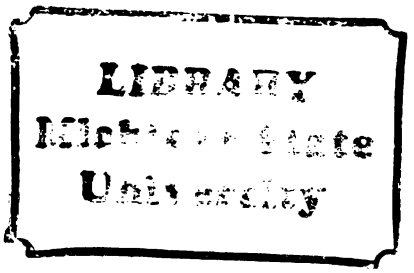


This is to certify that the

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A STUDY OF THE PREAURICULAR SULCUS

IN A CADAVER POPULATION

presented by

Samuel Strong Dunlap

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Anthropology

Norman J. Sauer
Major professor

Date July 31, 1981

# A STUDY OF THE PREAURICULAR SULCUS IN A CADAVER POPULATION

By

Samuel Strong Dunlap

A DISSERTATION

Submitted to
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ABSTRACT

A STUDY OF THE PREAURICULAR SULCUS
IN A CADAVER POPULATION

By

Samuel Strong Dunlap

This study examines the preauricular sulcus of 97 ilia from the human bony remains of a dissecting room population for whom life history data is available. The preauricular sulci of 67 females and 30 males were analyzed with respect to sex, age, body weight, degenerative joint phenomena, obstetrical events and sexual dimorphic characteristics in the posterior pelvis. The preauricular sulcus is an attachment site for the antero-inferior sacroiliac joint ligament which is assumed to be strongly sexually dimorphic. Much of this dimorphism is presumably related to pregnancy and parturition. Although human females who have borne children are reported to have a sulcus morphology which is visually clearly distinct from nulliparous females and males. The preauricular sulcus has never been adequately examined in human skeletal remains with life history data.

Specimens were obtained from dissecting room populations and several forensic examination cases for which life history data has been obtained. Analyses of preauricular sulcus morphology and measurements indicate the sexual dimorphism is clear and distinct

and that preauricular sulcus variation is also significantly related to obstetrical events, lumbo-sacral anomalies and the sciatic notch angle. Examination of samples of reproductive aged pelves from forensic, archeological and Hammon-Todd collection specimens revealed no inconsistencies with the findings presented in this analysis. It is clear that the well-developed preauricular sulcus frequently found in female pelves forms under any of several conditions, including pregnancy, that are favorable to pelvic joint instability.

To Sheba

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I only regret that Dr. Terrell W. Phenice, who provided me with excellent guidance early in my graduate studies, cannot see the results of this work.

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# CHAPTER I

# INTRODUCTION

## The Preauricular Sulcus

The preauricular sulcus is a bony structure adjacent to the antero-inferior margin of the sacroiliac joint. (See Figure 1.) It is an attachment site for the antero-inferior sacroiliac joint ligament. A well developed preauricular sulcus is commonly found in human adult females and virtually never found in human adult males. Although it is reported to be an excellent aid in sexing human skeletal remains (Derry, 1909, 1911; Smith and Fiddes, 1955; Cornwall, 1956; Krogman, 1962; Bass, 1971; and Stewart, 1979), no study has been undertaken to examine the preauricular sulcus in a human sample for which life history data is available.

The literature on the preauricular sulcus suggests that the conditions of gestation may account for its formation (Derry, 1909, 1911; Houghton, 1974, 1975). Recently, its presence in female remains has begun to be accepted as strongly indicative of past obstetrical events (Smith and Fiddes, 1955; Houghton, 1974, 1975; Ullrich, 1975; and Stewart, 1979).

Derry (1909, 1911) and Houghton (1974, 1975) have suggested that during gestation, hormonally mediated pelvic joint relaxation and increasing body weight passing through the sacroiliac joints may be important etiological factors responsible for the formation of the

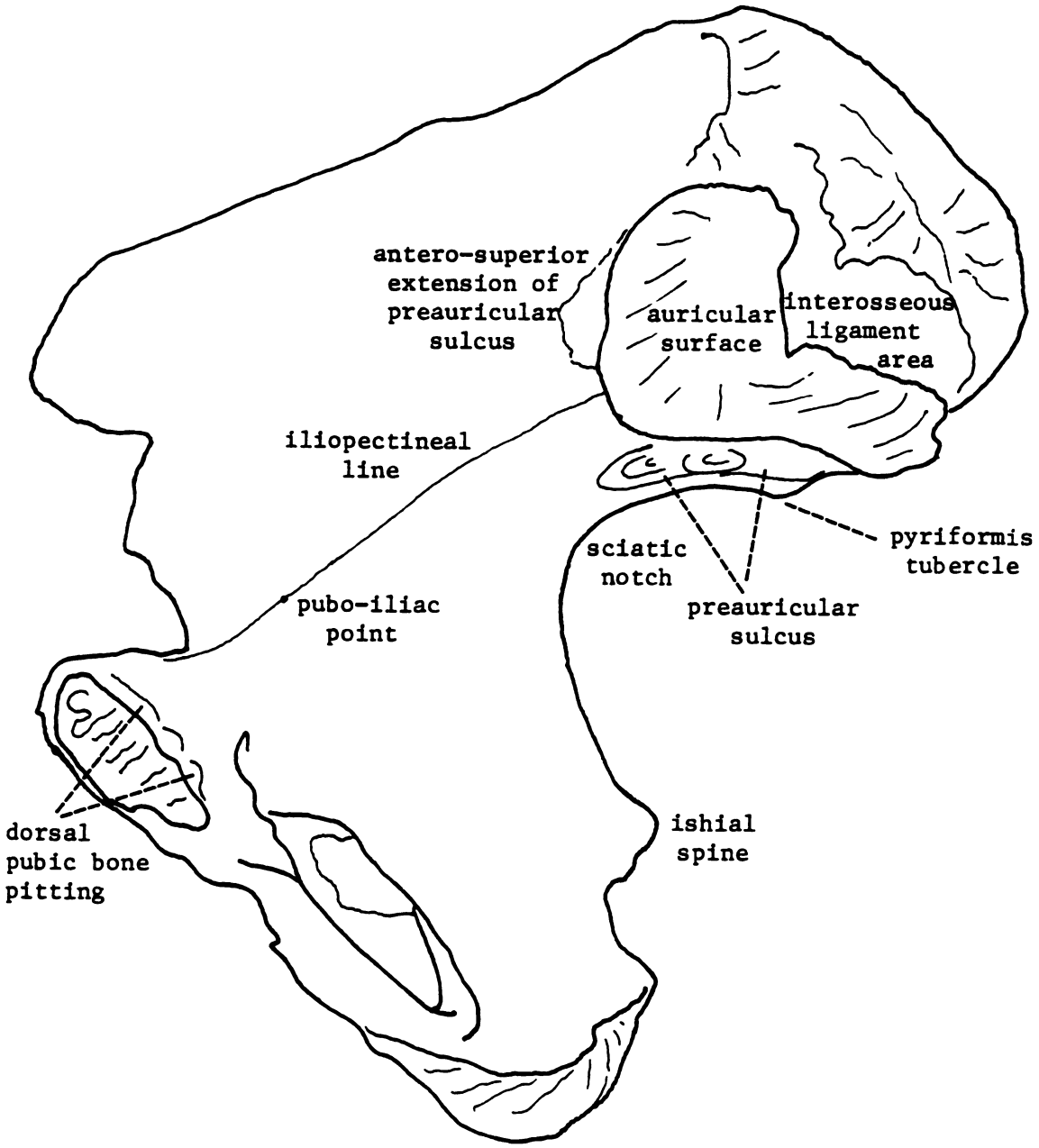


Figure 1. Antero-inferior View of Right Innominate Pelvic Surface

well-developed preauricular sulcus in females. Derry (1909, 1911) also discussed sexual dimorphic characteristics in the sacroiliac joint area which might contribute to preauricular sulcus formation.

Many of these ideas discussed by Derry and Houghton remain to be studied in pelvic specimens for which sex and other life history data are known. Undoubtedly Derry knew sex on some of the pelves he examined since he dissected embalmed cadavers and Nubian remains which included enough soft anatomy for indisputable sex determination. However, Derry (1909, 1911) did not indicate how many specimens in his sample were indisputably sexed. Houghton's (1974) sample of pelvic remains from 119 individuals are of unknown sex. In 1975, Houghton reported on a few female pelvic specimens with life history data.

This study attempts to fill the gap in knowledge about the preauricular sulcus. The extensive use of preauricular sulcus morphology in sexing skeletal remains (Smith, 1955; Cornwell, 1956; Krogman, 1962; Bass, 1971; and Stewart, 1979) and its increasing use in obstetrical history assessment suggest the need for the examination of a sample of ilia from females and males with life history data. The specimens under study consisted of a post-reproductive aged sample of dissecting room cadavers. Additionally, pelvic remains of many reproductive age members of both sexes were examined from forensic cases, the Hammon-Todd collection, and archeological specimens.

Using the cadaver sample, the variations in preauricular sulcus size and morphology will be described. The relationship of the sulcus will be discussed with reference to its being an integral part of the sacroiliac joint. The sulcus variation will be compared with such

variables as sex, age, body weight, obstetrical histories, degenerative joint phenomena and pelvic sexual dimorphism.

## Literature Review

References to the preauricular sulcus in the anthropological and medical literature are few. Derry (1909, 1911) examined the sulcus in male and female innominates from archeological and dissecting room sources. He determined that a well-developed sulcus was invariably associated with female remains, and served as the attachment site for an enlarged, inferior portion of the anterior sacroiliac ligament which inserted medially on the antero-lateral area of the third sacral segment. The preauricular sulcus associated with most female innominates ". . . is broad and deep, frequently with sharp overhanging edges, and often pitted, the floor of the groove being of unequal depth." (1909:272) See Plate 1. Derry described the male sulcus as very shallow and indistinct. A sulcus in males is often suggested by the pyriformis tubercle lying closely adjacent to the inferior auricular surface margin. See Plate 2. Derry's length and breadth measurements of the sulcus demonstrate a clear separation of the sexes. He found only three male sulci out of 167 male innominates which resembled a typical female sulcus. The largest of the three measured well below the female mean and ". . . was very shallow and lacked the well-marked edges of the female sulcus." (1909:273) Derry further found support for the distinct sexual differences in the sulcus when the method was cross checked in Nubian remains where enough soft anatomy remained to establish sex.

Derry (1909, 1911) agreed with earlier suggestions (Zaaijer, 1893) that the well developed sulcus seen in female innominates was possibly related to pregnancy and childbirth. He offered his observations on female cadaver material as supporting evidence. He stated, " . . . a well-marked sulcus praeauricularis is rare in young female bone, while it is comparatively common in those of mature age." (1911:19)

Further detailed work on the preauricular sulcus was not undertaken until Houghton (1974) reexamined the structure in the bony pelves from skeletal remains of questionable origin. In the intervening decades, few papers on the preauricular sulcus appeared.

