evaluation of the feature either in adults or subadults. While it is known that the ventral arc develops later in puberty, at about 16 to 17 years of age, it is unclear how overall pubic body size relates to growth.

The analysis of the three populations found that pubic body width was not associated with sex when right and left sides were separated, although the HTH population approached statistically significance. However, in the fetal age group, many times this feature was not developed sufficiently for measurement and in both the NMNH and Trotter samples, roughly half of the individuals were not evaluated for this trait. The pubic symphyseal face was also difficult to ascertain, as this feature must be clear for this measurement, adding to the number of missing measurements. This feature was much easier to assess in older children (six months and over), and this is reflected in the correlation values.

Graphically, when this trait was appraised in the HTH population, females obtained larger pubic body widths than males, even at early ages (Table 4.3 and Figures 3.30 and 3.31). This was also seen in the Trotter sample, for those at birth or older. Again, as the pubic body was not adequately formed at the fetal/newborn ages, few of those in the fetal/newborn age range were analyzed for this trait. The NMNH population was heavily skewed to the newborn age group, so that nearly half were not evaluated for this trait. For those who were measured, graphs indicated that males grow less quickly in this feature (Figures 3.28 and 3.29). This research suggested that females had variations in growth in the pubic body area at a younger age than males do, which did not support previous ventral arc studies that suggested that the pubic bone grew differentially only in the late teen/early adult years (Anderson 1990; Sutherland and Suchey 1991), this finding provided evidence that divergence in pubic body growth between males and females starts in early childhood. More analysis on this feature on subadults with well developed pubic bodies is required to test the validity of this assessment. In particular, samples with larger numbers of individuals of pre-pubertal and pubertal ages would aid in understanding the role that puberty plays on this trait.

4.3.7 Auricular surface

Two methods were used to evaluate the auricular surface elevation, a binary approach and a ranked approach. In the NMNH direct sample, females had more raised surfaces than males, with males showing the not raised form. While this confirmed previous studies (Weaver 1980), the number of females in the not raised form was too high to create a means of distinguishing sex. Regardless of which evaluative method was used, the results did not strictly correspond with previous trait analysis. One problem was the variation found in this trait, as the surface ranged from clearly marked and easy to distinguish elevations to half raised sides or questionable elevations. Few surfaces were completely and obviously flush to the bone, and only these were considered not raised. In photographs, this feature was easier to distinguish than directly on bones, perhaps because the camera provided a more distinct edge than what was seen by the naked eye. However, this did not change the overall results, as increases were only seen in the not raised female category. Moreover, as accuracy was reduced using photographs, the percentage correctly assigned to sex was more accurate in direct analysis, at 61%, compared to only 48% in the photographic analysis. In the HTH material, more males were found in the not raised category, and fewer females were raised. Correct sex assignment was 58% for direct and 51% for photographic analysis, higher than in the NMNH sample, but neither provided a better evaluative method than chance provided. In the Trotter material, more males were in the not raised state – unfortunately, so were many females.

One thing unaccounted for when initially reviewing this feature was the fact that several of individuals actually had depressed auricular surfaces, with the bone having a lytic appearance. This may reflect some pathology suffered by the individual or normal variation. While etiology was unclear, this condition was not anticipated and was not previously mentioned in the literature.

Weaver (1980) evaluated the NMNH sample for this feature, and correctly identified 85.4% of males and 57.7% of females (Table 4.3). This current study did not replicate these results, as only 72% of males and 39% of females were correctly assigned using Weaver's methods. Weaver assessed individuals in age groups (fetal, newborn, six months). The highest accuracy rate found by Weaver was in the fetal group of 48 individuals, with males at 92% and females at 75% accuracy, but the newborn and six month age categories at lower levels. Additionally, Weaver's study required elevation of the entire anterior and posterior edges to be classified as raised, omitting individuals without complete elevation along one or both sides or those elevated on superior and inferior sides, but not anterior and/or posterior sides. This current study found many intermediate conditions of elevation, with many surfaces exhibiting superior and anterior elevated surfaces but not posterior. This may explain the differences in results between this study and Weaver's of the same population. In addition, this study did not separate the individuals into the fetal, newborn, six month age groups as Weaver did, but evaluated the sample as a whole. It should be noted that it is possible that the two studies did not evaluate the same individuals as neither study evaluated the complete NMNH collection. Regardless, neither study categorized the sexes sufficiently for sex determination method requirements.

Table 4.3. Comparison of auricular surface elevation studies of correctly sexed individuals

Study	Male	Female	Combined
Weaver (1980)	85.4%	57.7%	73.5%
Mittler & Sheridan (1992)	85.3%	58.3%	74.1%
Sutter (2003)	84.6%	58.3%	72.0%
NMNH			
Binary technique	72.0%	39.0%	46.5%
Ranked technique	57.9%	50.9%	51.6%
HTH			
Binary technique	57.6%	30.6%	43.5%
Ranked technique	57.6%	50.0%	53.6%
Trotter			
Binary technique	12.9%	9.5%	11.0%
Ranked technique	67.7%	13.7%	37.0%

Hunt's (1990) evaluation of this trait was conducted on a sample in which sex was not known. He anticipated a 1:1 sex distribution ratio, but a much higher 6:1 ratio was actually produced in his research. A weak association to sex was suggested, as Hunt found this trait correlated more directly with age. The analysis of the three samples for this study found that age correlated with the HTH and NMNH samples, but not the Trotter sample. This trait only correlated with sex in the HTH sample for direct measurements and the NMNH sample for photographic measurements. Utilizing Weaver's method, this study followed Hunt's results more closely than Weaver's; however sex was not known in Hunt's study.

Mittler & Sheridan (1992) tested Weaver's (1980) methods, and correctly assigned sex in 74.1% of individuals (males 85.3% and females 58.3%). Age played a role in reliability as older individuals (10-18 yrs) were more correctly sexed (males 100% and females 66.7%). In this study, those individuals in the HTH sample aged 10 – 16 were evaluated separately; however, sex designation did not improve. As individuals in this age group were all considered "not raised", this correctly assigned males and incorrectly selected females.

If the sides were separated and ranked individually, a technique seen in Sutter's (2003) article, sex assessment did not improve. This current study showed 57.9% of males and 50.9% of females in the NMNH sample with a raised surface on two or more sides, (Table 4.3). Over 23% of females did not demonstrate a raised surface, while 28% of males expressed a completely raised surface. This pattern was not followed in the HTH sample, as males were more often found in the not raised state and females in the raised condition.

Rates of correct sex assignment for the three samples from this study (Table 4.3) illustrate that this feature was not useful for determining sex of subadults. Furthermore, as suggested by Hunt, this feature may be driven more by age than sex. Population variation could also account for the differing results; however, since this study evaluated the same collection as Weaver and found different results, it may reflect differences in age makeup between the Weaver sample and the NMNH sample used in this study. The lack of correlation between this feature and sex (see Table 4.37) as well as lack of equality in t-tests also established this point.

4.3.8 Arch criterion

For the arch criterion evaluation, males fared poorly, as nearly 67% of those determined as males were actually females. Overall, females were assessed correctly the majority of the time, similar to what was seen in the NMNH population, although less overwhelmingly. Also similar to NMNH, the majority of the borderline cases were actually male.

For these two criteria alone, it was clear that something very different occurred in the samples from HTH and NMNH and the Spitalfields sample used by Schutkowski. This may be due to age sample differences or just sample size differences, as the Spitalfields collection only contained a total of 55 individuals, aged 0 to 5, with 22 females and 29 males. Geographic location and chronological differences may have played a role, as the Spitalfields collection was from 19th century England. Regardless of cause, the two American samples used for this study were more closely aligned than the Spitalfields sample. For this study, the arch criterion was particularly difficult to detect as often the arch drawn along the vertical side of the sciatic notch crossed an upper point, not at or above the lateral rim, and was not counted as “male”. Perhaps this feature needs to be adjusted in some fashion to accommodate for the variation observed in these samples.

As for the arch criterion, males and females were not distinguished by this feature as Schutkowski ascertained in his study. While some arches crossed above the auricular surface itself, much variation was seen in this trait. Cardoso and Saunders (2008) tested Schutowski's (1993) arch criterion method and found little correlation with this trait to sex. They determined that this trait varied substantially from one population to another. These authors also found that this trait was often hard to distinguish, and had issues orienting the ilium to determine whether or not the arch crossed the auricular surface or above it. Similar problems existed in this study, as I had difficulty in determining where the arch began in some individuals and which arch to utilize in individuals where two possible arches existed. Some anterior sciatic notch surfaces were easy to orient vertically and provided straightforward assessment, but others were uneven or irregular and determining where to line up the anterior edge of the sciatic notch was difficult. Schutkowski oriented the anterior sciatic notch vertically, but after comparing orientations, it was often more easily analyzed with the posterior sciatic notch held vertically and will be an area of further research. Aligning the anterior sciatic notch not was easier in photographic assessments than on dry bone, and this may explain the difference between the results. However, this difference in analysis did not provide any clearer sex determination. This feature showed variability in the samples, indicating that some factor other than sex affected shape of the sciatic notch and the resulting arch criterion.

For the NMNH sample, the direct analysis was about equally split into center or top, while the photographic analysis exhibited an overwhelming number in the across-center category. The numbers of males and females in these grouping followed this overall pattern, and no pattern associated with sex was detected. This trait correlated to sex in the HTH photographic analysis but not in the direct measurement analysis. This suggested differences in the assessment pattern between the two methods. As age is the primary difference between the NMNH and HTH populations, age was the most obvious factor; however, none of the samples showed any correlation of arch criterion with age.

Sutter's (2003) findings were the direct opposite of Schutkowski, as most of the males showed the arch crossing the auricular surface, while there were mixed results for females. Mixed results were also revealed in the variation of this trait across the three populations and between photographic and direct assessment. This added even more confusion to the assessment of this feature, leading to the conclusion that this feature varied and cannot be relied upon for sex determination.

4.3.9 Anterior and posterior sciatic notch measurements

The anterior and posterior sciatic notch lengths have not been assessed before in any studies, but were developed for this study. This was an attempt to quantify the symmetry and asymmetry of the sciatic notch. If the two lengths were directly compared, then an asymmetric notch would show one side longer than another. This theory was borne out through the statistical significance of this feature in the HTH and Trotter populations. Preliminary analysis showed that this index did not reach a statistically significantly level in relation to sex in t-tests and correlation analyses for the HTH and NMNH samples. Interestingly, in several instances, only one side, either the anterior or posterior sciaitic notch, was determined to be sexually dimorphic at a statistically significant level, but not necessarily both. This feature requires further analysis.

4.4 INDICES ANALYSIS

The development of indices was important to allow for the difference in bone size as a child ages. The length of the ilium differs greatly between an eight month old and an eight year old child, making direct comparisons extremely difficult; however, indices were developed to account for size. Indices may also hold value to tease out age as a factor affecting results. For example, in the NMNH sample, none of the indices correlated with age, but there were correlations to sex. As the size of bones was less a factor in an index, age may also become less of a factor.

4.4.1 Ischio-pubic index

The ischio-pubic index ranged from 62 to 91 in the NMNH direct measurements and 63 to 93 in the NMNH photographic measurements. Among adult individuals, measurements less than 84 were typically male, while those greater than 95 were female, with those 84-95 in the indeterminate range (Washburn 1948). As none of the individuals were over 95 in this group, the adult guidelines were not applicable. In addition, no cut off or difference existed between the sexes in the index measurements. This index did not correlate with age for the NMNH or HTH populations, nor did it correlate with sex.

4.4.2 Sciatic notch index

The sciatic notch index, an index of sciatic notch width divided by sciatic notch depth, did not correlate with sex in any of the sample populations. This feature correlated with age in the HTH sample.

4.4.3 Iliac/sciatic notch index

The iliac/sciatic notch index, the iliac length divided by the sciatic notch width, was created for this study. In the three samples, the means for this index were larger for females than in males for both direct and photographic measures. This index correlated with age for the HTH sample, but not for the NMNH or Trotter groups. This feature correlated with sex for the NMNH sample. As age played some role in the results of the older HTH sample, further research on additional samples is necessary.

4.4.4 Pubic index

The pubic index, dividing pubic body width by pubic length, showed mixed results for the three samples, with no clear pattern emerging. The index correlated with sex in the Trotter direct and NMNH photographic groups, but did not correlate with age in either the NMNH or HTH samples. Further research on specific age groups and different samples may shed light on this index's future viability.

4.4.5 Anterior/Posterior sciatic notch index

The anterior/posterior sciatic notch index was an index developed for this study that was the anterior sciatic notch length divided by the posterior sciatic notch length. While this trait correlated with sex for some analyses, this relationship did not exist collectively. Age correlated at a statistically significant level with this index in the HTH sample, suggesting that multiple factors influenced this trait. When compared against non-metric sciatic notch shape analysis, there was a strong association between the shape analysis and the measurement indices, with p= 0.001 or less for the HTH and NMNH direct samples and the NMNH photographic group. Interestingly, in the Trotter collection, sex correlated with the left anterior/posterior sciatic notch index only, and not connection was observed between sciatic notch shape and age.