Frequently, the preauricular sulcus appears in A/P radiographs of the pelvis. (Hofer, 1929) Ferguson (1931) attributes its presence as a groove for the hypogastric (internal iliac) vessels. In the dissection and cleaning of the specimens under study, no vessels of any kind were ever found in the preauricular sulcus. Derry (1909) and Houghton (1974) also failed to find vessels in the sulcus. When these vessels lay over or adjacent to the ligamentous structures, no indentations were found which might suggest an underlying bony indentation similar to the preauricular sulcus. Infrequently, the superior gluteal artery (which originates from the internal iliac and exits the pelvis through the greater sciatic notch near its apex) will leave a bony groove in the region of the sciatic notch. See Plates 3 and 4. This groove is clearly not associated with the antero-inferior ligament attachment of the sacroiliac joint.

In The Radiology of Bones and Joints, Brailsford (1948) regards the preauricular sulcus as a structure associated with the anterior sacroiliac joint ligament attachment. Its presence is not to be confused with arthritic or pathological conditions in the sacroiliac joint. Brailsford does note that the preauricular sulcus " . . . appears to show greater development in women who have borne children." (p. 243) Sir Sydney Smith (1955, 1959), who used the preauricular sulcus to sex human skeletal remains, also recognized and utilized the structure as evidence for past obstetrical events. He stated, " . . . there is reason to believe that it is increased in size by repeated parturition." (1955:68)

Hoshi (1961) examined the preauricular sulcus in 60 males and 40 female adult Japanese pelves. His classification scheme varies considerably from that of Derry and Houghton. Hoshi rejected Hoyme's theory (1957, 1959) that the preauricular sulcus is a "growth scar" (Hoyme, 1959:67) presumably associated with sexual differentiation in the true pelvis during bone development. He failed to examine any other possible reasons for its incidence or variation even though he finds his classification scheme demonstrates a statistically significant sex difference.

Houghton's study (1974) of the preauricular sulcus was undertaken on 119 pelves of unknown sex. The pelves were sexed by visual assessments of the sciatic notch, sub-pubic arch, and the pubic bone shape (Houghton, 1979), but no attempt was made towards quantitation. Assuming correct sexing, his visual, subjective morphological criteria clearly supported the earlier observations of Derry. Houghton's

categories of sulcus morphology were essentially the same as Derry's (1909). He named the preauricular sulcus commonly found in females a " . . . groove of pregnancy . . ." (pregnancy sulcus) and that found in males a " . . . groove of ligament . . ." (ligament sulcus) (1974). He found that 71% of the female, but none of the male specimens exhibited a pregnancy sulcus. On the other hand, 81% of the males and only 21% of the females exhibited a ligament sulcus.

Houghton attributed the pregnancy sulcus to bone resorption concomitant with the ligamentous changes known to occur during pregnancy at the pubic symphysis. The co-occurrence of the pregnancy sulcus in most females and the documented dorsal pubic bone pitting occurring during pregnancy led Houghton to conclude that sulcus formation was related to pregnancy. He stated that a pelvic exhibiting these bony changes " . . . must be of a female who has borne at least one child." (Houghton, 1974:383) Houghton also reported (1979) that " . . . there was a clear-cut increase in [pregnancy] markings with increase in age" in 59 female pelves from his New Zealand material. As mentioned above, Derry (1911) also noted that the well-developed sulcus is more frequently encountered in older females. This certainly is not inconsistent with the notion that sulcus formation occurs during gestation. Older females are more likely to have had more pregnancies than younger females.

Houghton's 1975 publication discussed the preauricular sulcus and dorsal pubic bone changes associated with gestation in a few specimens of known sex, age and parity. Nothing in his examination of these

specimens is inconsistent with his 1974 publication or with Derry's publications (1909, 1911).

Very little is known about the physiological changes which produce the well-developed sulcus (or pregnancy sulcus) in females. Houghton suggested (1974, 1975, 1979) that hormonal changes associated with gestation probably play an important role in pre-auricular sulcus formation in females. This is supported by a review of the medical literature available on pelvic joint changes during pregnancy in humans and other mammals. Increased pelvic joint mobility in the pregnant human female has been recognized since ancient times and this has been supported by radiographic observations and measurements of pelvic joint separation during pregnancy (Lynch, 1920; Abramson et al., 1934; Borell and Fernstrom, 1967; and Ohlsen, 1974). Studies of the sacroiliac joint in autopsy material have noted increased joint mobility in gravid and parturient women compared to other women and men (Brooke, 1924; Sashin, 1930; and MacDonald and Hunt, 1952).

Sexual differences in the sacroiliac joints related to mobility and degenerative changes have also been documented by Brooke (1924) and Sashin (1930). In females, sacroiliac joint mobility rarely begins to decrease before the fifth decade, and the degenerative changes which usually appear by the fourth decade progress slowly. In males, mobility begins to decrease by the fourth decade, and degenerative changes progress rapidly to fibrous and even bony ankylosis. The preauricular sulcus is not mentioned in the works of Brooke or Sashin.

Histological studies, primarily on the pubic symphysis, suggest that irreversible changes occur in the ligamentous and bony tissue as a result of pregnancy and parturition. (Lang and Haslhofer, 1932; Sutro, 1936; and Putschar, 1931, 1976). In several mammal species, the hormone relaxin, which is also present in gravid and parturient human females (Quagliarello et al., 1979; and Weiss et al., 1976, 1977, 1978), is known to play an important role in effecting pelvic joint changes during pregnancy (Schwabe et al., 1978).

The preauricular sulcus has not been studied with respect to other sexually dimorphic features of the pelvis or as a structure which is an integral part of the sacroiliac joints which function in weight passage to the lower limbs.

Sexual dimorphism of the human bony pelvis has been well documented. It is most strongly expressed in those portions which are located in the true pelvis (Phenice, 1969; Coleman, 1969; Breathnach, 1965; and Grant and Basmajian, 1965). This is not surprising, since the female true pelvis is adapted to provide for specific conditions of gestation and parturition (Jordaan, 1976; and Schultz, 1949).

The preauricular sulcus is located in the posterior portion of the true pelvis. Other sexually dimorphic characteristics in this posterior portion include larger sciatic notch angles in females (Singh and Potturi, 1978; Javanovic, et al., 1968; and Hanna and Washburn, 1953), more posteriorly located sacroiliac joints in females (Derry, 1923; and Straus, 1927, 1929), and larger transverse diameters in females (Krukierek, 1951; Howells and Hotellings, 1936; Schultz, 1949; and Young and Ince, 1940).

The preauricular sulcus and these other sexually dimorphic features of the sacroiliac region and posterior true pelvis are, in part, related to the obstetrical requirements of females. However, a major anatomical function performed in the posterior pelvis is the transfer of weight from the lumbo-sacral articulation through the sacroiliac joints to the lower limb (Schultz, 1930). The sacroiliac joints are designed to carry large laods (Coventry and Tapper, 1972; Gunterberg et al., 1977), and, due to the close apposition of the cartilage surfaces by the short, strong ligaments surrounding the joints, very little movement is permitted in these diarthrodial joints.

Approximately 60% of body weight lies above the sacroiliac joints in an erect, free standing position (Goel and Svensson, 1977). In this position, the center of gravity lies anterior to the auricular surface (Hirt et al., 1944; Akerblom, 1948; and White and Panjabi, 1978). The sacroiliac joint ligaments are presumably under a greater or lesser load depending upon the length of the moment arm about the joint (Solonen, 1957). See Figure 2. Ligaments are strong, usually inelastic, collagenous fiber-bundle structures which surround diarthrodial joints and prevent joint movements beyond the normal range. Any conditions which might increase the load on the rotational moment arm about the sacroiliac joint or lengthen the moment arm might also lead to the development of larger ligaments necessary to the maintenance of joint stability. Such conditions might include increased body weight, relaxation of the joint ligaments in females during gestation, or the sexually dimorphic characteristics of the

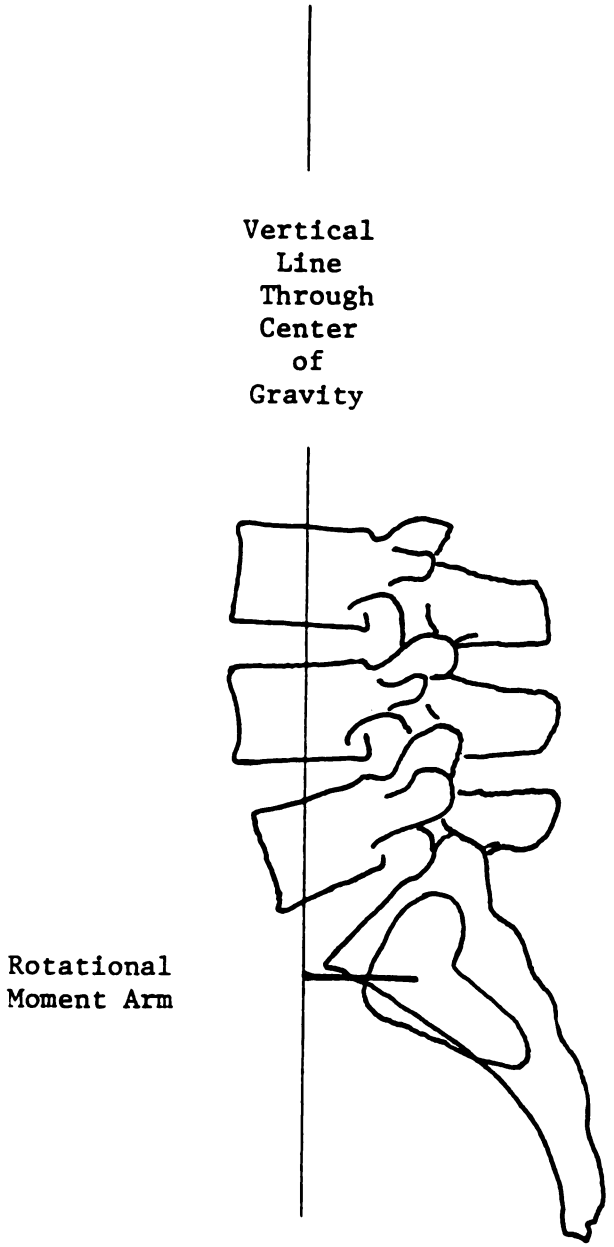


Figure 2. Lateral View of Sacroiliac Joint and Lower Lumbar Vertebrae

sacroiliac anatomy which include a more posterior placement of the joints in the female relative to ilium size. Evidence for a significant increase in lower lumbar and lumbo-sacral disc lesions in pregnant women compared to other women and men (O'Connell, 1960; Kelsey, et al., 1975; and DePalma and Rothman, 1970) suggests the sacroiliac joint may also experience increased load during gestation.

## Research Objectives

No analysis of the preauricular sulcus has been conducted on a pelvic joint collection from individuals of known sex and with life history data. The objectives of this study are to provide such an analysis. The preauricular sulci in the cadaver specimens will be described and factors that may be important in preauricular sulcus variation will be discussed. Data control is an important consideration in this study. Sex is indisputable in the cadaver specimens. The obstetrical data problems are discussed, particularly with respect to the age of the physician's obstetrical records and the importance of abortions and adoptions.

Several hypotheses which attempt to explain preauricular sulcus variation will be tested. Sexual dimorphism and the effects of pregnancy have been most commonly used to explain preauricular sulcus variation. These explanations will both be tested. From a consideration of the anatomy and function of the sacroiliac joints, several other factors emerge which may effect preauricular sulcus variation. These are age, body weight, degenerative joint conditions in the

sacroiliac joints and lumbo-sacral joints, and the location of the sacroiliac joint, all of which will be compared with preauricular sulcus variation.

# CHAPTER II

# MATERIALS AND METHODS

## Cadaver Specimens

The specimens under study consist of the posterior ilia from 67 female and 30 male cadavers which became available through the willed body programs in the Departments of Anatomy at Michigan State University and Wayne State University. The sacrum, fifth lumbar vertebra and pubic bones have also been retained for nearly all the specimens. Whole innominates and sacra are available for 19 of the 67 females and eight of the 30 males. The age distribution of the sample appears below by decade:

Table 1. Age Distribution by Decade of Male and Female Cadaver Specimens

| | Age by Decade | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 20s | 30s | 40s | 50s | 60s | 70s | 80s | 90s | n |
| Female | | | 2 | 13 | 16 | 18 | 14 | 5 | 67 |
| Male | 1 | | 1 | 7 | 13 | 5 | 3 | | 30 |

Additionally, data from the pelvic remains of 69 adult archeological specimens, 42 (33 female and nine male adults) forensic anthropology cases, and 182 (132 female and 50 male adults) Hammon-Todd Collection specimens will be included in discussion.

All the cadaver specimens are from individuals of Caucasian descent except for two Black Females, aged 60 and 64, and one 47-year old Oriental female.

The cadaver specimens were excised from the dissected remains and macerated with hot water, a potassium hydroxide solution and/or by natural bacterial action. Dermestid beetles were also employed in some cases. Only a few specimens were completely degreased and bleached, while most were left in the grease.

Obstetrical histories are available on 49 females. Obstetrical histories were obtained by writing to the physician who signed the death certificate. Newspaper obituaries were also searched in most cases. Where conflicting information was available from both sources, the physician's was used in the subsequent analysis. Although there are a few grandpara cases, specimens with obstetrical histories for the most part represent low parity individuals. This distribution is probably typical for dissecting room populations (Stewart, 1957) but may also reflect inaccurate obstetrical histories on this aged sample (see Table 2).

Body weight was also requested and frequently obtained in the obstetrical history request to the physician who signed the death certificate. Additionally, available weight records were requested in every case from the Michigan Driver's License application records available through the Michigan Department of State. Some hospital records where donors expired were also checked for weights.

Table 2. Obstetrical Information on Female Cadaver Specimens Listed by Age

| Age | G/P* | Age | G/P | Age | G/P |
|---|---|---|---|---|---|
| 42 | 4/2 | 68 | 0/0 | 79 | 0/0 |
| 51 | 4/3 | 68 | 2/3 | 80 | 0/0 |
| 51 | ?/5 | 68 | 0/0 | 80 | 0 |
| 52 | 2/2 | 69 | 2/2 | 81 | 2/2 |
| 55 | 1/1 | 70 | 4/4 | 82 | 2/0 |
| 55 | 2/2 | 70 | 0/0 | 82 | 0/0 |
| 57 | 9/7 | 71 | 2/1 | 82 | 2/2 |
| 58 | 3/2 | 72 | 0/0 | 85 | 1/1 |
| 59 | 2/2 | 72 | ?/1 | 86 | 0/0 |
| 60 | 1/0 | 72 | ?/1 | 87 | 2/2 |
| 60 | 4/2 | 73 | 2 | 87 | 3 |
| 64 | 2/2 | 75 | 1 | 89 | 6/6 |
| 64 | ?/2 | 75 | 2/2 | 89 | 0/0 |
| 65 | 1/1 | 76 | 2/3 | 93 | 3/3 |
| 65 | 10/4 | 77 | 2 | 94 | 1/1 |
| 66 | 0 | 78 | 8 | 96 | 2 |
| 67 | 1 | | | | |

*G/P is physician-reported gravidity/parity. Single digits in G/P column are surviving children listed in obituary.

## Preauricular Sulcus Observations

### Morphology

Descriptions of sulcus morphology by Derry (1909) and Houghton (1974) are accurate and useful, and their criteria were adopted in assessing the specimens under study. In keeping with those criteria, any visual scoring and measurements were carried out only on sulci which appear inferior to the iliopectineal line, although occasionally in females, the sulcus does extend antero-superiorly in the form of a shallow depression with irregular, lateral margins. Ligament also attaches in this antero-superior extension. See Figure 1.

Every specimen was examined for the presence or absence of a preauricular sulcus. Five subjective, visual sulci scores were employed in this analysis: none, ligament, slight, moderate, and heavy. The ligament sulcus (see Plates 2, 7, 11, and 12) is quite variable in length and width. Its margins are usually irregular. The floor of the ligament sulcus is shallow and may exhibit a uniform or irregular surface. The slight, moderate and heavy scores are all associated with characteristics used by Derry (1909) to describe the well-developed sulcus presumably seen only in females, and by Houghton (1974) to describe the pregnancy sulcus, also presumably seen only in females (see Plates 1, 3, 6, 8, 9, 10, and 14). The essential characteristic of the pregnancy sulcus (all the slight, moderate and heavy scores) is the scooped-out appearance which forms a groove or series of overlapping pits in the cortical bone surface lateral to the antero-inferior auricular surface margin. These sulci may be of any length, width or depth. Usually their

margins are clearly defined due to the scooped-out appearance. The scoring of pregnancy sulci into slight, moderate and heavy categories is obviously subjective. Measurements were not taken before this visual scoring of pregnancy sulcus morphology was done. Since the essential feature of pregnancy sulcus morphology is its scooped-out appearance, a visual evaluation of the volume of bone resorption was used to score a sulcus as either slight, moderate or heavy. The depth of the scooped-out area (again not by actual measurement) was a more important factor than its length or width when scoring was done.

Measurements

Figure 3 illustrates the manner in which the length, width, and depth measurements were taken.

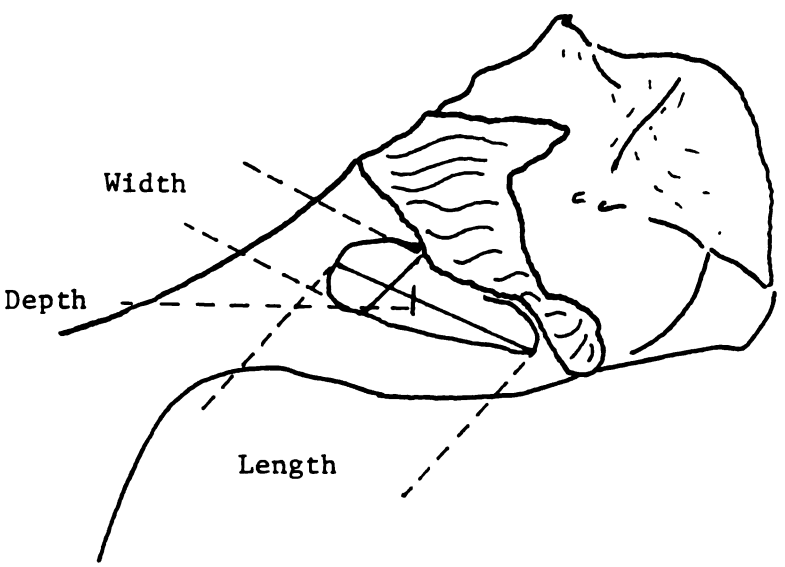


Figure 3. Length, Width and Depth Measurements on the Preauricular Sulcus

Length. The maximum length of each sulcus as it appears between the iliopectineal line and the most anterior-inferior point on the auricular surface was measured in mm.

Width. The maximum width of each sulcus was taken in mm at the widest point perpendicular to the length.

Depth. The depth of each sulcus was taken in mm at the deepest point as determined by the measurement of the length of a perpendicular to a straight line across the margins of the sulcus.

Area. The sulcus is an irregular shape on a slightly curved area of bone. Measurement difficulties are primarily due to reproducibility. This was overcome by orienting the ilium under the dioptograph so that the margins of the sulcus were in a plane roughly parallel to the surface glass. The edge of a small triangle of glass, slightly larger than the sulcus, was then placed on the most lateral margins and the opposite angle was then allowed to rest on the auricular surface margin which is the medial margin of the sulcus (see Figure 4).

The glass was then held in place against the bone while orienting its surface parallel to the dioptograph glass top. The glass was then removed and the perimeter of the sulcus was traced with the eyepiece, movements of which were reproduced on the mounted paper. Using a planimeter, the area of the sulcus, as reproduced in the perimeter, was measured in $mm^2$.

The preauricular sulcus perimeter of the specimens was not outlined. This measurement would have relied on a single

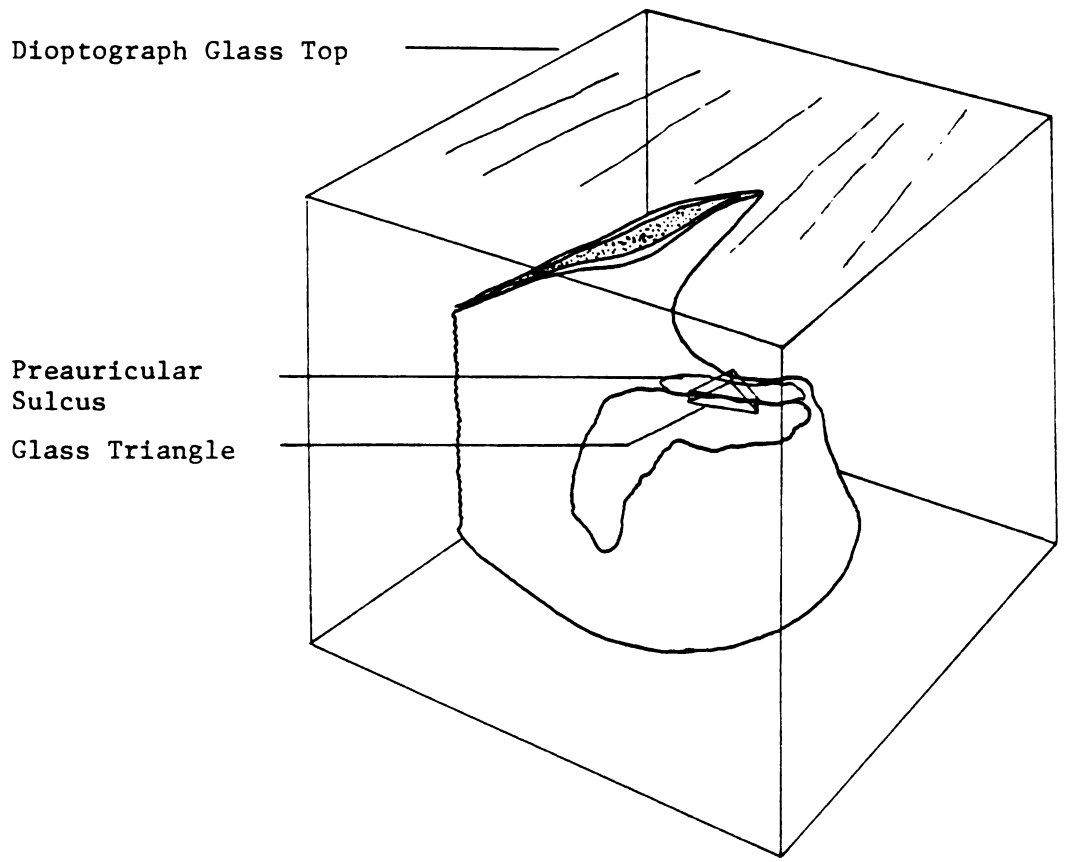


Figure 4. Orientation of Preauricular Sulcus for Area Measurement

accurately-reproducible observation, and would have biased the results. However, repetitive area measurements on ten randomly selected females indicated considerable intraobserver variation. One had no sulci and another had no sulcus on one side. The random sample of 17 ilia included seven ligament sulci, six slight and four heavy. Each of the 17 sulci were oriented, drawn and measured five times. The percent difference in measurements for each sulcus was figured and the average of those percentages was 16%. This large difference is due mainly to the random sample containing a high proportion of ligament and slight sulci. These sulci (particularly the ligament) tend to have irregular margins. Although it might have improved the reproducibility of the estimated area, outlining the sulcus margins would have been subjective and presumptuous, and was not done.