4.5 OVERALL AGE DIFFERENCES

Age differences existed between the collections, as the Trotter and NMNH were fetal and newborn individuals as the HTH group contained individuals from one to 16 years. This disparity led to analysis differences. For example, in the HTH material, the individuals over roughly 14 years old were partially fused at the ischio-pubic ramus. When these two bones are connected, the angle of assessment in photographs was more difficult to assess. Ventral and dorsal length measurements also were different, probably resulting from distortion as the ventral side of the pelvis was more curved for these individuals. Angles were not assessed on the dorsal side to remain consistent with the other photographic analyses. For those that were analyzed in photographs, the pubic symphyseal surface was particularly well developed, creating an accurate vertical axis from which to measure the subpubic angle.

A few traits, including the NMNH and Trotter anterior sciatic notch, the NMNH and HTH sub-pubic angle, the Trotter iliac/sciatic notch index, the Trotter sciatic notch index, and the Trotter sciatic notch depth, correlated to age on one side only. For the HTH and Trotter discrepancies, sample size was a factor; however, this does not explain the difference in the anterior sciatic notch for the NMNH sample. This variation in the sciatic notch, found in the width, depth, angle, and anterior and posterior side lengths, should be an area for follow-up research, especially as so much variation was observed in this study. In particular, when sciatic notch was compared with age in Figure 3.34, the female sciatic notch angle sizes were smaller than males at older ages. As adult male sciatic notch angles are narrower than female angles, this finding was unexpected. However, this result may be somehow related to the HTH sample size, which was small overall, with only a few individuals in each age category. The fact that the sciatic notch angles were larger in the infants and young subadults may provide an additional explanation for this trend.

From the statistical analysis, results indicated that age may be the reason for the increased number of sexually dimorphic traits between the NMNH and Trotter with the HTH sample. For the three samples, age related to more features than sex. By far, the HTH sample had more traits associated with age, but also had more traits correlated with sex, than the other two samples. Sex and sciatic notch angle was linked with age in the HTH population, but not in the NMNH or Trotter samples. This may be due to the nature of the two younger populations – representing near to newborn to less than one year of age. In these two younger groups, only three features, iliac length, pubic length, and ischial length, correlated with age. This was anticipated, as this represented age-related growth of these elements. In particular, as the length of a bone increased as age increased, it would be surprising if these three traits were not found to be age-related. However, Figures 3.24 and 3.25 demonstrate that these three pelvic elements do not grow at the same rate for males and females, with differential growth seen in the iliac and pubic lengths in particular. Values were higher in females over age eight for both these elements.

Those features that were not strictly a reflection of growth were the indices, auricular surface elevation, the arch criterion, and possibly, the angles. These features were primarily dimorphic between males and females in ways may be completely unrelated to growth, and the indices should, in theory, factor out the size differences. The pubic index and ischio-pubic index were not associated with age in any of the groups, and sciatic notch index and iliac/sciatic notch index were not associated with age in the NMNH sample. These results indicated that at least two of the indices removed age growth factors. Furthermore, the arch criterion and sciatic notch shape also did not correlate with age in any sample, suggesting that these were not associated with age.

As puberty may begin prior to the teenaged years, analysis of the features should include all childhood ages. As can be seen in Figures 3.30, 3.31 and 3.34, males and females begin to differ at roughly age 10. In particular, the sciatic notch width and depth and pubic body width values are higher in females than males by age 12. This result indicates that pelvic changes between the sexes begin early in the pubertal process and suggest that sex differentiation may be possible before the end of puberty and final somatic growth. Differences were seen in growth as early as age eight in the pubis and ilium and can be seen by age 12 in sciatic notch and pubic body values, suggesting that sex differentiation may be possible as young as these ages.

However, the HTH sample size and age category sizes were small and further investigation of this is necessary.

Inclusion of age in subadult evaluations is necessary as the growth of bones played a substantial role in the measurements obtained. Finding features that do not associate with age or finding ways to accommodate the dynamic nature of bone growth are vital in sex assessment tool design for these individuals.

4.6 ANALYSIS METHOD COMPARISONS

4.6.1 Direct versus photographic

The ability to assess skeletal material with accuracy from a photograph will be increasingly important as governmental agencies around the world seek to rebury archaeological collections (Sample 2011; Walker 2000). A photograph may be the only available medium for an osteologist to assess skeletal material, so it is critical that any problems between photographic and direct measurements that affect analysis be identified now.

For the sciatic notch analysis, differences were evident between direct and photographic measurements. In particular, the photographic measurements were consistently larger than the angle measurements taken from dry bone. This evaluative increase was problematic when using Schutkowski's method of less than or greater than 90° discrimination method. As all photographs were assessed at greater than 90°, this system was unable to determine sex in any of the three samples. Separate guidelines may be necessary for sciatic notch photographic analysis.

For metric analyses, both the direct and indirect photographic methods correlated for nearly every trait, suggesting that photographs can be used to analyze a sample if necessary with comparable results. Issues affecting photographs include initial set up of equipment, correct angle and orientation of the camera, and consistent distances to the bone. Infant bones, which are more two-dimensional, allowed for a more straightforward analysis than when the bone becomes more three-dimension with development and fusion of the growth centers. To achieve the most accurate assessment, photographs must be taken in ways that account for any curvature of the bone. One particular issue found during this research was that the subpubic angle was difficult to assess in individuals with fused pelves if the pelvis was not oriented parallel to the camera lens. In addition, a scale must be included in any photograph of osteological material to allow for accurate measurement with computer software. Once these issues are addressed, osteologists could confidently interchange photographs with direct measurements.

For this project, it was anticipated that angle measurements would actually be more accurate and easier to discern through photographs than through direct measurements. The measurement was easy to conduct using ImageJ as the program allowed the photograph to be enlarged and enhanced for clear endpoint determination. For the HTH population, the sciatic notch angle readings were quite similar and they correlated to one another. Photographic measurement ranges were wider by about 19° than the direct measurement ranges, and also generated a larger mean. In the NMNH and Trotter samples, larger angle measurements were observed in the photographs than in the direct measurements. For the three samples, the sciatic notch angles were determined to be over 90° for photographic analysis. This result was different than what was found in the direct measurement assessment.

4.7 DEVELOPMENT OF TESTING METHODS

Several of the traits reach statistically significant levels of sexual dimorphism in at least one of the samples analyzed, but not at a sufficient level to develop predictive methods. As Vlak and colleagues (2008) noted, a method needed to 1) predict sex at an accuracy level that is high enough for forensic standards, 2) be common across all populations, and 3) contain little overlap between the sexes.

Several researchers have used discriminant function on a variety of skeletal elements with fairly good sex determination success rates, even of subadult individuals (Gapert *et al.* 2009a; Gapert *et al.* 2009b; Hsiao *et al.* 2010; Schulter-Ellis *et al.* 1983; Taylor and Dibennardo 1984; Walker 2008). In particular, more precise sex determination models were presented when multiple traits were used instead of one trait alone (Gapert *et al*. 2009b). Logistic regression has been proposed as a better tool for analysis than discriminant function as the assumptions that must be met are less stringent (Gapert *et al.* 2009b). As the two means of analysis often are used to answer similar research questions (Spicer 2005), they were compared in this analysis.

The logistic regression analysis of the NMNH sample revealed only four traits below the 0.15 entry level for stepwise analysis (Table 4.4). The threshold levels for selecting and removing predictors from the model were set at 0.15 and 0.20 respectively. Using this method, these tests produced a fairly low predictive value of 0.68317. This value did not change greatly when cross-validation was conducted (0.604). Cross-validation was conducted to determine how accurate the model was and as the values were similar, the model was reasonably accurate. Even though a low value was obtained, this model was tested on the other two samples with similar predictive levels. This result suggested that the logistic regression model was not an effective tool for predicting sex, as only four traits were sufficiently statistically significant to build the model, this may have contributed to the low level.

Table 4.4. Logistic regression statistically significant values for the NMNH sample

Feature	Chi-square value
Right iliac length	0.0147
Right ischial length	0.0493
Right auricular surface elevation	0.1161
Right sciatic notch shape	0.0235

For discriminant function, the traits of the ilium, pubis, and ischium, as well as the iliac traits alone, were analyzed to determine if relationships existed between the traits and sex. The traits found statistically significant in discriminant function analysis were right sciatic notch shape, right ischio-pubic index, and right sciatic notch/iliac length index. The discriminant function prediction rate of 0.619 for the NMNH group was slightly lower than seen using logistic regression. As the sample approximated normality, it met the requisite assumptions for the discriminant function analysis and the large sample size met the requirements of logistic regression. It also provided evidence that the two methods of analysis were both similar in testing the data (Field 2006; Spicer 2005); unfortunately, neither method was useful in providing a high enough level for a sex determination method.

Recovery of the subadult ilium is more likely than the other two bones, either due to lack of preservation or lack of developed features on the pubis and ischium. Determining if the iliac traits independently had discriminant power would be valuable. Unfortunately, when the traits were analyzed separately, the eigenvalues were low. Therefore, using the traits of the ilium alone did not provide any additional insight into the variation observed between males and females.

For both methods, higher predictive scores were found for right side features than left side traits. This finding suggested that studies which focus primarily on the left side may miss important data by eliminating the right side. Moreover, if the right side is not recovered either in a forensic or archaeological scenario, the assessment of these elements may be incomplete.

Comparative research by Taylor and DiBennardo (1984) offered high sex discrimination results, which were not replicated in this current study. Taylor and DiBennardo included ancestry into their sex determination calculations. Inclusion of ancestry in future research may provide an explanation for the differences in the results between the two studies, and for the variation observed in several of the features, such as sciatic notch shape. However, preliminary correlation analyses including the ancestry variable did not demonstrate any statistically significant correlations to ancestry. Furthermore, the ancestral designators used in both the NMNH and HTH collections have been disputed. When the collections were initially gathered, ancestral categorization was often rooted in the data collector's speculation of race based on skin color (Hunt 2010; Jellema 2009). Non-standard ancestral designators, such as mulatto, negro, and black, were used. While these may have signified specific racial designators to the original researcher, these discriminators no longer fit modern ancestral categories and correct interpretations could be problematic.

Lastly, while t-tests may have detected difference in the means between males and females for numerous traits, the logistic regression and discriminant function analyses were not able to predict sex. As many of the ranges for trait values overlapped between the males and females, no threshold was effective at differentiating sex. When values overlap to a large degree, the number of individuals incorrectly categorized was too high to accurately assign sex.

4.8 POPULATIONAL DIFFERENCE

Sexually dimorphic features varied among and within the three samples, and this variation in morphology played a role in this analysis's results. These differences between the geographic groups may be related to a factor not included in this evaluation. Gapert (2009a) and Walker (2008) noted that the expression of traits between adult males and females was not consistent in every population observed. This is supported in this current work, as clearly, visual assessments and statistical analyses were not consistent for the three groups. Morphological variation within each group may relate to other factors such as diverse ethnic origins, socio-economic statuses, health conditions, and levels of physical maturity. Further research is necessary to determine any other potential influences on the variability seen in both males and females within and between these groups.

4.9 FUTURE STUDY

This study has provided a basis for the analysis and potential development of sex determination methods from subadults. The mixed results achieved indicate that more work is necessary to truly understand the accuracy and reliability of the traits for global application to all groups and ages. Future research should build upon this study's foundation and include larger sample cohorts, more individuals in each age category, better assessment methods for the arch criterion, and additional metric methods for the sciatic notch. In particular, larger groups of older subadults (minimum one year old) may provide more insight into the influence of age on this study's findings. Preliminary analysis using the HTH sample to develop a logistic regression model found a high predictive rate (0.94, with cross-validation 0.88). However, as the sample was small and the bulk of the individuals were in the one-year age category, this sample did not meet the large sample size requirements of logistic regression. These high prediction rates may not persist when a larger sample that meets the necessary assumptions is used to create a model.

Other potential research avenues involve the arch criterion evaluation. One option is testing if the posterior positioning of the sciatic notch aids in visualization and categorization of the arch, as mentioned in 4.3.8. The second possibility, the inclusion of the double arch method developed by Bruzek (2002), analyzes the arch of the sciatic notch and the auricular surface in relation to one another.

As for the sciatic notch shape, further study of sciatic notch chord analysis is needed as presented in Listi and Bassett (2006). These authors analyzed where the line drawn down from D on Figure 2.1 met the line C-E. This method contributed supplementary insight into the sciatic notch shape analysis as this chord may reflect differences found in the sciatic notch shape overall that a score of asymmetric/symmetric cannot, and that was not witnessed in the metric analysis.

Ancestral group data could be added to these studies. As Taylor and DiBennardo (1984) included this variable into their research with much higher predictive results, this variable should be explored with the current samples, especially as this information was available for each group. This additional background information could elevate the statistical results and explain much of the variation observed in the three samples studied. However, as discussed above, preliminary testing does not reflect any potential in this area.

Furthermore, as age data are available for these three samples, these groups should be compared with existing age/growth studies (Fazekas and Kósa 1978; Molleson and Cox 1993). These age standards are based on European samples and comparison with an American population adds to the literature. Lastly, more work also needs to be conducted on right and left side differences. As many studies only incorporate the left side into their research, and differences between the two sides were observed in this study, omitting the right side or not understanding side differences may alter results of future studies.