Any bone resorption on the ilium adjacent to the antero-inferior margin of the auricular surface is included in these measurements. Occasionally a well-developed pregnancy sulcus will thin laterally or superiorly towards the iliopectineal line. The preauricular sulcus will appear as if a pregnancy sulcus (with its well-defined margins) lies within the area of a large, shallow ligament sulcus. The areas encompassed by the margins of these shallow portions are included in the measurements, even though they do not conform to the "pregnancy sulcus" as described by Derry and Houghton. Ligament does attach in these shallow areas and a more difficult problem of what to measure arises if they are excluded. Males normally exhibit a short, narrow, and shallow sulcus. Only length and width measurements will be taken. The male preauricular sulcus is

often accentuated by the pyriformis tubercle. An obvious area of bone resorption as appears in females is virtually never present in males.

The Cuneate Index: BC/BD x 100. This index is a measurement of the relative posterior location of the sacroiliac joint. Figure 5 illustrates how the ilium was oriented and measured for obtaining the Cuneate Index.

Derry's method (1923) of orientation was employed and measurements very similar to his were also taken. After the fashion of Derry (1923), dioptograph drawings (refer to Figure 5) were obtained from each whole right innominate of 19 females. All measurements were taken along Derry's chilotic line (AD in Figure 5). The measure of relative posterior location of the sacroiliac joint is the index BC/BD x 100. This index and the distance BC both increase (see Figures 6 and 7) as the sacroiliac joint occupies less of the iliac length along line AD.

Derry's method (1923) for the location of osteological landmarks, innominate orientation and drawing is as follows: The line AD is based on two points: A, the pubo-iliac junction on the iliopectineal line; and C, the nearest point on the auricular surface margin to point A. The pubo-iliac point (A) is found by locating the pubo-iliac junction on the pelvic surface of the innominate. Often, a raised and/or roughened line of surface bone originating inferior to the iliopectineal line can be seen crossing it roughly at right angles. The crossing is Point A. Occasionally, the pubo-iliac junction is difficult to locate. Almost without exception, a remnant

Orientation of innominate under dioptograph after the fashion of Derry (1923). The points A, B, C and D and the line they establish are all located and drawn after the fashion of Derry (1923).

| | |
|---|---|
| BC | Portion of iliopectineal bone posterior to the sciatic notch apex |
| $\frac{BC}{BD} \times 100$ | Index for the posterior location of the sacroiliac joint |
| A | Pubo-iliac point |

This right innominate is from a female; 75 years of age; gravid 2; para 2; body weight 63.5 kg.

Figure 5. Pelvic Surface of Right Innominate After the Fashion of Derry (1923)

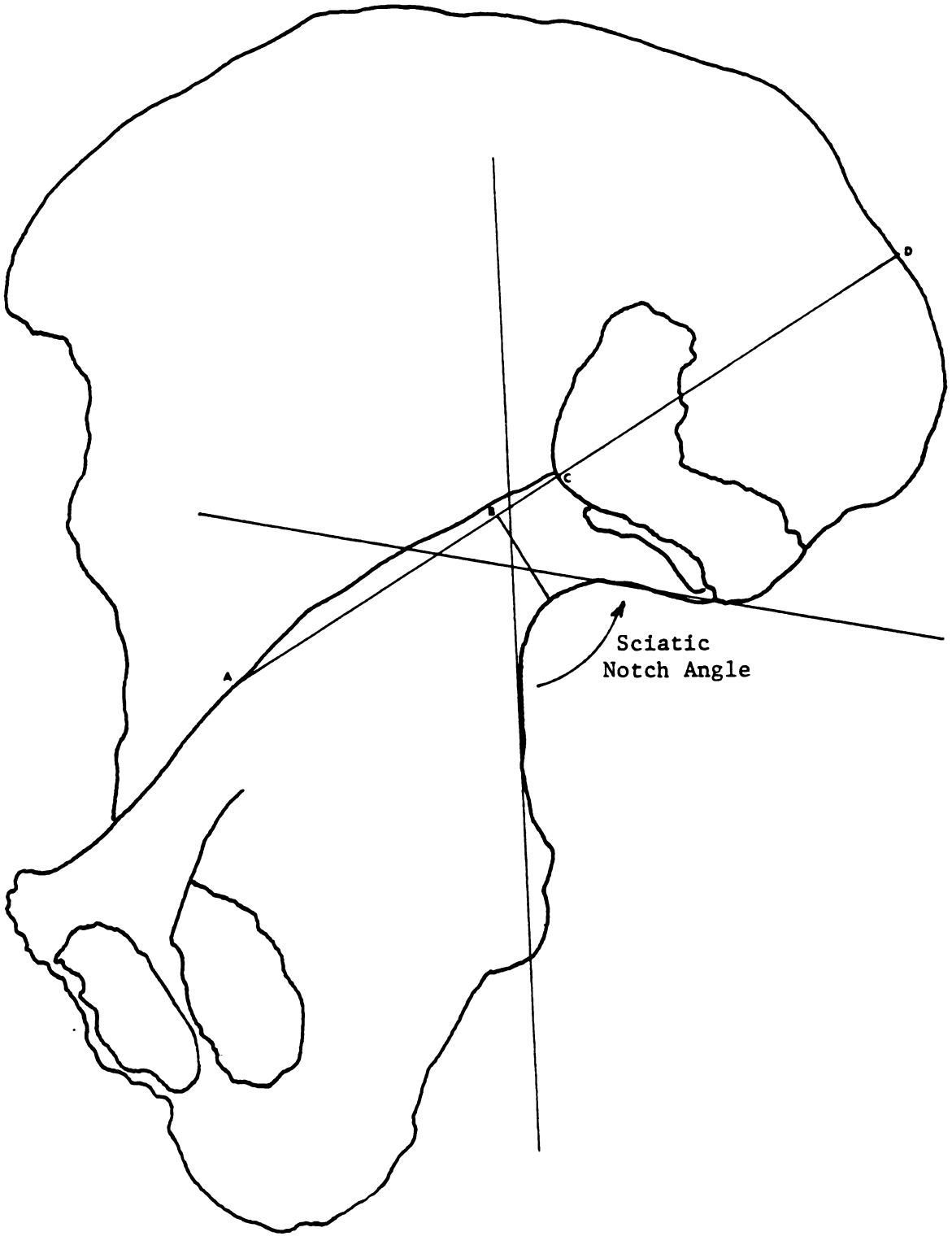


Figure 5. Pelvic Surface of Right Innominate After the Fashion of Derry (1923)