5.0 CONCLUSION

This study evaluated three distinct North American subadult samples to examine the sexual dimorphism found in the three innominate elements. The Forensic Fetal Osteological Collection (National Museum of Natural History, Smithsonian Institute, Washington, D.C.), the Hamann-Todd Collection (Cleveland Museum of Natural History), and Trotter Fetal Bone Collection (Washington University, St. Louis, M.O.), were assessed visually, metrically, and statistically for 13 measurements and five indices to evaluate levels of sexual dimorphism. These measurements included standardized pelvic measurements and features: iliac, ischial, and pubic lengths, sciatic notch measurements, subpubic angle assessment, auricular surface elevation, arch criterion analysis, and sciatic notch shape evaluation. Measurements unique to this study were the anterior and posterior sciatic notch lengths and the pubic body width. In addition to the traditional indices, the ischio-pubic and sciatic notch indices, three new indices were created for this study: the pubic, anterior/posterior sciatic notch, and sciatic notch width/iliac length indices. The sciatic notch shape was assessed using previous nonmetrical assessment techniques, then quantified to facilitate statistical analysis. The auricular surface elevation and arch criterion, both non-metric traits, were also analyzed for this study through previously presented methods. Although sexually dimorphic traits were found in each sample through t-tests and correlation analysis, these features were not consistent among the three samples. For several traits, sample means were sexually dimorphic between males and females but ranges overlapped considerably, making sex discrimination difficult. Statistical analysis via logistic regression and discriminant function did not predict sex at a high enough level to meet *Daubert* scientific standards for any of the traits reviewed, as the highest p-value was 0.68. Variation in traits found within and between the samples suggested that these features were problematic to use for sex discrimination because morphology was inconsistent. Evidence from this study suggests that although sexually dimorphic traits may be present, they vary too considerably for sex discrimination.

While no reliable sex determination method was developed, this research made several contributions to the study of sexual dimorphism among subadults. The three samples used have not previously been compared to one another nor have the samples been examined for all of the traits used in this study. The three different indices created for this study all demonstrated relationships to sex in at least one sample and require further investigation. Pubic body width, a feature not previously analyzed, was found to be sexually dimorphic among older subadults and demonstrated that the pubic body grows differentially to the pubic bone length. In addition, the comparison of right and left sides of an individual showed that differences do exist between the two sides. While the convention has been to study bones from the left side only, the exclusion of right side measurements overlooks valuable data. The photographic and metric comparison analyses add a unique contribution as traits such as the sciatic notch angle were observed to be larger in photographs, so that current sex determination techniques were not applicable to the photographic angle measurements. Any sex assessment protocol developed must incorporate different standards for metric and photographic analyses for angle measurements, in particular when assessing repatriated remains where only photographs are available for analysis.

Even though statistical analysis did not produce results at the level demanded by forensic anthropologists and feature analysis was inconsistent, some traits showed potential for sex discrimination. Future research requires larger samples of older subadult skeletons, and should include adult remains to further explore the three unique traits created for this study. Ultimately, while males and females may differ in their sample means, the overlap of trait scores between the two sexes indicates that sex determination for subadults will continue to elude both bioarchaeologists and forensic anthropologists for some time to come.

APPENDIX A

CORID APPROVAL

University of Pittsburgh

Health Sciences
Office for Oversight of Anatomic Specimens

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Pittsburgh, PA 15261
412-802-8280
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MEMORANDUM

TO: Kathleen Blake

FROM: Barbara E. Barnes, MD
Co-Chair

DATE: January 19, 2010

RE: CORID No. 237: *Sexual Determination from the Subadult Pelvis: A Morphometric Analysis of the Ilium, Pubis and Ischium*

The Committee for Oversight of Research Involving the Dead has reviewed and approved the Annual Renewal Report for the above-referenced study.

The next Report will be due on or before the date indicated below. When your study has been completed, a Final Report will be required.

Approval Date: 1/19/2010
Renewal Date: 1/18/2011

Should you have any questions, please contact Shoshana Matusak, CORID Administrator, at 412-802-8280, or via email at matusaksa@upmc.edu.

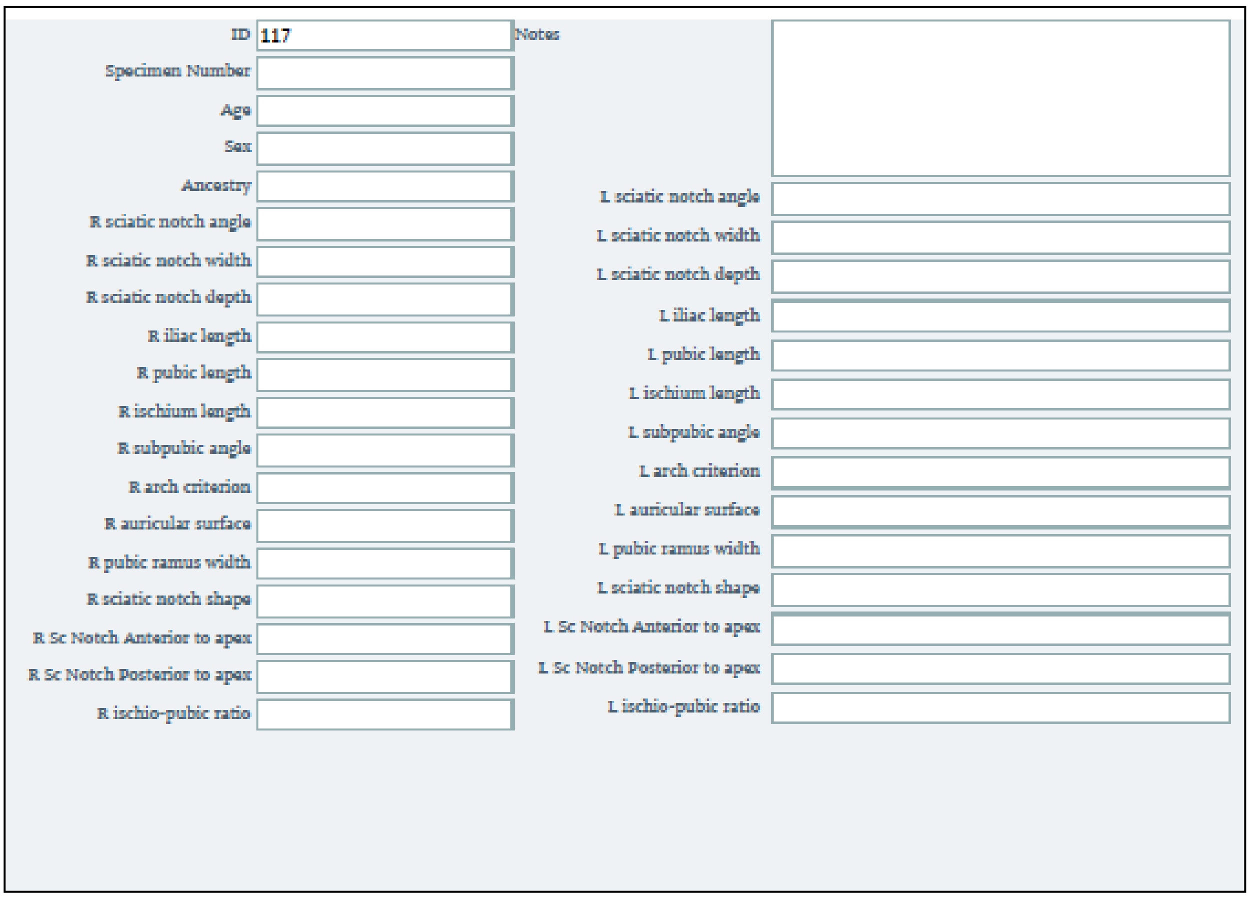
Thank you.

c: Shoshana A. Matusak

Figure A. 1 Corid approval letter

APPENDIX B

DATA COLLECTION SHEET



ID 117
Notes
Specimen Number
Age
Sex
Ancestry
R sciatic notch angle
R sciatic notch width
R sciatic notch depth
R iliac length
R pubic length
R ischium length
R subpubic angle
R arch criterion
R auricular surface
R pubic ramus width
R sciatic notch shape
R Sc Notch Anterior to apex
R Sc Notch Posterior to apex
R ischio-pubic ratio
L sciatic notch angle
L sciatic notch width
L sciatic notch depth
L iliac length
L pubic length
L ischium length
L subpubic angle
L arch criterion
L auricular surface
L pubic ramus width
L sciatic notch shape
L Sc Notch Anterior to apex
L Sc Notch Posterior to apex
L ischio-pubic ratio

Figure B. 1 Data collection sheet

APPENDIX C

APPENDIX ABBREVIATIONS

= Specimen Number
Age:
    L = Lunar months, mo = month, mos = months, yrs = years
Sex:
    M = Male, F = Female
Ancestry:
    W = White, B = Black
Side:
    R = Right, L = Left
SN = Sciatic Notch
AC = Arch Criterion
ASE = Auricular Surface Elevation
    0 = Not raised
    1 = 1 side raised
    2 = 2 sides raised
    3 = 3 sides raised
    4 = completely raised
Sciatic notch shape:
    A = Asymmetric, S = Symmetric
Arch Criterion:
    T = Top, C = Center
I/SN = Iliac/Sciatic Notch Width
I-P = Ischio-Pubic
A/P = Anterior/Posterior

All measurement were either in degrees for angle measurements or millimeters for length measurements

APPENDIX D

NMNH RAW DATA

D.1 NMNH SCIATIC NOTCH MEASUREMENTS

Table D. 1 Females aged one month

#	Age in mos.	Sex	Ancestry	Angle		Width		Depth		Shape		Anterior		Posterior	
				R	L	R	L	R	L	R	L	R	L	R	L
224704	1	F	W	106		9.28		2.17		A		3.38		6.36	
224859	1	F	B	88	89	9.32	8.09	3.40	3.52	A	S	4.37	3.73	6.59	6.33
224860	1	F	B	96	95	9.47	9.68	2.95	2.11	A	S	4.56	4.40	5.38	6.61
224861	1	F	B	90	94	11.32	11.08	3.65	3.46	A	A	4.53	5.50	8.62	9.01
224867	1	F	B	101	103	10.32	10.67	3.01	2.57	A	A	5.30	4.52	7.49	7.48
224868	1	F	B		118	10.01	11.15	1.90	1.94		S		4.94		6.38
224871	1	F	B	90	85	10.24	10.32	2.94	3.11	A	A	2.65	3.56	8.92	9.13
224874	1	F	B	99	99	9.91	8.96	2.67	2.66	A	S	5.02	3.97	7.72	6.84
224875	1	F	B	104	108	10.54	11.09	2.01	1.73	A	A	4.18	4.12	8.20	7.52
224876	1	F	B	116	116	10.51	11.16	2.43	2.23	S	S	4.96	5.45	8.03	6.95
224879	1	F	B	99	99	7.45	8.18	2.17	1.92	A	S	3.67	4.55	6.22	5.19
228449	1	F	B	96		7.15		1.72		S		3.60		4.83	
228804	1	F	B	103	97	9.56	9.17	2.39	2.11	A	A	3.35	3.66	9.12	7.71
228808	1	F	W	99	95	11.42	10.67	3.68	2.49	A	A	4.69	4.04	9.09	7.91
228810	1	F	B	86	86	9.45	8.93	2.84	2.50	A	A	3.80	3.74	7.52	8.18
228812	1	F	B	108	108	14.66	13.20	4.19	2.65	A	A	6.76	6.70	10.99	9.02
228822	1	F	B	92	90	6.87	6.24	2.31	2.39	S	S	4.33	3.60	5.75	4.66
228827	1	F	W	96	95	13.17	13.28	3.22	3.13	A	A	5.27	5.75	10.58	9.76
228833	1	F	B	111	105	9.94	9.44	2.13	1.89	S	S	4.23	4.76	7.28	6.28
228840	1	F	B	84	89	10.89	11.54	2.87	2.25	A	A	3.65	3.15	8.37	9.21
228846	1	F	B	96	98	10.84	11.87	3.13	2.85	A	A	5.15	5.00	8.69	9.34
228847	1	F	B	110	108	12.16	10.60	3.39	2.69	A	A	4.31	3.30	9.36	8.29
228850	1	F	W	95	100	9.72	10.32	2.91	2.92	A	A	4.24	6.25	7.77	7.27
228852	1	F	W	99	90	13.34	12.73	3.57	3.23	A	A	5.33	5.58	11.07	9.62
229370	1	F	W	94	100	10.41	9.29	3.09	2.44	A	A	4.40	3.90	7.58	7.48
249558	1	F	W	96	95	11.58	11.43	3.53	2.87	A	A	3.76	4.63	9.95	8.54
249563	1	F	W	82	84	11.53	10.75	3.74	2.68	A	A	4.80	4.51	9.74	9.12
249575	1	F	W	90	90	8.36	8.16	2.31	2.71	A	A	4.16	4.82	6.18	5.27
249577	1	F	B	100	100	8.82	8.42	2.27	2.06	S	S	4.63	4.63	5.16	5.14
249578	1	F	B	95	87					A	S				
249579	1	F	W	110	112	13.95	13.03	3.75	3.17	S	A	7.27	8.00	8.58	7.38
249581	1	F	B	105	103	13.58	12.96	3.00	3.12	A	A	5.21	6.04	10.60	9.02
249583	1	F	B	99	99	12.30	11.06	3.53	2.78	S	S	6.43	5.72	9.01	7.74
249587	1	F	B	83	75	10.64	10.28	3.47	3.36	A	A	3.12	4.08	10.15	10.14
249590	1	F	W	103	104	10.97	11.95	2.58	2.73	A	S	4.86	5.91	9.24	7.31
249597	1	F	B	101	105	9.92	8.61	2.30	1.92	A	A	2.95	4.19	8.71	6.50
249600	1	F	W	100	105	8.04	10.25	2.69	2.74	A	A	3.77	4.48	6.77	8.72
249603	1	F	W	94	92	11.60	10.87	3.15	3.01	A	A	4.88	4.23	8.81	8.24
253844	1	F	B	112	110	11.65	11.04	2.55	2.12	S	S	6.69	5.73	7.71	7.18
253855	1	F	W	96	95	8.25	9.13	2.68	2.38	S	S	4.40	3.49	6.93	6.58
253860	1	F	B	95	98	9.01	9.49	2.65	2.31	S	S	3.93	4.04	7.16	5.82
253862	1	F	B	84	89	10.81	10.18	2.84	2.31	A	A	4.00	3.77	9.66	8.63
253866	1	F	B	104	115	10.30	9.43	2.35	1.72	S	A	4.63	3.74	7.71	7.72
255286	1	F	B	90	94	8.29	8.57	2.37	2.22	A	A	3.62	4.07	5.48	5.83
299230	1	F	B	100	97	7.01	5.92	1.29	1.50	A	A	3.44	3.13	3.74	3.79
299231	1	F	W	90	93	8.17	6.93	1.92	2.41	A	S	3.47	3.89	5.57	4.33
228828A	1	F	B	100	100	11.58	11.94	3.84	3.31	S	S	5.37	6.39	8.33	7.88

Table D. 2 Males aged one month

#	Age in mos.	Sex	Ancestry	Angle		Width		Depth		Shape		Anterior		Posterior	
				R	L	R	L	R	L	R	L	R	L	R	L
224837	1	M	B	99	97	12.58	13.05	3.47	3.20	A	A	4.88	4.90	9.99	10.48
224854	1	M	B	103	103	12.28	11.89	3.00	2.19	A	A	4.98	5.61	9.25	8.08
224855	1	M	B	96	95	9.53	8.80	2.23	1.59	A	A	3.93	4.33	7.34	5.64
224857	1	M	B	120	112	14.05	11.70	2.18	1.95	A	A	4.47	4.68	9.89	8.21
224858	1	M	B	90		6.01		2.39		S		3.61		4.53	
224862	1	M	B	101	96	11.10	10.79	3.71	3.12	A	S	5.08	5.63	7.50	7.01
224863	1	M	B	103	104	10.92	10.13	2.87	2.60	A	A	4.82	4.93	7.45	7.00
224865	1	M	B	104	105	12.57	12.53	3.21	3.30	A	A	5.22	5.26	10.52	9.76
224872	1	M	B	119	121	10.97	10.45	2.70	2.05	S	S	5.99	6.07	7.17	6.76
224897	1	M	B	92	94	11.31	11.69	3.76	3.24	S	S	6.22	6.79	7.61	8.86
228473	1	M	B	84		9.99		3.32		A		3.40		8.47	
228803	1	M	W	89	91	11.36	11.78	3.96	3.69	A	S	5.21	5.06	8.57	8.73
228809	1	M	W	101	98	13.12	11.43	2.97	2.75	A	A	4.52	5.10	10.78	8.83
228815	1	M	W	99	100	9.79	10.34	2.24	2.65	A	S	4.70	4.75	7.18	6.98
228817	1	M	W	90	89	11.05	10.43	3.25	3.09	S	S	6.05	5.36	9.11	6.99
228831	1	M	W	105	105	11.01	10.99	2.99	2.76	S	A	5.04	4.88	8.18	8.32
228832	1	M	B	103	98	10.06	10.26	2.38	2.33	S	S	5.39	4.71	7.67	6.89
228834	1	M	B	100	93	11.00	9.73	3.39	3.00	S	A	3.96	4.13	8.66	7.74
228837	1	M	B	94	91	12.15	12.56	3.26	3.21	A	A	3.87	4.05	10.18	9.88
228841	1	M	W	95	100	9.89	9.72	2.93	2.30	A	A	3.17	4.18	7.71	8.10
228843	1	M	B	105	106	11.47	12.95	3.46	2.86	A	A	4.92	5.19	8.43	10.24
228845	1	M	B	93		12.60		3.49		A		4.84		9.87	
228848	1	M	B	95	95	8.67	8.42	2.62	2.61	S	S	5.19	5.17	5.26	5.76
228853	1	M	B	92	90	10.67	10.47	3.56	3.25	S	A	5.72	5.20	7.13	6.76
229371	1	M	W	84	76	9.89	9.56	3.63	2.27	A	A	4.30	4.62	8.37	8.38
247688	1	M	A	107	101	9.48	9.49	2.20	1.73	A	S	3.30	4.67	7.39	5.41
248573	1	M	W	101	103	11.23	12.42	3.64	2.97	A	A	4.32	5.10	8.65	9.23
249555	1	M	B	77	80	9.05	8.94	3.00	2.70	A	A	3.11	4.56	8.12	7.32
249557	1	M	W	98	100	11.87	11.97	3.15	3.22	S	S	6.41	5.97	8.30	7.58
249562	1	M	W	99	92	10.77	11.85	3.27	3.32	S	S	5.09	6.33	8.27	8.15
249572	1	M	W	103	103	11.35	11.36	3.03	2.64	S	S	5.66	6.63	6.50	5.90
249573	1	M	W	97	97	10.02	10.56	2.62	2.60	S	S	5.42	5.38	6.89	6.60
249576	1	M	B	93	94	9.79	10.17	3.00	2.80	S	A	5.25	4.44	8.02	7.41
249580	1	M	B	100	93	8.45	9.28	2.08	2.02	S	S	4.24	4.66	5.45	5.40
249586	1	M	B	99	95	13.11	10.60	3.05	2.95	A	A	4.67	5.22	10.81	8.25
249589	1	M	B	94	90	9.61	8.38	2.15	2.09	A	A	4.86	4.11	6.56	5.32
249591	1	M	B	103	103	11.75	11.28	2.47	2.13	S	A	5.64	4.35	7.01	5.48
249593	1	M	B	95	86	11.43	11.26	3.59	2.77	A	A	5.08	5.71	8.09	8.75
249594	1	M	B	99	100	10.41	12.30	3.29	3.23	S	S	5.72	5.89	8.47	8.19
249595	1	M	B	78	75	8.68	8.41	3.84	3.45	S	S	5.47	6.10	6.98	5.99
249601	1	M	B	85	90	9.28	8.52	2.51	2.14	A	A	3.58	3.79	7.41	7.39
249602	1	M	B	98	97	12.17	12.16	3.41	2.35	A	A	5.27	5.40	10.50	9.30
249604	1	M	B	90	85	12.50	13.02	4.30	3.73	A	A	4.95	5.02	11.05	11.08
253842	1	M	B	97	104	10.84	9.65	2.53	2.00	A	A	3.07	3.21	9.17	7.09
253845	1	M	B	114	113	8.85	7.02	1.33	1.12	A	S	3.00	3.64	4.75	4.42
253863	1	M	B	92	92	11.12	10.03	3.16	3.07	S	S	5.45	5.46	7.81	7.44
253868	1	M	B	109	115	11.20	11.74	2.56	2.11	A	A	4.38	3.53	8.66	8.55
255285	1	M	W	85	82	8.16	8.83	2.87	1.73	A	A	2.81	2.99	8.93	8.25
255287	1	M	B	105	104	10.54	10.56	2.89	2.77	S	S	5.50	5.25	6.90	6.91
299303	1	M	W	95	104	9.14	7.38	2.14	1.85	S	S	4.55	4.06	6.74	4.06
299369	1	M	W	92	95	9.58	9.97	2.99	2.58	S	A	5.05	5.71	7.05	6.67

Table D. 3 Males and females two months and older

#	Age in mos.	Sex	Ancestry	Angle		Width		Depth		Shape		Anterior		Posterior	
				R	L	R	L	R	L	R	L	R	L	R	L
249559	2	F	B	97	95	13.21	13.98	3.94	3.34	A	A	5.12	6.05	11.75	10.68
249606	2	F	B	106	105	10.70	11.60	2.82	2.33	A	A	4.55	5.49	7.98	7.72
253865	2	F	B	94	97	11.09	10.41	2.91	2.28	A	A	3.45	3.58	9.28	9.89
249551	2	M	B	85	76	9.60	9.47	3.13	3.28	A	S	4.29	4.59	8.64	6.81
249553	2	M	B	103	101	11.46	12.14	3.52	2.85	S	S	4.27	6.32	9.00	8.00
249598	2	M	B	110	100	10.74	12.95	2.41	3.14	S	S	5.26	6.55	8.55	8.44
249561	3	F	B	104	95	12.65	12.14	3.90	2.74	A	A	5.24	5.47	10.14	10.27
249570	3	F	B	94	88	12.84	12.18	4.65	3.66	A	S	6.07	6.25	10.50	8.82
249582	3	F	B	100	92	12.56	12.26	3.00	2.90	A	A	4.69	5.04	10.05	9.50
249592	3	F	W	105	103	12.42	14.34	3.21	2.42	A	A	3.97	4.87	10.41	10.25
249588	4	F	W	108	110	13.55	14.86	3.25	2.89	S	S	6.63	7.34	9.55	9.12
249599	4	M	W	83	83	11.93	12.45	3.72	3.42	A	A	4.43	4.63	10.86	10.65
249605	5	M	B	96	90	16.32	14.49	5.14	4.60	A	A	5.55	6.55	12.63	11.42
228838	8	F	B	104	105	16.12	16.91	3.97	3.94	A	A	4.94	5.69	13.43	13.06

D.2 NMNH ILIAC, PUBIC, AND ISCHIAL AND NON-METRIC MEASUREMENTS

Table D. 4 Females aged one month

		Iliac length		Pubic length		Subpubic angle		Pubic body width		Ischium length		AC		ASE	
#	Ancestry	R	L	R	L	R	L	R	L	R	L	R	L	R	L
224704	W	31.12										C	-	3	-
224859	B	31.44	31.16	11.63	12.36					18.23	18.03	T	T	3	4
224860	B	27.18	27.18							13.58	13.58	C	C	3	0
224861	B	35.93	34.86	15.94	15.97	30	30	4.52	4.27	20.41	21.71	C	C	4	4
224867	B	32.90	31.33							16.78	17.09	C	C	1	3
224868	B	19.11	21.90										C	-	4
224871	B	34.28	33.74		16.11		35		4.39		18.41	T	T	2	2
224874	B	29.85	30.10	14.08	13.58					17.86	18.03	C	C	4	4
224875	B	31.20	31.10							17.33	17.61	T	T	3	4
224876	B	26.61	26.37							16.35	16.52	C	C	0	0
224879	B	22.60	22.80	10.80	10.25					13.10	12.95	C	C	2	2
228449	B	25.55		11.90	11.45			2.97	2.94	13.92	13.69	C	-	4	-
228804	B	33.49	33.48	16.74	16.25	23	35	4.78	5.53	18.37	18.38	T	T	4	2
228808	W	36.20	36.71	16.23	15.80	31	33	5.15	5.16	20.43	20.33	C	T	3	2
228810	B	33.62	35.00		18.43		35		7.16	20.90	20.74	C	T	3	1
228812	B	34.89	35.15	18.10	17.85	35	35	5.83	5.95	21.42	21.40	C	C	1	2
228822	B	24.55	24.74							11.11	9.74	C	C	1	2
228827	W	36.39	35.57	14.57	13.46					21.34	21.54	T	T	4	4
228833	B	34.35	34.43		15.62						17.56	C	C	0	0
228840	B	35.79	36.29	14.25	13.79			4.75	4.59	20.94	20.86	C	C	4	4
228846	B	40.03	39.99	18.38	18.67	24	30	5.66	6.50	22.56	22.85	T	T	0	0
228847	B	34.88	34.16	15.26	16.23	31	24	5.26	4.85	19.61	19.71	C	C	1	1
228850	W	35.77	35.25	15.96	15.74					20.23	20.02	T	C	1	2
228852	W	38.10	38.56	15.16	15.21	30	22	5.30	5.94	20.00	19.74	T	T	0	1
229370	W	28.88	29.28							12.21	12.75	C	C	2	2
249558	W	35.51	34.74	14.79	14.28			4.60	5.00	18.35	17.57	T	T	1	4
249563	W	36.00	36.25	14.22	14.38	23	21	5.02	5.06	20.05	20.90	T	T	1	1
249575	W	32.90	32.80	15.77	15.56	34	34	4.87	5.09	18.87	19.20	C	C	2	1
249577	B	22.25	23.96									T	T	4	4
249578	B	32.38	31.76	13.33	14.07					20.15	19.44	T	T	-	-
249579	W	35.24	35.72	13.60	13.36					18.79	18.42	C	C	3	2
249581	B	33.17	33.75	14.85	14.09			4.26	4.69	19.35	19.36	T	T	4	4
249583	B	38.55	38.07	16.16	15.58					20.59	20.40	T	T	1	1
249587	B	34.92	34.54	15.53	15.33			6.15		20.25	19.72	T	T	0	1
249590	W	35.10	34.90	14.95	14.39					16.87	17.87	T	T	0	0
249597	B	28.45	28.36	11.24	11.40					15.94	15.81	T	T	3	3
249600	W	29.87	29.67	14.24	13.69					17.13	16.56	T	T	2	2
249603	W	36.80	37.87	16.93	17.20	25	30	5.04	5.84	21.79	21.34	T	T	2	0
253844	B	29.87	30.44							14.99	15.42	C	C	0	0
253855	W	28.62	29.93							15.35	15.58	T	T	0	2
253860	B	29.85	30.15							14.26	14.13	T	T	1	1
253862	B	32.15	31.90	14.10	14.46	30	22	4.24	4.05	16.46	16.31	T	T	3	2
253866	B	28.05	26.97	11.25	11.78					14.43	14.28	C	C	1	1
255286	B	31.07	31.06							17.34	17.55	T	T	2	2
299230	B	21.18	21.02									C	C	1	
299231	W	16.66	16.77							7.13	6.60	T	T	0	0
228828A	B	36.47	36.67	14.28	15.14	24	21	4.90	4.93	18.46	18.54	C	C	0	0