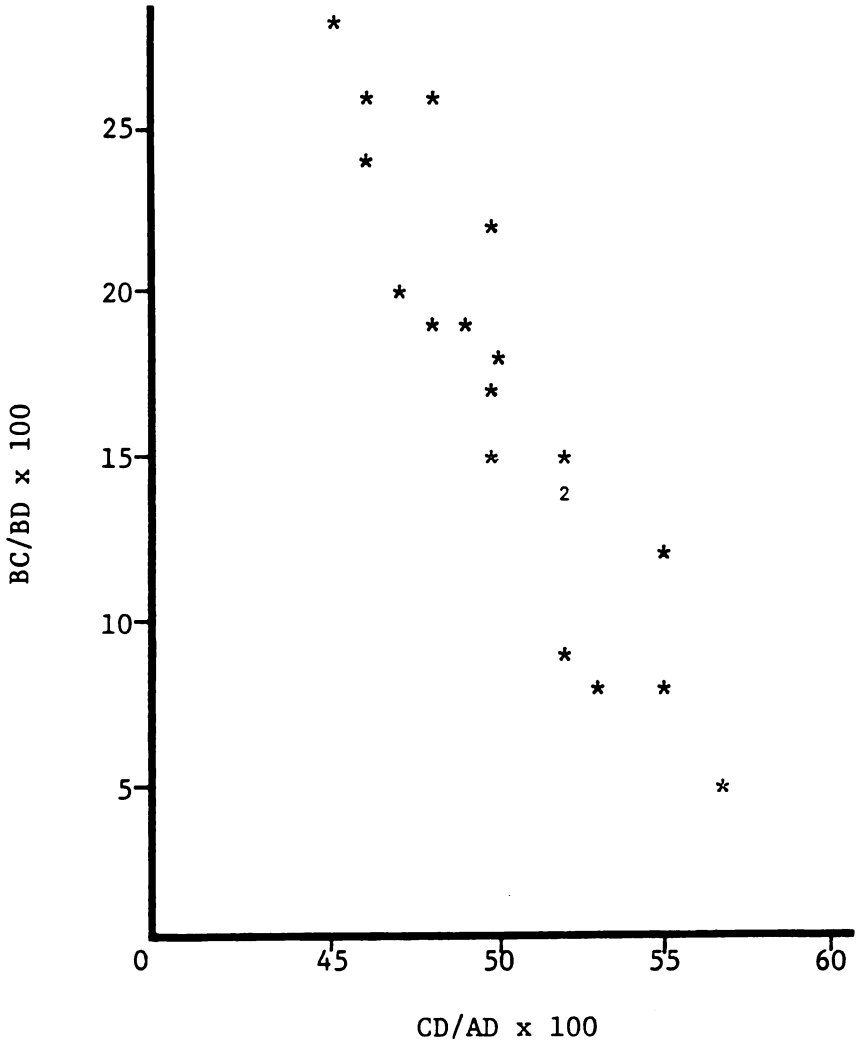


Figure 6. BC/BD x 100 Versus CD/AD x 100

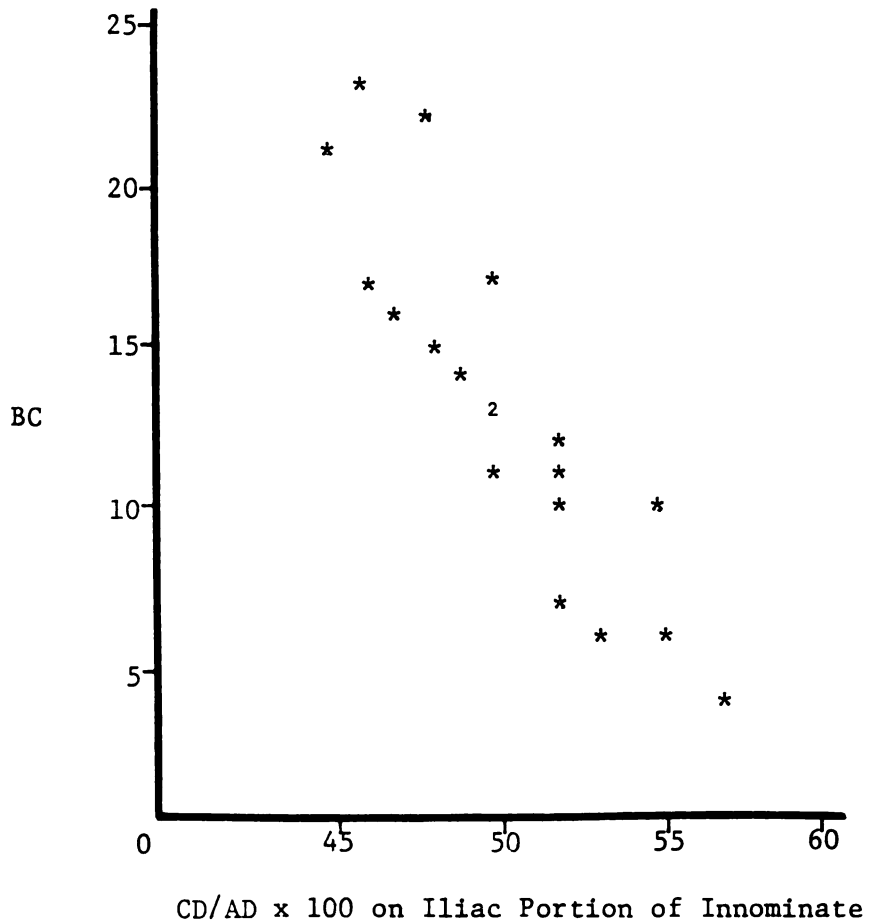


Figure 7. BC Versus CD/AD x 100

of the junction can be located along the acetabular rim and along the acetabular surface margin bordering the acetabular fossa. These junction remnants are depressions in the rim and surface margin and may be used to confirm the location of Point A. If they are used to confirm or establish Point A, " . . . a line should be drawn from the notch in the rim of the acetabulum at right angles to the axis of this part of the ilium, the pencil dot being placed on the ilio-pectineal line, where the latter is cut by the line from the acetabulum." (Derry, 1923:73) The nearest point, C, on the auricular surface margin to Point A is located with dividers.

Innominate orientation is accomplished by placing the bone, pelvic surface up, on the dioptograph board and inserting a sand bag under the posterior gluteal surface until the points A and C form a straight line parallel to the dioptograph surface glass. The drawing is then produced by outlining the innominate, auricular surface, iliopectineal line and points A and C. On the drawing, AC is extended to cross the iliac crest, point D. A line perpendicular to AD is dropped to the nearest point along the sciatic notch. The junction of this perpendicular to AD is point B.

## Reorientation of Whole Innominates

In order to apply the Cuneate Index to the posterior pelvic specimens, which comprise most of the sample under study, the following procedure was employed: (1) The 19 complete right innominates were reoriented under the dioptograph and drawings made as if they were only posterior iliac specimens; (2) The index BC/BD x 100 was calculated for each of the 19; (3) These new indices

were compared with the indices taken when the 19 innominates were oriented after the fashion of Derry to establish comparability.

It was determined during the original orientation of the innominates that the auricular surface was usually inclined anteroposteriorly slightly below the horizontal plane containing the line AD. Also, the iliopectineal line on the ilium just anterior to the auricular surface inclined below the horizontal plane at about a 15 degree angle. The 19 innominates and all the posterior iliac specimens were oriented under the dioptograph on the basis of these observations. On the innominate drawings done after the fashion of Derry, the intersection of line AD with the auricular surface was found to average 5 mm inferior to the iliopectineal line. When the line AD was drawn on the posterior iliac specimens and reoriented innominate drawings, it was placed about 5 mm inferior to the iliopectineal line. See Figure 8. If it was obvious from the shape of the auricular surface margin that the nearest point might be in a different location, the line was drawn through that point.

Cuneate Index comparison between innominates and the posterior ilia of innominates. The index BC/BD x 100 was calculated for each of the 19 innominates from the drawings of the reorientation. This series of indices is graphically compared in Figure 9 with the series calculated from the innominate drawings after the fashion of Derry (1923). A t test, Formula 1, for the comparison of small samples from the same or identical populations (Blalock, 1972) indicates there is no significant difference between the means. See Table 3.

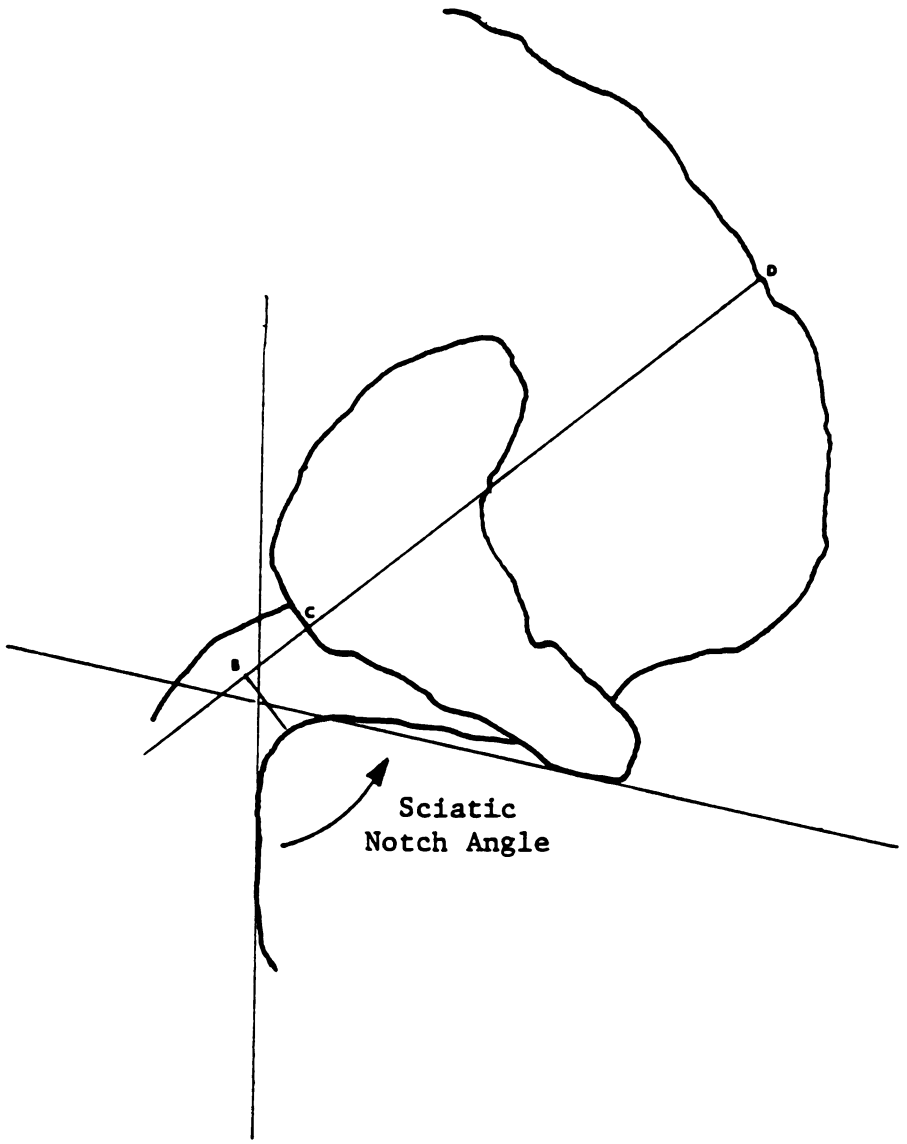


Figure 8. Dioptograph Drawing of Posterior Ilium

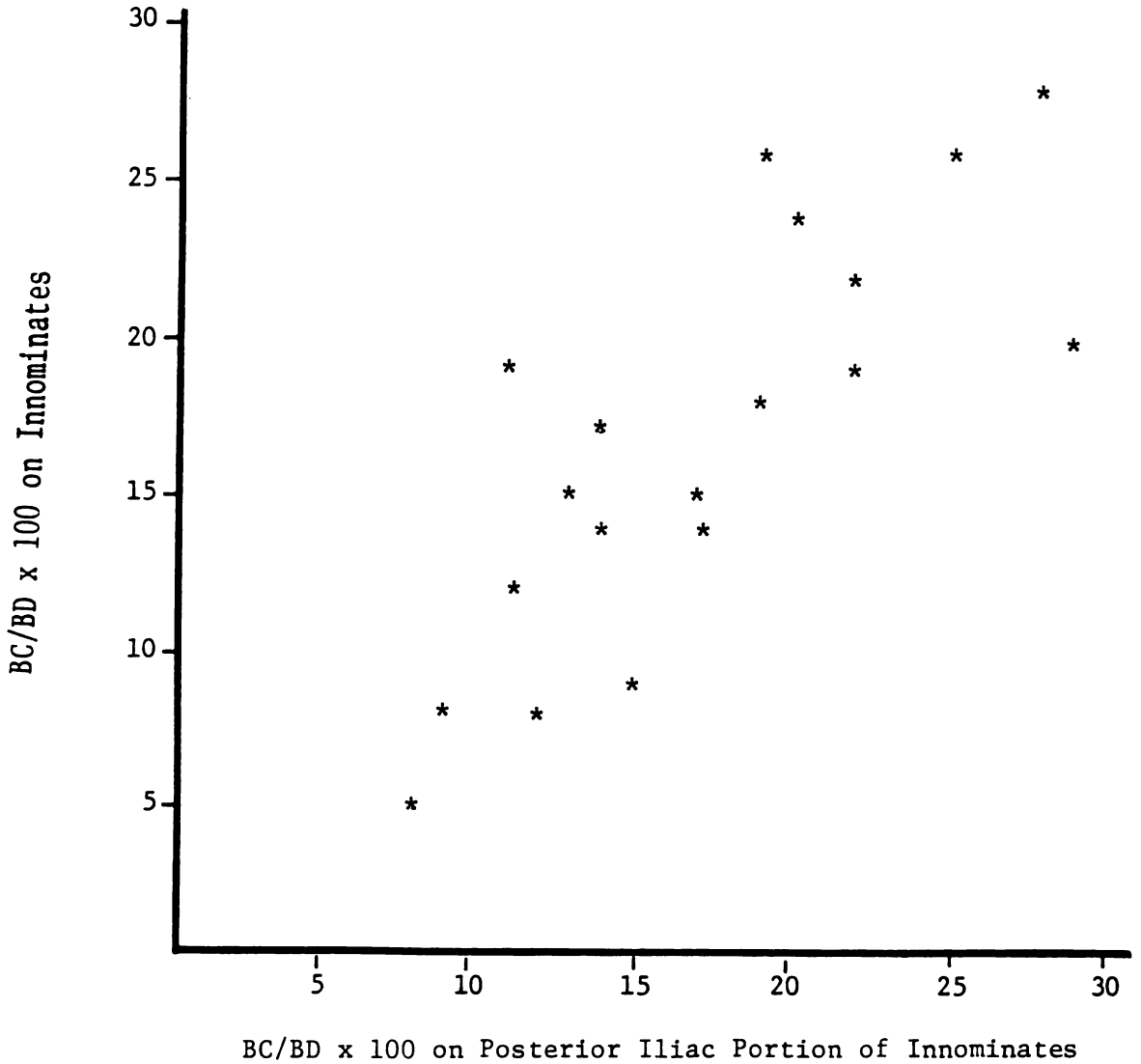


Figure 9. Cuneate Index on Innominates Versus Cuneate Index on Posterior Portion of Innominates