Table D. 5 Males aged one month

#	Ancestry	Iliac length		Pubic length		Subpubic angle		Pubic body width		Ischium length		AC		ASE	
		R	L	R	L	R	L	R	L	R	L	R	L	R	L
224837	B	35.06	34.90	13.30	13.45					20.06	19.97	T	T	4	2
224854	B	38.38	37.72	17.59	17.22	25	29	3.94	5.61	21.25	21.32	C	C	4	4
224855	B	28.75	28.88		12.24					14.87	15.28	C	C	1	1
224857	B	26.94	27.67							13.78	14.26	C	C	0	0
224858	B	26.13									11.95	T	-	4	-
224862	B	38.10	37.49	15.72	15.82	26	26	4.04	3.96	19.31	19.37	C	C	4	4
224863	B	36.64	34.76	16.33	16.12	34	31	4.63	4.21	18.66	18.03	C	C	4	3
224865	B	33.30	33.35	12.18						15.77	15.50	T	T	3	2
224872	B	32.67	30.81							17.25	17.56	C	C	4	4
224897	B	35.65	35.84	16.68	16.24	17	15			20.63	20.29	T	T	4	4
228473	B	31.46		15.03	14.55	29	26	4.48	4.62	19.19	19.21	T	-	4	-
228803	W	39.05	38.40	17.07	16.73	31	31	5.36	5.59	21.19	21.10	C	T	1	2
228809	W	35.60	34.98	14.87	14.78	26	30	4.96	4.70	18.48	18.54	C	C	2	1
228815	W	34.11	34.47	15.56	14.85	41	30	4.56	4.60	17.44	17.47	C	C	4	4
228817	W	36.91	35.92	16.14	15.72	24	26	5.52	5.53	21.40	20.88	T	T	4	4
228831	W	33.97	33.82	13.26	12.96			3.92	4.85	18.01	17.86	T	C	4	3
228832	B	30.93	30.75	13.39	12.71			4.41	4.53	17.32		T	C	2	1
228834	B	36.01	35.92							18.70		C	T	1	1
228837	B	44.19	44.22	20.29	19.15	26	30	6.51	6.76	23.97	24.20	T	T	0	0
228841	W	35.68	35.14	13.30	13.39					18.16	18.76	T	T	2	2
228843	B	33.66	24.51	13.64	13.88					17.60	17.90	C	C	3	4
228845	B	38.77		16.83	17.54	20	25	6.50	6.27	22.55	22.97	C	-	0	-
228848	B	29.41	29.79	12.15	11.69					16.11	16.34	C	C	4	4
228853	B	37.69	37.82	16.46	16.50	35	36	5.64	6.13	19.42	20.01	T	T	2	2
229371	W	35.56	36.27	17.18	16.94	23	25	6.07	6.28	20.20	20.53	T	T	4	2
247688	A	31.06	31.26	13.70	12.69					15.45	15.93	T	T	1	2
248573	W	36.21	36.11	14.47	14.54	24	23	4.98	5.20	18.52	18.80	T	T	4	4
249555	B	33.32	33.45	15.71	15.52	18	19	4.39	5.26	18.20	17.93	T	T	1	1
249557	W	33.80	33.48	14.23	14.09			4.71		17.23	17.40	T	T	2	2
249562	W	40.41	39.71	18.65	18.25	23	22	5.72	5.99	20.89	21.35	C	C	3	4
249572	W	35.25	36.04	16.05	16.40			5.78		18.50	18.25	C	T	1	2
249573	W	35.18	35.28	14.16	14.98					18.94	18.25	T	T	1	1
249576	B	29.78	30.19	12.41	12.49					17.14	16.92	T	T	-	-
249580	B	31.06	31.77	13.98	13.81	30	28	3.82	4.64	17.49		C	C	2	4
249586	B	37.84	39.67	16.26	16.96	31	35	4.21	4.86		21.96	T	T	1	2
249589	B	28.41	28.32							15.07		C	C	1	4
249591	B	34.22	34.76	15.38	14.83					19.22	19.20	C	C	1	1
249593	B	36.46	36.26	14.96	15.32	20	21	4.46	4.40	20.88	20.55	C	C	2	2
249594	B	38.06	38.05	13.24	14.02					18.54	18.43	T	T	1	2
249595	B	34.80	34.44	15.10	14.60					19.94	19.74	C	C	2	3
249601	B	36.72	36.08	17.24	17.56	25	27	5.23	5.37	19.85	19.50	C	C	1	2
249602	B	37.17	37.08	14.12	14.36	25	23	5.27	5.05	21.98	21.77	T	T	2	1
249604	B	39.56	38.80	17.64	16.80	25	32	5.72	6.39	20.19	20.33	T	T	2	2
253842	B	30.27	29.88							14.46	14.13	T	T	1	4
253845	B	23.39	23.98									C	C	0	0
253863	B	32.65	33.23	15.82	15.55	32	33	4.51	4.65	18.94	19.13	C	C	1	4
253868	B	30.00	30.05	12.20						15.53	15.66	T	T	1	1
255285	W	27.91	27.40	10.96	10.23					14.57	14.38	T	T	1	1
255287	B	31.07	31.50	13.84	14.27	30	26	5.15	4.53	17.88	18.77	C	C	4	4
299303	W	25.07	25.16	10.41	9.74			3.53	3.88	12.79	12.28	C	C	1	1
299369	W	34.70	34.68	12.92						16.80	13.69	C	C	0	1

Table D. 6 Males and females two months and older

#	Age in mos.	Sex	Ancestry	Iliac length		Pubic length		Subpubic angle		Pubic body width		Ischium length		AC		ASE	
				R	L	R	L	R	L	R	L	R	L	R	L	R	L
249559	2	F	B	41.19	40.80	18.25	19.51	30	27	6.02	6.54		24.56	T	T	1	1
249606	2	F	B	38.20	36.96	16.91	16.55	31	35	5.83	6.03	21.76	21.60	C	C	0	0
253865	2	F	B	38.15	39.32	16.85	15.68	36	43	5.44	5.54	21.76	21.87	C	C	1	1
249551	2	M	B	31.16	32.66	15.57	15.33	26	24	4.94	4.97	19.77	19.84	T	T	1	0
249553	2	M	B	36.12	36.28	16.89	16.48	19	30	4.56	4.71	21.74	21.34	T	T	1	1
249598	2	M	B	37.95	38.00	15.14	15.67	24	30	4.25	5.70	21.20	20.63	C	C	1	2
249561	3	F	B	41.11	41.00	21.38	21.02	29	30	5.94	5.83	23.89	23.50	T	T	0	1
249570	3	F	B	44.50	43.84	18.10	18.56	22	27	5.58	5.40	23.70	23.88	T	T	2	2
249582	3	F	B	38.73	38.11	16.42	16.08					23.69	23.38	T	T	4	1
249592	3	F	W	39.18	38.48	18.53	18.28	25	32	6.54	6.23	21.92	21.51	T	T	1	1
249588	4	F	W	41.10	40.40	19.52	19.89	28	28	5.29	5.86	24.49	24.05	C	C	0	0
249599	4	M	W	49.60	49.40	22.56	22.04	35	41	7.90	7.10	28.80	28.02	T	T	0	0
249605	5	M	B	51.22	51.11	22.61	21.67	33	30	8.14	7.87	29.38	29.82	T	T	0	2
228838	8	F	B	49.05	50.07	23.23	22.73	35	42	7.95	7.47	28.70	28.90	T	T	0	2

D.3 NMNH INDICES

Table D. 7 Females aged one month

#	Ancestry	SN index		I/SN index		Pubic index		I-P index		A/P SN index	
		R	L	R	L	R	L	R	L	R	L
224704	W	4.28		0.30						0.53	
224859	B	2.74	2.30	0.30	0.26			0.64	0.69	0.66	0.59
224860	B	3.21	4.59	0.35	0.36					0.85	0.67
224861	B	3.10	3.20	0.32	0.32	0.28	0.27	0.78	0.74	0.53	0.61
224867	B	3.43	4.15	0.31	0.34					0.71	0.60
224868	B	5.27	5.75	0.52	0.51						0.77
224871	B	3.48	3.32	0.30	0.31		0.27		0.88	0.30	0.39
224874	B	3.71	3.37	0.33	0.30			0.79	0.75	0.65	0.58
224875	B	5.24	6.41	0.34	0.36					0.51	0.55
224876	B	4.33	5.00	0.39	0.42					0.62	0.78
224879	B	3.43	4.26	0.33	0.36			0.82	0.79	0.59	0.88
228449	B	4.16		0.28		0.25	0.26	0.85	0.84	0.75	
228804	B	4.00	4.35	0.29	0.27	0.29	0.34	0.91	0.88	0.37	0.47
228808	W	3.10	4.29	0.32	0.29	0.32	0.33	0.79	0.78	0.52	0.51
228810	B	3.33	3.57	0.28	0.26		0.39		0.89	0.51	0.46
228812	B	3.50	4.98	0.42	0.38	0.32	0.33	0.85	0.83	0.62	0.74
228822	B	2.97	2.61	0.28	0.25					0.75	0.77
228827	W	4.09	4.24	0.36	0.37			0.68	0.62	0.50	0.59
228833	B	4.67	4.99	0.29	0.27				0.89	0.58	0.76
228840	B	3.79	5.13	0.30	0.32	0.33	0.33	0.68	0.66	0.44	0.34
228846	B	3.46	4.16	0.27	0.30	0.31	0.35	0.81	0.82	0.59	0.54
228847	B	3.59	3.94	0.35	0.31	0.34	0.30	0.78	0.82	0.46	0.40
228850	W	3.34	3.53	0.27	0.29			0.79	0.79	0.55	0.86
228852	W	3.74	3.94	0.35	0.33	0.35	0.39	0.76	0.77	0.48	0.58
229370	W	3.37	3.81	0.36	0.32					0.58	0.52
249558	W	3.28	3.98	0.33	0.33	0.31	0.35	0.81	0.81	0.38	0.54
249563	W	3.08	4.01	0.32	0.30	0.35	0.35	0.71	0.69	0.49	0.49
249575	W	3.62	3.01	0.25	0.25	0.31	0.33	0.84	0.81	0.67	0.91
249577	B	3.89	4.09	0.40	0.35					0.90	0.90
249578	B							0.66	0.72		
249579	W	3.72	4.11	0.40	0.36			0.72	0.73	0.85	1.08
249581	B	4.53	4.15	0.41	0.38	0.29	0.33	0.77	0.73	0.49	0.67
249583	B	3.48	3.98	0.32	0.29			0.78	0.76	0.71	0.74
249587	B	3.07	3.06	0.30	0.30	0.40	0.00	0.77	0.78	0.31	0.40
249590	W	4.25	4.38	0.31	0.34			0.89	0.81	0.53	0.81
249597	B	4.31	4.48	0.35	0.30			0.71	0.72	0.34	0.64
249600	W	2.99	3.74	0.27	0.35			0.83	0.83	0.56	0.51
249603	W	3.68	3.61	0.32	0.29	0.30	0.34	0.78	0.81	0.55	0.51
253844	B	4.57	5.21	0.39	0.36					0.87	0.80
253855	W	3.08	3.84	0.29	0.31					0.63	0.53
253860	B	3.40	4.11	0.30	0.31					0.55	0.69
253862	B	3.81	4.41	0.34	0.32	0.30	0.28	0.86	0.89	0.41	0.44
253866	B	4.38	5.48	0.37	0.35			0.78	0.82	0.60	0.48
255286	B	3.50	3.86	0.27	0.28					0.66	0.70
299230	B	5.43	3.95	0.33	0.28					0.92	0.83
299231	W	4.26	2.88	0.49	0.41					0.62	0.90
228828A	B	3.02	3.61	0.32	0.33	0.34	0.33	0.77	0.82	0.64	0.81

Table D. 8 Males aged one month

#	Ancestry	SN index		I/SN index		Pubic index		I-P index		A/P SN index	
		R	L	R	L	R	L	R	L	R	L
224837	B	3.63	4.08	0.36	0.37			0.66	0.67	0.49	0.47
224854	B	4.09	5.43	0.32	0.32	0.22	0.33	0.83	0.81	0.54	0.69
224855	B	4.27	5.53	0.33	0.30				0.80	0.54	0.77
224857	B	6.44	6.00	0.52	0.42					0.45	0.57
224858	B	2.51		0.23						0.80	
224862	B	2.99	3.46	0.29	0.29	0.26	0.25	0.81	0.82	0.68	0.80
224863	B	3.80	3.90	0.30	0.29	0.28	0.26	0.88	0.89	0.65	0.70
224865	B	3.92	3.80	0.38	0.38			0.77		0.50	0.54
224872	B	4.06	5.10	0.34	0.34					0.84	0.90
224897	B	3.01	3.61	0.32	0.33			0.81	0.80	0.82	0.77
228473	B	3.01		0.32		0.30	0.32	0.78	0.76	0.40	
228803	W	2.87	3.19	0.29	0.31	0.31	0.33	0.81	0.79	0.61	0.58
228809	W	4.42	4.16	0.37	0.33	0.33	0.32	0.80	0.80	0.42	0.58
228815	W	4.37	3.90	0.29	0.30	0.29	0.31	0.89	0.85	0.65	0.68
228817	W	3.40	3.38	0.30	0.29	0.34	0.35	0.75	0.75	0.66	0.77
228831	W	3.68	3.98	0.32	0.32	0.30	0.37	0.74	0.73	0.62	0.59
228832	B	4.23	4.40	0.33	0.33	0.33	0.36	0.77		0.70	0.68
228834	B	3.24	3.24	0.31	0.27					0.46	0.53
228837	B	3.73	3.91	0.27	0.28	0.32	0.35	0.85	0.79	0.38	0.41
228841	W	3.38	4.23	0.28	0.28			0.73	0.71	0.41	0.52
228843	B	3.32	4.53	0.34	0.53			0.78	0.78	0.58	0.51
228845	B	3.61		0.32		0.39	0.36	0.75	0.76	0.49	
228848	B	3.31	3.23	0.29	0.28			0.75	0.72	0.99	0.90
228853	B	3.00	3.22	0.28	0.28	0.34	0.37	0.85	0.82	0.80	0.77
229371	W	2.72	4.21	0.28	0.26	0.35	0.37	0.85	0.83	0.51	0.55
247688	A	4.31	5.49	0.31	0.30			0.89	0.80	0.45	0.86
248573	W	3.09	4.18	0.31	0.34	0.34	0.36	0.78	0.77	0.50	0.55
249555	B	3.02	3.31	0.27	0.27	0.28	0.34	0.86	0.87	0.38	0.62
249557	W	3.77	3.72	0.35	0.36	0.33		0.83	0.81	0.77	0.79
249562	W	3.29	3.57	0.27	0.30	0.31	0.33	0.89	0.85	0.62	0.78
249572	W	3.75	4.30	0.32	0.32	0.36		0.87	0.90	0.87	1.12
249573	W	3.82	4.06	0.28	0.30			0.75	0.82	0.79	0.82
249576	B	3.26	3.63	0.33	0.34			0.72	0.74	0.65	0.60
249580	B	4.06	4.59	0.27	0.29	0.27	0.34	0.80		0.78	0.86
249586	B	4.30	3.59	0.35	0.27	0.26	0.29		0.77	0.43	0.63
249589	B	4.47	4.01	0.34	0.30					0.74	0.77
249591	B	4.76	5.30	0.34	0.32			0.80	0.77	0.80	0.79
249593	B	3.18	4.06	0.31	0.31	0.30	0.29	0.72	0.75	0.63	0.65
249594	B	3.16	3.81	0.27	0.32			0.71	0.76	0.68	0.72
249595	B	2.26	2.44	0.25	0.24			0.76	0.74	0.78	1.02
249601	B	3.70	3.98	0.25	0.24	0.30	0.31	0.87	0.90	0.48	0.51
249602	B	3.57	5.17	0.33	0.33	0.37	0.35	0.64	0.66	0.50	0.58
249604	B	2.91	3.49	0.32	0.34	0.32	0.38	0.87	0.83	0.45	0.45
253842	B	4.28	4.83	0.36	0.32					0.33	0.45
253845	B	6.65	6.27	0.38	0.29					0.63	0.82
253863	B	3.52	3.27	0.34	0.30	0.29	0.30	0.84	0.81	0.70	0.73
253868	B	4.38	5.56	0.37	0.39			0.79		0.51	0.41
255285	W	2.84	5.10	0.29	0.32			0.75	0.71	0.31	0.36
255287	B	3.65	3.81	0.34	0.34	0.37	0.32	0.77	0.76	0.80	0.76
299303	W	4.27	3.99	0.36	0.29	0.34	0.40	0.81	0.79	0.68	1.00
299369	W	3.20	3.86	0.28	0.29			0.77		0.72	0.86

Table D. 9 Males and females two months and older

#	Age in mos.	Sex	Ancestry	SN index		I/SN index		Pubic index		I-P index		A/P SN index	
				R	L	R	L	R	L	R	L	R	L
249559	2	F	B	3.35	4.19	0.32	0.34	0.33	0.34		0.79	0.44	0.57
249606	2	F	B	3.79	4.98	0.28	0.31	0.34	0.36	0.78	0.77	0.57	0.71
253865	2	F	B	3.81	4.57	0.29	0.26	0.32	0.35	0.77	0.72	0.37	0.36
249551	2	M	B	3.07	2.89	0.31	0.29	0.32	0.32	0.79	0.77	0.50	0.67
249553	2	M	B	3.26	4.26	0.32	0.33	0.27	0.29	0.78	0.77	0.47	0.79
249598	2	M	B	4.46	4.12	0.28	0.34	0.28	0.36	0.71	0.76	0.62	0.78
249561	3	F	B	3.24	4.43	0.31	0.30	0.28	0.28	0.89	0.89	0.52	0.53
249570	3	F	B	2.76	3.33	0.29	0.28	0.31	0.29	0.76	0.78	0.58	0.71
249582	3	F	B	4.19	4.23	0.32	0.32			0.69	0.69	0.47	0.53
249592	3	F	W	3.87	5.93	0.32	0.37	0.35	0.34	0.85	0.85	0.38	0.48
249588	4	F	W	4.17	5.14	0.33	0.37	0.27	0.29	0.80	0.83	0.69	0.80
249599	4	M	W	3.21	3.64	0.24	0.25	0.35	0.32	0.78	0.79	0.41	0.43
249605	5	M	B	3.18	3.15	0.32	0.28	0.36	0.36	0.77	0.73	0.44	0.57
228838	8	F	B	4.06	4.29	0.33	0.34	0.34	0.33	0.81	0.79	0.37	0.44

APPENDIX E

HTH RAW DATA

E.1 HTH SCIATIC NOTCH MEASUREMENTS

Table E. 1 Males and females with age in years

#	Age in yrs.	Sex	Ancestry	Angle		Width		Depth		Anterior		Posterior	
				R	L	R	L	R	L	R	L	R	L
HTH2714	1	F	B	106	104	14.90	15.80	4.27	4.50	7.14	6.80	10.44	12.28
HTH1435	2	F	B	103	93	14.71	14.71	6.03	6.60	8.77	6.59	14.55	13.70
HTH1074	4	F	B	111	114	32.75	30.61	9.31	8.22	13.73	10.49	23.05	25.88
HTH1115	4	F	B	110	110	24.81	27.75	7.21	8.41	11.56	14.16	16.55	18.13
HTH2141	4	F	B	110	110	23.79	25.24	7.67	7.89	11.63	13.67	17.47	18.03
HTH1098	5	F	B	111	106	26.35	25.92	9.15	8.45	15.78	12.49	19.31	20.41
HTH0624	6	F	B		104	28.70	31.95	9.88	10.56	13.50	12.99	23.87	26.40
HTH2036	7	F	W	110	105	29.08	26.05	8.93	7.67	12.58	10.96	27.39	25.99
HTH0872	8	F	B	106	116	27.31	27.42	7.65	7.58	8.93	9.55	18.99	20.81
HTH1156	8	F	B	101	105	26.99	28.54	9.34	10.15	13.86	14.08	20.14	19.95
HTH2074	8	F	B	118	111	31.77	32.50	9.45	10.49	14.26	16.76	24.87	26.68
HTH0632	10	F	B	103	103	31.20	26.62	10.62	8.49	16.12	10.49	20.58	23.79
HTH0526	11	F	B	101	100	31.89	36.94	10.97	12.10	15.07	13.99	26.16	30.39
HTH0645	12	F	W	95	93	37.10	37.25	16.59	15.47	21.32	17.78	27.97	33.76
HTH1240	12	F	B	75	80	46.37	50.48	29.53	30.17	46.25	45.11	33.44	35.05
HTH1772	12	F	W	99	89	27.78	26.37	11.90	12.71	17.76	15.60	23.24	20.78
HTH0633	13	F	B	66	69	43.17	40.40	32.40	29.49	46.56	39.12	35.24	34.07
HTH2118	13	F	B	95	101	27.86	28.73	10.92	10.19	16.09	15.21	20.11	22.78
HTH2135	14	F	B	84	85	45.45	47.22	27.08	28.36	35.69	35.47	37.31	36.24
HTH1168	1	M	B	104	97	13.36	13.14	4.37	3.57	5.93	4.29	11.25	10.18
HTH1379	1	M	B	95	101	10.91	10.30	3.87	4.05	4.98	4.69	8.93	8.98
HTH1385	1	M	B	109	100	15.19	15.08	5.25	5.41	7.33	8.40	12.81	11.69
HTH1583	1	M	W	95	104	12.98	13.38	5.33	5.44	7.75	8.19	9.19	10.80
HTH1768	1	M	B	116	116	15.21	15.64	4.14	4.34	6.32	7.97	11.65	11.69
HTH1894	1	M	B	99	104	13.67	14.80	4.69	4.60	5.33	7.94	12.86	12.21
HTH2075	1	M	B	116	115	13.53	13.07	3.93	3.40	5.10	5.13	9.58	10.40
HTH2370	1	M	B	97	100	11.22	10.67	3.82	3.79	5.59	5.16	8.25	8.93
HTH1557	3	M	B	91	91	15.29	17.72	6.73	7.95	9.80	8.89	13.01	13.91
HTH1950	4	M	B	106	109	14.38	12.55	5.92	5.02	7.27	7.81	10.69	9.74
HTH1784	6	M	B	109	111	28.83	29.62	9.34	8.52	14.36	14.43	19.92	19.09
HTH2144	6	M	B	107	110	26.07	27.25	8.13	8.93	11.86	11.95	20.21	20.99
HTH1834	8	M	B	104	99	26.84	27.67	9.40	8.57	13.68	13.31	22.46	23.58
HTH0710	10	M	B	101	103	32.41	34.48	13.71	14.31	20.03	19.09	22.94	25.07
HTH1441	10	M	B	100	100	29.18	29.94	11.20	10.84	18.72	16.49	24.66	23.26
HTH1688	10	M	B	109	104	33.24	34.63	9.74	10.68	19.34	18.85	21.25	24.65
HTH0404	11	M	B	101	99	33.35	34.99	13.32	13.75	21.43	18.42	24.87	29.41
HTH3112	16	M	B	92	85	34.24	33.00	12.42	16.19	16.70	19.78	28.86	29.91

E.2 HTH NON-METRIC MEASUREMENTS

Table E. 2 Males and females with age in years

#	Age in yrs.	Sex	Ancestry	Sciatic notch shape		Subpubic angle		AC		ASE	
				R	L	R	L	R	L	R	L
HTH2714	1	F	B	A	A	35	31	C	C	2	2
HTH1435	2	F	B			43	43				
HTH1074	4	F	B	A	A	45	44	C	C	3	3
HTH1115	4	F	B	A	A	36	30	C	C	3	3
HTH2141	4	F	B	A	A	21	23	C	C	0	0
HTH1098	5	F	B	A	A	37	30	C	C	2	2
HTH0624	6	F	B	A	A	37	43	T	T	4	2
HTH2036	7	F	W	A	A	44	45	T	T	4	4
HTH0872	8	F	B	A	A	29	32	C	C	1	2
HTH1156	8	F	B	A	A	30	31	T	T	2	2
HTH2074	8	F	B	A	A	32	36	C	C	0	0
HTH0632	10	F	B	A	A	26	26	C	C	3	3
HTH0526	11	F	B	A	A	35	27	T	T	2	2
HTH0645	12	F	W	A	A	25	28	T	T	0	1
HTH1240	12	F	B	S	S	37	40	T	T	4	4
HTH1772	12	F	W	A	A	39	39	T	T	3	4
HTH0633	13	F	B	S	S	42	44	T	T	4	4
HTH2118	13	F	B	A	S	37	40	C	C	2	4
HTH2135	14	F	B	S	S	45	49	T	T	4	4
HTH1168	1	M	B	A	A	28		T	T	3	
HTH1379	1	M	B	A	A	15	21	C	C	0	0
HTH1385	1	M	B	A	A	23	23	C	C	2	2
HTH1583	1	M	W	S	S	25	25	T	T	0	0
HTH1768	1	M	B	A	S	23	23	C	C	2	0
HTH1894	1	M	B	A	A	26	21	T	T	0	0
HTH2075	1	M	B	A	A	26	25	C	C	0	0
HTH2370	1	M	B	A	A	30	25	C	C	0	0
HTH1557	3	M	B	A	A	30	28	T	T	0	2
HTH1950	4	M	B			45	41				
HTH1784	6	M	B	S	S	34	35	C	C	4	4
HTH2144	6	M	B	A	A	31	29	C	C	3	0
HTH1834	8	M	B	A	A	17	22	T	T	0	0
HTH0710	10	M	B	S	S	37	35	C	C	0	0
HTH1441	10	M	B	A	A	26	21	T	T	0	0
HTH1688	10	M	B	S	S	34	35	C	C	3	2
HTH0404	11	M	B	A	A	29	30	T	T	2	2
HTH3112	16	M	B	A	A	34	28	C	C	4	4