Formula 1.

$$t \text{ test value} = \frac{\bar{X}_1 - \bar{X}_2}{\frac{n_1 s_1^2 + n_2 s_2^2}{n_1 + n_2 - 2} \quad \frac{n_1 + n_2}{n_1 n_2}}$$

Table 3. t Test on Innominate Cuneate Indices

| | Innominates | Posterior Ilia | t Test | |
|---|---|---|---|---|
| n | 19 | 19 | test value | = .145 |
| $\bar{X}$ | 16.79 | 17.10 | | |
| SD | 6.646 | 6.127 | .05 level significance value | = 2.033 |

Comparison of all posterior ilia with innominates. The Cuneate Index was calculated for each of the posterior ilia. This series of indices is compared to those derived from whole innominates. The t test indicates there is no significant difference between the means. See Table 4.

The t tests indicate the index samples all come from the same population. Therefore, the Cuneate Index scores (derived from the posterior ilium specimens and the innominates oriented as if they were posterior ilia) represent the variable to be compared with preauricular sulcus morphology and measurements.

The sciatic notch angle. The measurement used in this study is taken from the intersecting tangents of the borders of the notch as

seen in dioptograph tracings made for the Cuneate Index. See Figures 5 and 8.

Table 4. t Test on Cuneate Indices of Innominates and All Posterior Ilia

| | Innominates | All Posterior Ilia | t Test | |
|---|---|---|---|---|
| n | 19 | 48 | test value | = .819 |
| $\bar{X}$ | 16.79 | 15.23 | | |
| SD | 6.646 | 7.06 | .05 level significance value | = 2.033 |

The anterior margin of the sciatic notch includes a virtually straight length of bone between the superior portion of the ishial spine and the curved inferior portion of the deepest portion of the notch. A line constructed along this straight length of bone established the anterior border of the sciatic notch as one side of the angle measured.

The superior side of the angle was determined by joining the lowest point on the auricular surface margin with a point anterior to the pyriformis tubercle on the margin of the superior border of the sciatic notch where the curvature has the greatest rate of increase.

The obstetrical and sexually dimorphic characteristics of the sciatic notch are most accurately expressed using these two lines. The pyriformis tubercle is quite variable in its presence or absence, size, and location. It does not appreciably obstruct the birth canal as it serves as an attachment site for a small portion of the

pyriformis muscle. Therefore, it is not used to establish the superior border of the sciatic notch, since functionally it is not related to the obstetrical function of the birth canal. The sciatic notch measurements employed in the analysis all come from the same drawings of the posterior ilia and posterior iliac orientations of the 19 innominates used in establishing the index measurements.

A t test (Formula 1), comparing the means of the sciatic notch angle scores from the innominate drawings after the fashion of Derry (1923) with the reoriented innominate drawings as described previously, indicates there is no significant difference. See Table 5.

Table 5. t Test on Innominate Sciatic Notch Angles

| | Innominates | Posterior Ilia | t Test | |
|---|---|---|---|---|
| n | 19 | 19 | test value | = .917 |
| $\overline{X}$ | 74.58 | 72.47 | | |
| SD | 7.28 | 6.90 | .05 level significance value | = 2.033 |

A t test comparing the means of the sciatic notch angle scores from the innominate drawings after the fashion of Derry (1923) with the scores from the posterior ilia indicates there is no significant difference. See Table 6. Therefore, the sciatic notch angle scores derives from the posterior ilium specimens and the innominates oriented as if they were posterior ilia represent the variable to be compared with preauricular sulcus morphology and measurements.

Table 6. t Test on Sciatic Notch Angles of Innominates and All Posterior Ilia

| | Innominates | Posterior Ilia | t Test | |
|---|---|---|---|---|
| n | 19 | 44 | test value | = 1.674 |
| $\overline{X}$ | 74.58 | 71.32 | | |
| SD | 7.283 | 6.846 | .05 level significance value | = 2.033 |

## Analysis

The analysis was performed on the right side of nearly all specimens. The left side was used only when the right was missing or damaged postmortem. Two lefts were included in the male specimens and ten in the female.

Twelve, or 17.9%, of the 67 female cadaver specimens were scored differently between the right and left sides. From the comparison of data on these 12 specimens in Table 7, it is evident that the analysis would not be significantly affected by these side differences. Therefore, the preauricular sulcus is considered a bilaterally symmetrical structure.

Preauricular sulcus morphology and measurements were compared with sex, age, lumbo-sacral anomalies, body weight, gravidity, parity, sacroiliac joint osteoarthritis, L5/S1 osteoarthritis, spondylosis deformans and osteochondrosis, L5 osteoarthritis, spondylosis deformans and osteochondrosis, the sciatic notch angle and an index for sacroiliac joint location. Males were only

*Table 7.* Female Cadaver Specimens with Side Differences

| Side Used in Analysis | Opposite Side | G/P | Age | Weight | Anomalies |
|---|---|---|---|---|---|
| Moderate | Heavy | 0/0 | 72 | 40.8 | None |
| Moderate | Slight | 4/4 | 70 | 71.7 | L5 sacralization<br>Right hip pin |
| Moderate | Slight | 1/1 | 65 | 65.8 | None |
| Moderate | Slight | - | 85 | -- | L5 sacralization |
| Slight | Moderate | 1/1 | 85 | 41.7 | None |
| Slight | Ligament | -/5 | 51 | 74.8 | None |
| Slight | Ligament | -/2 | 64 | 62.6 | None |
| Slight | Ligament | - | 53 | 54.4 | Right L5 transverse process/sacral-ala fusion |
| Ligament | Slight | 0/0 | 79 | 52.2 | Hypobasal sacrum |
| None | Slight | 4/3 | 51 | 63.9 | None |
| None | Ligament | 0/0 | 89 | 49.0 | L5 and sacrum missing |
| None | Ligament | 0/0 | 86 | 54.4 | None |

included in the comparison with sex. The working hypotheses were as follows:

1. The preauricular sulcus is a sexually dimorphic structure which is related to sex, gravidity, and parity;

2. The preauricular sulcus is an integral part of the sacroiliac joint and is related to lumbo-sacral anomalies, body weight, degenerative joint phenomena, the sciatic notch angle and location of the sacroiliac joint. Body weight and anatomical and degenerative phenomena of the joint are reflected in preauricular sulcus morphology and measurments.

Tests

Since the sample of specimens under study was not large, and much of the data was nominal and ordinal, the simple chi square test provided the most appropriate test. All chi square tests are 2 x 2 contingency tables. Most of the critical values and test values are reported in Tables 8, 14 and 20 along with the sample size for each test. The other chi square tests are presented in the text. In this study, test values are reported and discussed in terms of whether or not a significant relationship exists. However, the chi square tests the null hypothesis. A test value less than the .05 level critical value means that the null hypothesis cannot be rejected and therefore, no significant relationship exists between the variables under consideration. A test value equal to or greater than the .05 level critical value means that the null hypothesis may be rejected and the variables under consideration may be significantly related.

According to Blalock (1972), the chi square test's assumption of continuity may not be valid if any expected values are near or less than five. A correction formula applicable to 2 x 2 contingency tables will be used in this analysis where any expected value falls below 6.00.

Formula 2.

$$\chi^2 = \frac{N\left(|ad - bc| - \frac{N}{2}\right)^2}{(a+b)\ (c+d)\ (a+c)\ (b+d)}$$

Grouping of ordinal and interval data for use in the chi square tests is established as follows:

1. The visual preauricular sulcus scores are divided into: none, ligament, and slight for one category, and moderate and heavy for the second category. For some tests, the ligament sulcus is considered differently and a few other tests employ different categories. These categories are made explicit in the test reporting.

2. The ordinal scales which are used in scoring the degenerative phenomena are placed in two categories simply by dividing the scale in the middle.

3. Gravidity and parity are treated as nominal data in all chi square tests.

4. Except for age, interval data are divided into two categories at the median score. Age is nearly equally categorized by the division half way between 40 and 100.

Additionally, graphic presentations of selected bivariate and trivariate data are presented.

# CHAPTER III

# RESULTS

## Sex

The literature on the sulcus indicates that sulcus morphology is strongly sexually dimorphic. Neither Derry (1909) nor Houghton (1974) found male ilia exhibiting a sulcus morphology similar to the frequently observed female sulcus associated with pregnancy. The cadaver specimens under study in this report clearly support the previously suggested sexual dimorphism. Chi square tests were performed comparing sex to each of three preauricular sulcus observations: morphology, length, and width. Test results (see Table 8) indicate that sex is significantly related to all these preauricular sulcus observations.

Tables 9 and 10 illustrate the distribution of preauricular sulcus morphology in the cadaver specimens under study.

In Table 11, Derry's reported statistics are compared with this study. The male specimen in the cadaver collection under study which has a "pregnancy sulcus" is one of two males in the collection with ankylosing spondylitis. It exhibits bony bilateral sacroiliac joint fusion across the antero-superior margins. Refer to Plate 5. The lumbar vertebrae (L5, L4, and inferior L3) all exhibit the typical bony changes associated with ankylosing spondylitis. This specimen's

Table 8. Chi Square Test Values on Anatomical, Obstetrical and Metric Variables, Including Ligament Sulcus Specimens

| | Sulcus Visual Score | Sulcus Length | Sulcus Width | Sulcus Depth | Sulcus Area | Body Weight | Sciatic Notch Angle |
|---|---|---|---|---|---|---|---|
| Sex | 97† | 93 | 93 | | | | |
| | 45.286*** | 25.189** | 35.320* | | | | |
| Age | 67 | 67 | 67 | 67 | 67 | | |
| | 2.773 | .343 | 2.504 | 2.013 | 1.888 | | |
| Body Weight | 44 | 44 | 44 | 44 | 44 | | |
| | 2.316 | 2.276 | .000 | 1.466 | .361 | | |
| Gravida | 36 | 36 | 36 | 36 | 36 | | |
| | 8.346** | 3.75 | .000 | .929 | .150 | | |
| Para | 36 | 36 | 36 | 36 | 36 | | |
| | 5.280* | 1.979 | .453 | .198 | .500 | | |
| Cuneate Index | 67 | 67 | 67 | 67 | 67 | 44 | 63 |
| | .017 | .765 | .012 | .188 | .322 | .092 | .418 |
| Sciatic Notch Angle | 63 | 63 | 63 | 63 | 63 | 44 | |
| | 3.438 | 1.278 | 3.581 | .167 | 8.318* | 1.454 | |

†Upper whole number is n and lower number is $\chi^2$ test value for each 2 x 2 contingency table. df = 1; .05 critical value = 3.841; .01 critical value = 6.635; .001 critical value = 10.827.

* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$

Table 9. Distribution of Preauricular Sulcus Morphology in Cadaver Specimens

| | Preauricular Sulcus Morphology | | | | |
|---|---|---|---|---|---|
| | None | Ligament | Slight | Moderate | Heavy |
| Females | 4 | 12 | 27 | 11 | 13 |
| n = 67 | 6% | 18% | 40.2% | 16.4% | 19.4% |
| Males | 7 | 22 | 1 | 0 | 0 |
| n = 30 | 23.3% | 73.3% | 3.3% | | |

Table 10. Distribution of Preauricular Sulcus Morphology in Female Cadaver Specimens with Obstetrical Histories

| | Preauricular Sulcus Morphology | | | | |
|---|---|---|---|---|---|
| | None | Ligament | Slight | Moderate | Heavy |
| Females | 3 | 9 | 19 | 10 | 8 |
| n = 49 | 6% | 18.3% | 39% | 20.4% | 16.3% |

Table 11. Comparison of Derry's (1909) Statistics With This Study

| | Preauricular Sulcus Statistics | | | | |
|---|---|---|---|---|---|
| | n | Aver. Length | Aver. Width | Greatest Length | Greatest Width |
| Females in this study | 67 | 31.1 | 9.2 | 51.7 | 17.6 |
| Males in this study | 26 | 15.3 | 2.9 | 33.7 | 7.2 |
| Derry's females | 239 | 29.5 | 8 | 35 | 13.5 |
| Derry's males | 167 | -- | -- | 22† | 5† |

†One male innominate described as the largest sulcus of three male sulci all of which " . . . resemble the typical female groove." (Derry, 1909)

preauricular sulci are oval with shallow depressions not typically seen in males. These sulci may represent the early stages of osteitis and osteoporosis characteristic of the onset of ankylosing spondylitis (Smukler, 1975).

## Age

Houghton (1974) excluded four pelves from study with sacroiliac joint ankylosis on the grounds that preauricular sulcus morphology would be obliterated. As the present material under study is from aged individuals, the problem of degenerative joint conditions affecting preauricular sulcus morphology is addressed below when the preauricular sulcus is compared with several degenerative conditions in the sacroiliac joint and the lumbo-sacral joints.

Chi square tests were performed on the females comparing age with preauricular sulcus morphology, length, width, depth and area. Test results (see Table 8) indicated that age was not significantly related to any of these preauricular sulcus observations. However, during the specimen collection, it was noted that ligament sulci in females were frequently associated with older individuals and anomalous lumbo-sacral conditions. See Table 12.

In the visual score categories, the ligament sulci are included with the none and slight scores. Even though the ligament sulci are usually long and wide, their overall shallow appearance suggests they be placed in a slight category. Only one is from an individual under 70, the age being 68. They tend to be found in nulliparous or low parity individuals. Although body weight is available for only

six of the individuals with ligament sulci, there appears to be no relationship between these variables.

Table 12. Ligament Sulcus Specimens in Females

| Age | Body Weight | G/P | Anomalies and Pelvic Joint Destruction |
|---|---|---|---|
| 68 | 42.6 | 0/0 | Right accessory sacroiliac joint |
| 70 | -- | 0/0 | L5 sacralization and spina bifida |
| 71 | -- | -- | None |
| 71 | 90.7 | 2/1 | Right L5 transverse process/sacral-ala fusion |
| 72 | 56.2 | -/1 | L5 sacralization |
| 72 | -- | -/1 | None |
| 75 | 67.1 | -/1 | Sacrum missing--presumed none |
| 75 | -- | -- | S1 spina bifida |
| 79 | 52.2 | 0/0 | Hypobasal sacrum |
| 82 | 52.2 | 0/0 | L5 sacralization |
| 89 | -- | -- | Total destruction of left acetabulum |
| 93 | -- | 3/3 | Right pubic body fracture and pubic symphysis bony ankylosis |

Table 12 illustrates the high proportion of lumbo-sacral anomalies found in the specimens. Ligament sulci may be associated with lumbo-sacral anomalies and pelvic alterations such as acetabular and pubic bone destruction. The female specimens which consisted of L5, the sacrum and adjacent ilia were all examined for spina bifida, L5 spondylolysis, L5 sacralization, hypobasal sacrum, accessory sacroiliac joints, L5 transverse process/sacral-ala fusion, and acetabular and pubic bone destruction. Any of these congenital and acquired conditions may significantly effect the weight load at the sacroiliac joints. When the ligament sulcus scores were compared in a 2 x 2 contingency table with the anomalous conditions listed above,

the test results (see Table 13) indicated that a significant relationship exists.

Table 13. Chi Square Test Comparing the Ligament Sulcus in Females with Lumbo-Sacral Anomalies and Joint Destruction

| | No Ligament Sulcus | Ligament Sulcus | | $\chi^2$ Values | |
|---|---|---|---|---|---|
| No Anomalies | 39 | 3 | 42 | Corrected test value | = 7.022 |
| Anomalies* | 16 | 9 | 25 | .01 level significance value | = 6.635 |
| | 55 | 12 | 67 | | |

*Spina bifida, L5 spondylolysis, L5 sacralization, hypobasal sacrum, accessory sacroiliac joints, L5 transverse process/sacral-ala fusion, pubic bone destruction, and acetabular destruction.

It is probable that these anomalies have contributed to sulcus enlargement, and by implication, ligament enlargement due to their effect on sacroiliac joint stability, apart from obstetrical effects. Therefore, in many of the subsequent chi square tests, the preauricular sulcus was compared both with and without the ligament sulcus scores.

Chi square tests were again performed on the female specimens excluding the ligament sulcus scores comparing age with preauricular sulcus morphology, length, width, depth and area. Test results (see Table 14) again indicated that age was not significantly related to any of these preauricular sulcus observations.

Table 14. Chi Square Test Values on Anatomical, Obstetrical and Metric Variables Excluding Ligament Sulcus Specimens

| | Sulcus Visual Score | Sulcus Length | Sulcus Width | Sulcus Depth | Sulcus Area | Body Weight | Sciatic Notch Angle |
|---|---|---|---|---|---|---|---|
| Age | 55† | 55 | 55 | 55 | 55 | | |
| | .531 | 1.534 | 3.167 | .778 | 3.31 | | |
| Body Weight | 38 | 38 | 38 | 38 | 37 | | |
| | 1.688 | .990 | .093 | .349 | .161 | | |
| Cuneate Index | 55 | 55 | 55 | 55 | 55 | 38 | 53 |
| | .022 | 2.339 | .197 | .305 | .000 | .001 | .925 |
| Sciatic Notch Angle | 53 | 53 | 52 | 54 | 53 | 38 | |
| | 3.179 | 2.275 | 7.719** | .306 | 11.990*** | 1.688 | |

†Upper whole number is n and lower number is $\chi^2$ test value for each 2 x 2 contingency table. df = 1; .05 critical value = 3.841; .01 critical value = 6.635; .001 critical value = 10.827.

* $p \leq 0.05$
** $p \leq 0.01$
*** $p \leq 0.001$

Figure 10 is a trivariate display in which parity instead of points are inserted in the plot of preauricular sulcus area and depth. The ligament sulci are circled. From this figure, it is clear that the ligament sulcus tends to be shallow and often large in area. It is also clear that ligament sulcus measurements overlap with pregnancy sulcus measurements. The visual scoring of preauricular sulcus morphology cannot be accomplished by measurement alone. A subjective consideration of the presence or absence of the essential characteristics of the pregnancy sulcus, i.e., the scooped-out appearance and/or the steep overhanging edges, must be used if a reasonable assessment of past obstetrical events is to be attempted.

## Body Weight

Specimens with available body weight information present a normally distributed sample (see Table 15). There are obvious problems with body weight records. Body weight can fluctuate rapidly and over a wide range in response to nutritional, behavioral and/or pathological conditions. Body weight is also frequently not correctly stated by an individual or is estimated by the individual or the person recording. However, correspondence between physician's and driver's license records is fairly close (see Table 16). The close correspondence suggests that the body weight data may be close to the individual's average adult life time weight. Weights from the driver's license records were used when there was a choice. The physician reported weights tend to be lower and may have been taken during the person's terminal illness. Chi square tests were performed on the female specimens, including and excluding the