E.3 HTH ILIAC, PUBIC, AND ISCHIAL MEASUREMENTS

Table E. 3 Males and females with age in years

#	Age in yrs.	Sex	Ancestry	Iliac length		Pubic length		Pubic body width		Ischium length	
				R	L	R	L	R	L	R	L
HTH2714	1	F	B	55.63	54.95	24.62	25.09	7.86	7.45	29.00	28.77
HTH1435	2	F	B	60.04	57.93	27.52	29.83	--	--	40.06	39.82
HTH1074	4	F	B	97.23	96.13	39.12	41.23	14.30	14.05	52.00	51.61
HTH1115	4	F	B	74.78	75.44	35.54	36.16	12.02	11.38	43.20	42.95
HTH2141	4	F	B	80.81	80.52	37.79	38.75	11.45	12.40	45.27	44.46
HTH1098	5	F	B	71.81	71.47	36.45	38.18	11.77	12.05	45.25	47.66
HTH0624	6	F	B	88.97	89.38	42.52	41.96	15.25	15.80	51.63	50.52
HTH2036	7	F	W	86.38	83.80	39.70	40.02	11.38	11.40	47.97	47.41
HTH0872	8	F	B	104.75	102.53	54.32	57.68	16.72	16.26	62.86	63.65
HTH1156	8	F	B	89.16	90.31	41.61	41.19	13.03	10.42	51.50	51.48
HTH2074	8	F	B	90.04	89.18	42.79	42.46	12.53	13.41	58.29	57.37
HTH0632	10	F	B	93.89	93.19	43.15	43.70	13.89	14.06	51.69	53.82
HTH0526	11	F	B	109.43	109.04	48.66	50.18	15.19	15.82	63.90	61.74
HTH0645	12	F	W	126.47	125.37	61.82	61.88	22.27	23.96	75.96	77.71
HTH1240	12	F	B	125.45	126.67	58.75	59.47	22.44	23.73	69.20	69.68
HTH1772	12	F	W	111.02	109.53	58.63	57.25	17.96	17.38	71.95	69.96
HTH0633	13	F	B	122.78	122.27	68.05	66.16	22.16	23.11	67.81	70.99
HTH2118	13	F	B	89.01	90.39	47.13	46.94	13.57	14.75	57.93	56.44
HTH2135	14	F	B	131.53	130.77	65.59	67.29	17.54	17.91	71.32	73.68
HTH1168	1	M	B	50.35	50.65	23.02	--	8.25	--	29.36	28.33
HTH1379	1	M	B	44.11	44.15	20.75	20.62	7.44	7.70	26.59	27.01
HTH1385	1	M	B	61.34	61.15	29.39	30.68	9.10	8.04	38.56	38.59
HTH1583	1	M	W	50.46	49.94	22.97	23.22	8.86	8.76	30.91	30.31
HTH1768	1	M	B	55.37	55.19	25.59	26.22	7.81	8.60	30.36	30.98
HTH1894	1	M	B	52.24	51.34	21.45	21.95	6.64	6.58	29.04	28.63
HTH2075	1	M	B	53.92	54.30	25.11	25.84	6.34	6.72	31.83	31.22
HTH2370	1	M	B	47.10	47.05	22.23	21.95	6.95	7.35	29.16	29.71
HTH1557	3	M	B	70.31	70.93	34.52	32.94	10.30	11.60	44.31	43.58
HTH1950	4	M	B	50.92	50.68	22.19	23.35	--	--	35.24	35.97
HTH1784	6	M	B	78.95	79.65	39.69	39.69	14.55	14.22	52.00	51.78
HTH2144	6	M	B	74.41	74.25	34.44	33.17	12.29	12.21	46.16	44.03
HTH1834	8	M	B	100.72	99.87	43.57	44.59	14.20	12.39	56.48	56.18
HTH0710	10	M	B	109.25	110.10	50.63	48.42	16.64	15.23	66.45	67.12
HTH1441	10	M	B	104.56	101.95	49.06	48.90	17.43	17.51	63.51	62.90
HTH1688	10	M	B	101.90	99.11	48.64	48.05	14.87	15.28	61.28	59.89
HTH0404	11	M	B	121.05	119.49	51.62	53.78	18.74	17.41	75.38	69.81
HTH3112	16	M	B	121.65	119.57	59.34	56.27	15.37	15.88	82.11	79.40

E.4 HTH INDICES

Table E. 4 Males and females with age in years

#	Age in yrs.	Sex	Ancestry	SN index		I/SN index		Pubic index		I-P index		A/P SN index	
				R	L	R	L	R	L	R	L	R	L
HTH2714	1	F	B	3.49	3.51	0.27	0.29	0.32	0.30	0.85	0.87	0.68	0.55
HTH1435	2	F	B	2.44	2.23	0.25	0.25			0.69	0.75	0.60	0.48
HTH1074	4	F	B	3.52	3.72	0.34	0.32	0.37	0.34	0.75	0.80	0.60	0.41
HTH1115	4	F	B	3.44	3.30	0.33	0.37	0.34	0.31	0.82	0.84	0.70	0.78
HTH2141	4	F	B	3.10	3.20	0.29	0.31	0.30	0.32	0.83	0.87	0.67	0.76
HTH1098	5	F	B	2.88	3.07	0.37	0.36	0.32	0.32	0.81	0.80	0.82	0.61
HTH0624	6	F	B	2.90	3.03	0.32	0.36	0.36	0.38	0.82	0.83	0.57	0.49
HTH2036	7	F	W	3.26	3.40	0.34	0.31	0.29	0.28	0.83	0.84	0.46	0.42
HTH0872	8	F	B	3.57	3.62	0.26	0.27	0.31	0.28	0.86	0.91	0.47	0.46
HTH1156	8	F	B	2.89	2.81	0.30	0.32	0.31	0.25	0.81	0.80	0.69	0.71
HTH2074	8	F	B	3.36	3.10	0.35	0.36	0.29	0.32	0.73	0.74	0.57	0.63
HTH0632	10	F	B	2.94	3.14	0.33	0.29	0.32	0.32	0.83	0.81	0.78	0.44
HTH0526	11	F	B	2.91	3.05	0.29	0.34	0.31	0.32	0.76	0.81	0.58	0.46
HTH0645	12	F	W	2.24	2.41	0.29	0.30	0.36	0.39	0.81	0.80	0.76	0.53
HTH1240	12	F	B	1.57	1.67	0.37	0.40	0.38	0.40	0.85	0.85	1.38	1.29
HTH1772	12	F	W	2.33	2.07	0.25	0.24	0.31	0.30	0.81	0.82	0.76	0.75
HTH0633	13	F	B	1.33	1.37	0.35	0.33	0.33	0.35	1.00	0.93	1.32	1.15
HTH2118	13	F	B	2.55	2.82	0.31	0.32	0.29	0.31	0.81	0.83	0.80	0.67
HTH2135	14	F	B	1.68	1.67	0.35	0.36	0.27	0.27	0.92	0.91	0.96	0.98
HTH1168	1	M	B	3.06	3.68	0.27	0.26	0.36		0.78		0.53	0.42
HTH1379	1	M	B	2.82	2.54	0.25	0.23	0.36	0.37	0.78	0.76	0.56	0.52
HTH1385	1	M	B	2.89	2.79	0.25	0.25	0.31	0.26	0.76	0.80	0.57	0.72
HTH1583	1	M	W	2.44	2.46	0.26	0.27	0.39	0.38	0.74	0.77	0.84	0.76
HTH1768	1	M	B	3.67	3.60	0.27	0.28	0.31	0.33	0.84	0.85	0.54	0.68
HTH1894	1	M	B	2.91	3.22	0.26	0.29	0.31	0.30	0.74	0.77	0.41	0.65
HTH2075	1	M	B	3.44	3.84	0.25	0.24	0.25	0.26	0.79	0.83	0.53	0.49
HTH2370	1	M	B	2.94	2.82	0.24	0.23	0.31	0.33	0.76	0.74	0.68	0.58
HTh1557	3	M	B	2.27	2.23	0.22	0.25	0.30	0.35	0.78	0.76	0.75	0.64
HTH1950	4	M	B	2.43	2.50	0.28	0.25			0.63	0.65	0.68	0.80
HTH1784	6	M	B	3.09	3.48	0.37	0.37	0.37	0.36	0.76	0.77	0.72	0.76
HTH2144	6	M	B	3.21	3.05	0.35	0.37	0.36	0.37	0.75	0.75	0.59	0.57
HTH1834	8	M	B	2.86	3.23	0.27	0.28	0.33	0.28	0.77	0.79	0.61	0.56
HTH0710	10	M	B	2.36	2.41	0.30	0.31	0.33	0.31	0.76	0.72	0.87	0.76
HTH1441	10	M	B	2.61	2.76	0.28	0.29	0.36	0.36	0.77	0.78	0.76	0.71
HTH1688	10	M	B	3.41	3.24	0.33	0.35	0.31	0.32	0.79	0.80	0.91	0.76
HTH0404	11	M	B	2.50	2.54	0.28	0.29	0.36	0.32	0.68	0.77	0.86	0.63
HTH3112	16	M	B	2.76	2.04	0.28	0.28	0.26	0.28	0.72	0.71	0.58	0.66

APPENDIX F

TROTTER RAW DATA

F.1 TROTTER SCIATIC NOTCH MEASUREMENTS

Table F. 1 Males and females with age in years

				Angle		Width		Depth		Shape		Anterior		Posterior	
#	Age	Sex	Ancestry	R	L	R	L	R	L	R	L	R	L	R	L
14C-A	birth	F	B	91	86	10.4	10.2	3.63	3.31	A	A	4.79	4.61	8.43	8.33
28	birth	F	B	88	86	9.54	8.73	2.87	3.03	A	A	5.41	5.48	6.68	5.64
36	birth	M	W	-	92	-	11	-	3.18	-	A	-	6.03	-	7.13
38	birth	M	B	80	90	7.78	8.25	2.86	2.55	A	A	4.12	2.73	5.92	7.04
41	birth	F	W	90	85	10.6	10.1	3.7	3.42	A	A	4.63	4.66	7.84	7.77
42	birth	M	B	85	86	9.29	9.92	3.29	3.19	A	A	4.31	4.94	7.93	7.08
43	birth	M	B	93	95	8.58	8.84	2.15	2.25	A	A	3.76	5.14	5.93	6.19
11B	birth	M	W	88	88	11.1	11	3.21	3.4	A	A	4.62	4.23	8.9	8.1
12B	birth	F	B	88	93	10.8	10.6	2.43	2.24	A	A	3.44	3.94	8.1	7.86
12C	8 L mo	F	B	96	99	9.24	10	2.75	1.59	A	A	3.59	4.16	7.03	5.86
13B-1	1 mo	F	B	90	95	9.41	10.4	2.14	2.42	A	A	4.15	5	7.2	7.38
14B	birth	M	W	88	90	9.81	9.18	2.52	2.9	A	A	3.68	4.99	7.26	6.52
15B	birth	F	B	85	86	8.11	7.6	2.63	2.61	A	A	3.71	3.75	6.07	6.41
17B	birth	F	B	90	88	8.52	8.71	2.24	2.49	A	A	4.38	4.46	5.85	5.2
17C	birth	M	B	81	84	8.79	8.23	2.64	2.21	A	A	4.34	4.17	6.58	4.84
18B	birth	M	B	90	94	8.51	11	2.9	3	A	A	4.62	5.16	5.71	6.84
19B	2 mos	F	B	90	90	10.4	9.23	2.71	2.73	A	A	4.12	4.23	7.83	6.65
1B	birth	F	B	93	99	10.8	11.2	3.12	2.55	A	A	4.19	5.11	7.51	7.21
1C	birth	F	B	90	95	9.02	8.79	1.94	2.53	A	A	3.69	4.27	6.71	5.76
20C	8 L mo	F	B	96	100	8.87	9.97	2.7	2.61	S	S	4.69	5.13	5.81	6.14
21B	birth	M	B	86	86	8.91	7.59	2.7	2.44	A	A	4.74	3.38	6.95	6.08
22B	8 L mo	F	B	88	93	8.75	8.8	2.55	2.56	A	A	3.54	3.4	7.94	7.15
23B	birth	F	B	86	88	8.83	9.02	2.57	2.55	A	A	4.28	4.38	6.36	6.53
24B	birth	F	B	96	95	10.8	9.94	2.62	2.21	A	A	4.7	4.7	7.85	6.93
25B	birth	F	W	90	94	8.7	9.87	2.28	2.28	A	A	4.63	4.96	6.13	5.65
27B	birth	F	W	90	92	10.5	10.4	3.17	3.23	A	A	3.88	3.39	9.11	8.39
27C	birth	F	B	95	101	10.6	10.3	2.61	2.54	A	A	5.23	5.06	7.7	6.89
30A	8 L mo	F	B	88	88	7.46	8.44	1.93	2.43	A	A	4.09	3.4	6.29	5.14
30B	1 mo	M	B	100	104	10.8	10.7	2.55	3.09	S	S	6.8	6.7	6.62	5.55
31B	8 L mo	M	W	99	100	9.81	9.57	2.15	2.22	S	S	4.47	5.92	6.45	5.45
32B	birth	M	W	85	85	8.44	8.26	2.35	2.65	A	A	3.99	5.03	6.62	5.11
3C	birth	M	B	85	93	11.4	11.4	3.72	3.75	A	A	5.93	6.29	8.18	8.23
40-1	birth	M	W	96	98	11.9	11.9	2.9	3.76	S	S	6.02	6.54	8.07	7.8
4C	birth	F	B	94	90	9.39	9.08	2.81	2.35	A	A	4.96	5.14	6.65	6.33
5B	birth	F	B	91	95	10.3	9.56	2.62	2.26	A	A	4.4	4.21	7.49	6.51
6B	birth	M	B	85	95	10.1	10.6	2.92	2.77	A	A	4.3	3.82	8	7.92
Nil	birth	M	W	90	90	10.3	9.29	2.54	2.6	A	A	4.2	4.31	7.83	7.07

F.2 TROTTER NON-METRIC MEASUREMENTS

Table F. 2 Males and females with age in years

#	Age	Sex	Ancestry	Sciatic notch shape		AC		ASE	
14C-A	birth	F	B	R	L	R	L	R	L
28	birth	F	B	A	A	T	T	2	2
36	birth	M	W	A	A	T	T	2	0
38	birth	M	B	-	A	-	T	-	2
41	birth	F	W	A	A	C	C	1	2
42	birth	M	B	A	A	T	T	2	2
43	birth	M	B	A	A	T	T	4	2
11B	birth	M	W	A	A	T	T	1	1
12B	birth	F	B	A	A	T	T	3	4
12C	8 L mo	F	B	A	A	C	C	1	1
13B-1	1 mo	F	B	A	A	T	T	2	2
14B	birth	M	W	A	A	C	C	1	4
15B	birth	F	B	A	A	T	T	1	1
17B	birth	F	B	A	A	T	T	0	0
17C	birth	M	B	A	A	T	T	2	1
18B	birth	M	B	A	A	T	T	1	2
19B	2 mos	F	B	A	A	T	T	1	1
1B	birth	F	B	A	A	T	T	1	1
1C	birth	F	B	A	A	T	C	2	2
20C	8 L mo	F	B	A	A	C	C	2	2
21B	birth	M	B	S	S	C	C	2	1
22B	8 L mo	F	B	A	A	T	T	0	2
23B	birth	F	B	A	A	T	T	1	1
24B	birth	F	B	A	A	T	T	4	3
25B	birth	F	W	A	A	T	T	1	0
27B	birth	F	W	A	A	T	T	2	4
27C	birth	F	B	A	A	T	T	3	4
30A	8 L mo	F	B	A	A	T	T	1	0
30B	1 mo	M	B	A	A	C	C	1	1
31B	8 L mo	M	W	S	S	C	C	1	0
32B	birth	M	W	S	S	C	C	1	1
3C	birth	M	B	A	A	T	T	1	4
40-1	birth	M	W	A	A	T	T	0	0
4C	birth	F	B	S	S	T	T	1	1
5B	birth	F	B	A	A	T	C	1	2
6B	birth	M	B	A	A	T	T	0	1
Nil	birth	M	W	A	A	T	T	1	1
				A	A	T	T	2	1

F.3 TROTTER ILIAC, PUBIC, AND ISCHIAL MEASUREMENTS

Table F. 3 Males and females with age in years

#	Age	Sex	Ancestry	Iliac length		Pubic length		Subpubic angle		Pubic body width		Ischium length	
				R	L	R	L	R	L	R	L	R	L
14C-A	birth	F	B	32.81	32.44	14.13	14.79	-	-	4.16	4.19	17.7	17.95
28	birth	F	B	33.59	32.74	17.82	16.57	-	-	4.68	5.41	18.91	18.35
36	birth	M	W	-	29.84	11.7	11.54	-	-	-	-	14.34	14.33
38	birth	M	B	30.65	31.42	12.93	13.44	20	23	4.3	5.25	17.36	19.06
41	birth	F	W	34.14	33.42	15.88	16.1	23	23	5.15	5.68	19.14	19.42
42	birth	M	B	38.34	38.02	15.92	16.73	30	27	5.28	5.86	20.2	20.43
43	birth	M	B	28.08	27.53	11.26	11.65	-	-	-	-	14.6	14.56
11B	birth	M	W	31.8	32	13.4	13.02	-	-	-	-	17.92	17.73
12B	birth	F	B	28.18	28.56	12.4	12.09	-	-	-	-	14.93	14.78
12C	8 L mo	F	B	27.78	27.46	7.99	9.51	-	-	-	-	14.4	14.24
13B-1	1 mo	F	B	34.88	34.82	16.36	15.47	21	-	4.68	-	19.88	19.04
14B	birth	M	W	29.22	28.6	12.37	12.1	-	-	4.51	-	14.74	14.73
15B	birth	F	B	26.17	26.46	10.75	10.53	-	-	-	-	15.13	15.36
17B	birth	F	B	27.68	27.92	11.81	11.95	-	-	4.27	4.36	15.18	14.81
17C	birth	M	B	30.94	31.24	13.22	12.4	-	-	3.85	4.42	17.64	17.45
18B	birth	M	B	32.18	31.97	14.67	14.88	-	-	4.83	5	18.87	19.39
19B	2 mos	F	B	34.39	34.46	13.88	14.01	-	-	-	-	19.06	19
1B	birth	F	B	33	33.39	16.39	16.41	-	-	4.55	5.22	19.07	19.55
1C	birth	F	B	30	29.58	8.7	8.91	-	-	-	-	14.01	13.63
20C	8 L mo	F	B	26.34	25.42	11.59	11.52	-	-	-	-	13.68	13.72
21B	birth	M	B	27.63	27.57	11.52	11.93	-	-	3.55	3.41	16.02	16.23
22B	8 L mo	F	B	32.44	32.35	14.52	13.74	15	-	3.78	-	17.56	17.81
23B	birth	F	B	33.41	33.68	16.29	16.77	27	37	4.57	4.76	17.88	17.46
24B	birth	F	B	31.73	31.99	15.76	16.04	21	33	4.72	4.53	17.5	17.64
25B	birth	F	W	34.72	35.08	15.28	15.62	20	23	4.62	5.33	19.35	18.71
27B	birth	F	W	33.74	33.76	11.56	11.47	-	-	-	-	17.6	17.1
27C	birth	F	B	27.12	27.03	11.73	10.98	-	-	-	-	14.69	14.64
30A	8 L mo	F	B	27.46	27.78	11.74	12.03	-	-	3.48	4.2	14.72	14.79
30B	1 mo	M	B	33.85	33.42	14.41	15.07	15	-	4.48	5.39	18.52	19.09
31B	8 L mo	M	W	27.12	26.6	10.16	9.87	-	-	-	-	13.72	13.22
32B	birth	M	W	31.18	31.11	14.78	14.56	-	-	4.3	5.24	18.94	19.23
3C	birth	M	B	36.27	35.32	17.01	16.15	21	26	5.18	6.05	19.84	19.88
40-1	birth	M	W	34.12	35.15	13.76	13.96	-	-	-	-	17.61	17.74
4C	birth	F	B	28.4	28.35	-	-	-	-	-	-	14.72	14.74
5B	birth	F	B	30.67	30.98	12.85	12.94	-	-	-	-	16.6	16.78
6B	birth	M	B	30.16	30.67	13.86	13.83	-	-	-	-	17.13	17.55
Nil	birth	M	W	34.91	34.44	14.88	14.89	13	20	4.49	4.97	17.44	17.01

F.4 TROTTER INDICES

Table F. 4 Males and females with age in years

				SN index		I/SN index		Pubic index		I-P index		A/P SN index	
#	Age	Sex	Ancestry	R	L	R	L	R	L	R	L	R	L
14C-A	birth	F	B	2.87	3.08	0.32	0.31	0.29	0.28	0.43	0.46	0.57	0.55
28	birth	F	B	3.32	2.88	0.28	0.27	0.26	0.33	0.53	0.51	0.81	0.97
36	birth	M	W		3.46		0.37				0.39		0.85
38	birth	M	B	2.72	3.24	0.25	0.26	0.33	0.39	0.42	0.43	0.70	0.39
41	birth	F	W	2.87	2.96	0.31	0.30	0.32	0.35	0.47	0.48	0.59	0.60
42	birth	M	B	2.82	3.11	0.24	0.26	0.33	0.35	0.42	0.44	0.54	0.70
43	birth	M	B	3.99	3.93	0.31	0.32			0.40	0.42	0.63	0.83
11B	birth	M	W	3.45	3.23	0.35	0.34			0.42	0.41	0.52	0.52
12B	birth	F	B	4.44	4.71	0.38	0.37			0.44	0.42	0.42	0.50
12C	8 L mo	F	B	3.36	6.31	0.33	0.37			0.29	0.35	0.51	0.71
13B-1	1 mo	F	B	4.40	4.29	0.27	0.30	0.29		0.47	0.44	0.58	0.68
14B	birth	M	W	3.89	3.17	0.34	0.32	0.36		0.42	0.42	0.51	0.77
15B	birth	F	B	3.08	2.91	0.31	0.29			0.41	0.40	0.61	0.59
17B	birth	F	B	3.80	3.50	0.31	0.31	0.36	0.36	0.43	0.43	0.75	0.86
17C	birth	M	B	3.33	3.72	0.28	0.26	0.29	0.36	0.43	0.40	0.66	0.86
18B	birth	M	B	2.93	3.65	0.26	0.34	0.33	0.34	0.46	0.47	0.81	0.75
19B	2 mos	F	B	3.83	3.38	0.30	0.27			0.40	0.41	0.53	0.64
1B	birth	F	B	3.46	4.40	0.33	0.34	0.28	0.32	0.50	0.49	0.56	0.71
1C	birth	F	B	4.65	3.47	0.30	0.30			0.29	0.30	0.55	0.74
20C	8 L mo	F	B	3.29	3.82	0.34	0.39			0.44	0.45	0.81	0.84
21B	birth	M	B	3.30	3.11	0.32	0.28	0.31	0.29	0.42	0.43	0.68	0.56
22B	8 L mo	F	B	3.43	3.44	0.27	0.27	0.26		0.45	0.42	0.45	0.48
23B	birth	F	B	3.44	3.54	0.26	0.27	0.28	0.28	0.49	0.50	0.67	0.67
24B	birth	F	B	4.13	4.50	0.34	0.31	0.30	0.28	0.50	0.50	0.60	0.68
25B	birth	F	W	3.82	4.33	0.25	0.28	0.30	0.34	0.44	0.45	0.76	0.88
27B	birth	F	W	3.31	3.22	0.31	0.31			0.34	0.34	0.43	0.40
27C	birth	F	B	4.07	4.06	0.39	0.38			0.43	0.41	0.68	0.73
30A	8 L mo	F	B	3.87	3.47	0.27	0.30	0.30	0.35	0.43	0.43	0.65	0.66
30B	1 mo	M	B	4.22	3.46	0.32	0.32	0.31	0.36	0.43	0.45	1.03	1.21
31B	8 L mo	M	W	4.56	4.31	0.36	0.36			0.37	0.37	0.69	1.09
32B	birth	M	W	3.59	3.12	0.27	0.27	0.29	0.36	0.47	0.47	0.60	0.98
3C	birth	M	B	3.07	3.04	0.32	0.32	0.30	0.37	0.47	0.46	0.72	0.76
40-1	birth	M	W	4.09	3.16	0.35	0.34			0.40	0.40	0.75	0.84
4C	birth	F	B	3.34	3.86	0.33	0.32					0.75	0.81
5B	birth	F	B	3.94	4.23	0.34	0.31			0.42	0.42	0.59	0.65
6B	birth	M	B	3.44	3.84	0.33	0.35			0.46	0.45	0.54	0.48
Nil	birth	M	W	4.04	3.57	0.29	0.27	0.30	0.33	0.43	0.43	0.54	0.61

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