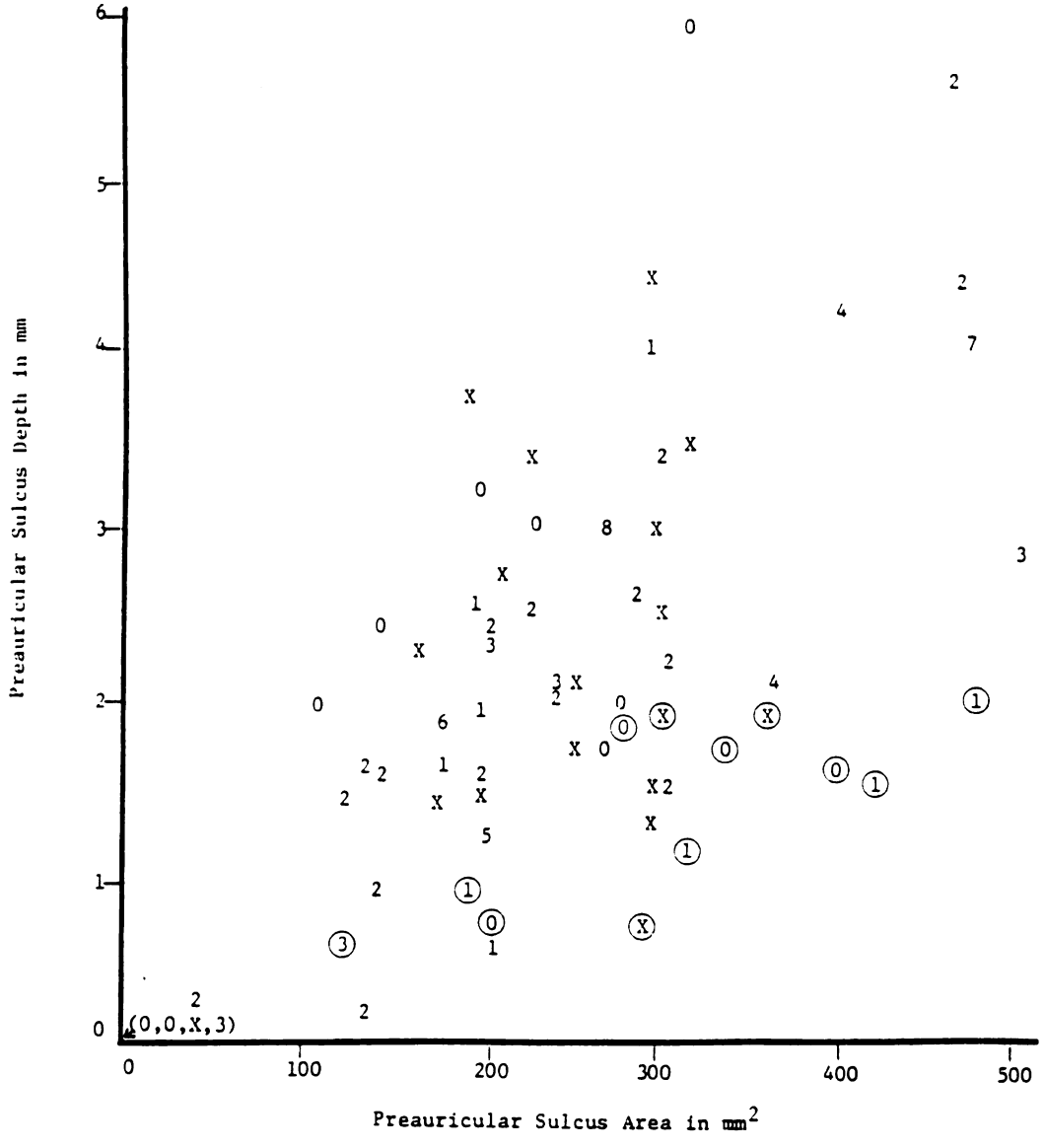


Figure 10. Preauricular Sulcus Depth Versus Preauricular Sulcus Area: Ligament Sulci Denoted

Numerical score is parity. X denotes specimen of unknown parity. Circled scores denote ligament sulcus specimens.

Table 15. Distribution of Body Weights in Kilograms

| | Weights | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40's | 50's | 60's | 70's | 80's | 90's --- | 150's | n |
| Female | 9 | 16 | 11 | 7 | 1 | 3 | | 47 |
| Male | | | 6 | 7 | 4 | 2 | 1 | 20 |

Table 16. Body Weight Comparisons of Specimens with More Than One Source

| | Females | | | | | | | | | | | | Males | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 51 | 52 | 55 | 58 | 59 | 60 | 64 | 65 | 71 | 79 | 80 | 89 | 54 | 69 |
| License | 140 | 140 | 100 | 120 | 136* | 117 | 138 | 145 | 200 | 115 | 125 | | 155 | 175 |
| Physician | 142 | 140 | 105½ | 121 | | 110 | 93 | 98 | 185 | 97 | 118½ | 108 | 125 | 165 |
| Hospital | | | | | 108 | 108 | | | 210½ | | | 135 | | |

*Taken during pregnancy

ligament sulci from the sample, comparing body weight with preauricular sulcus morphology, length, width, depth and area. Test results in Tables 8 and 14 indicated that no significant relationship exists.

Figure 11 is a plot of preauricular sulcus length versus body weight. There is no significant relationship between these variables. Figure 12 is a plot of preauricular sulcus morphology versus body weight and, again, no significant relationship exists between these variables.

## Obstetrical Events

There are two sets of obstetrical information, gravidity and parity, that can be compared with preauricular sulcus morphology and measurements. The gravidity information consists of physician reported gravidity. The parity information consists of physician reported parity and obituary information which may list surviving children. There are problems associated with the accuracy of the obstetrical information. The obstetrical histories and obituary information has been accepted at face value because there is no way to check its accuracy. Because of the aged nature of the sample under study, it is likely that the physician-reported obstetrical information contains fewer errors than the obituary information. The inclusion of errors has occurred because of lost records and inaccurate reporting of obstetrical events. Errors in obstetrical histories and particularly in obituaries probably resulted from unreported abortions, still births, adoptions, the exclusion of

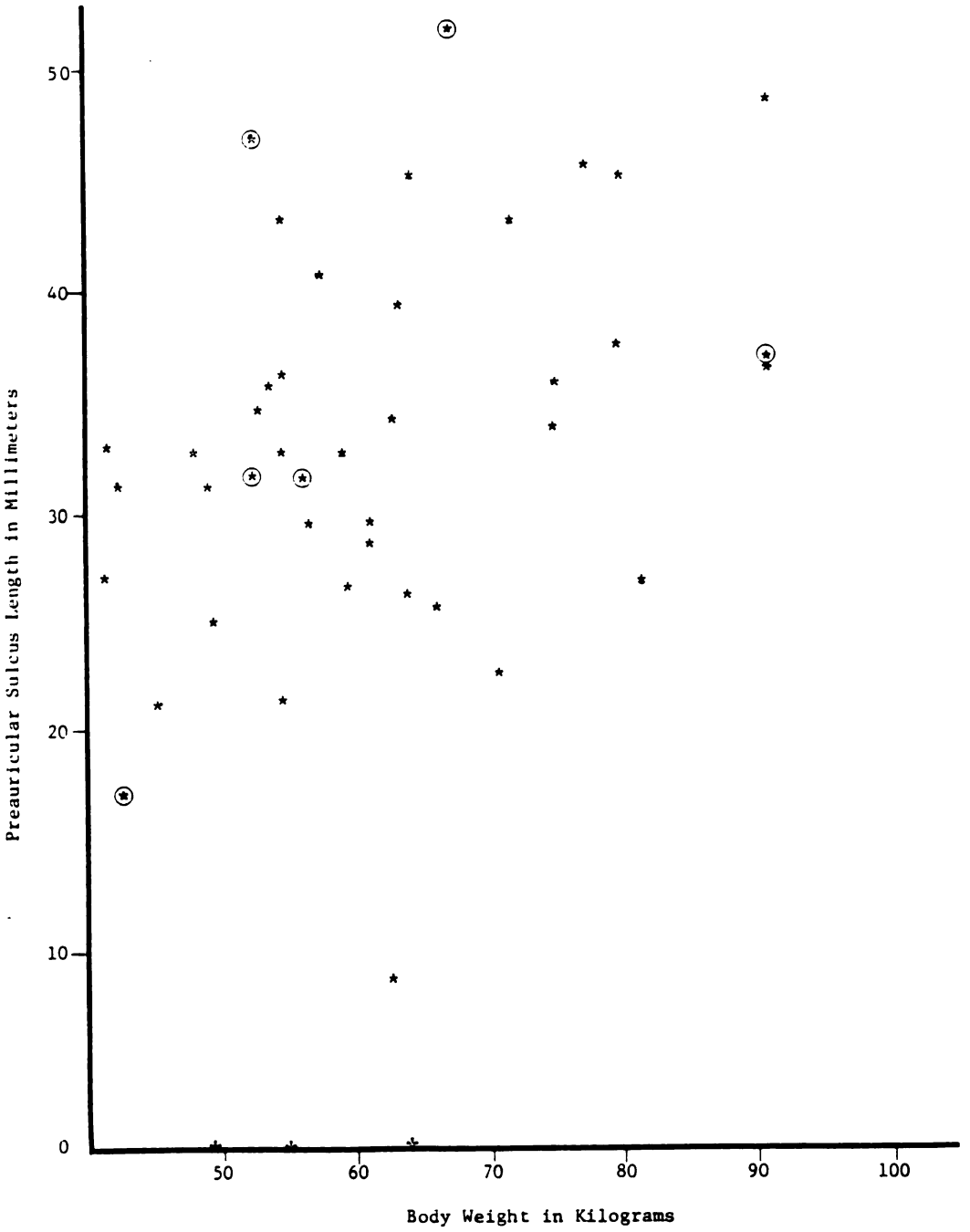


Figure 11. Preauricular Sulcus Length Versus Body Weight. Circled scores denote ligament sulcus specimens.

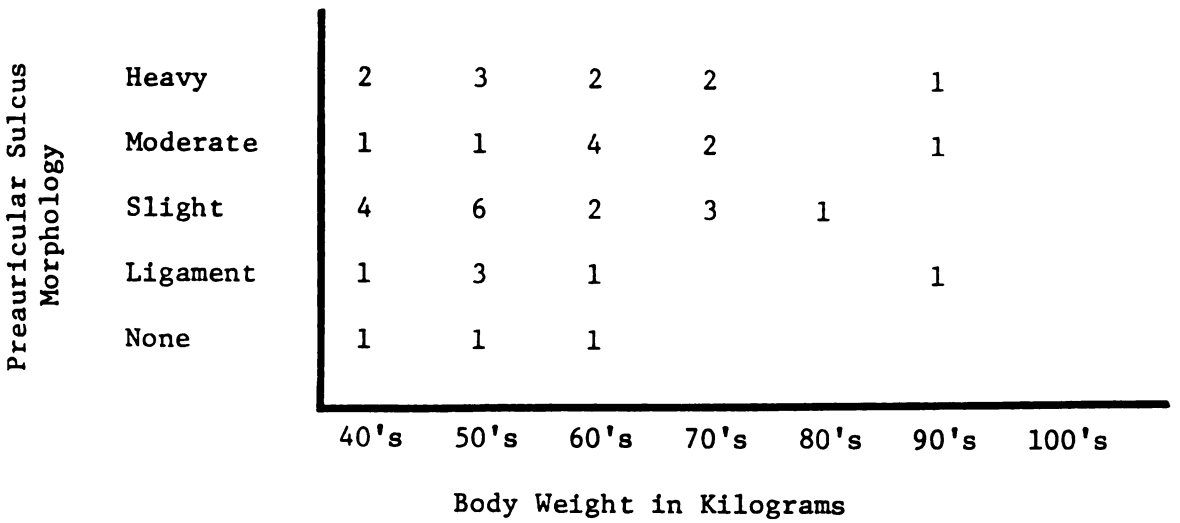


Figure 12. Preauricular Sulcus Morphology Versus Body Weight

unwanted children, and children who died before the date of the obituary. Part of these errors were eliminated by excluding from consideration the obituary data and comparing parity with the pregnancy sulcus on only those individuals for whom specific gravidity and parity information had been received by a physician.

Gravidity data is available on 36 females. Chi square tests were performed comparing gravidity with preauricular sulcus morphology, length, width, depth and area. Test results indicated gravidity was not significantly related to any of the measurements. See Table 8. However, gravidity was significantly related to preauricular sulcus morphology. See Tables 8 and 17.

Parity data is available from two sources, physician reported parity and obituary information. Chi square tests were performed on two samples. The first sample includes 49 females with parity information from physicians and from obituary information. Test results on this first sample are reported in Table 18. No significant

Table 17. Chi Square Test Comparing the Pregnancy Sulcus with Gravidity

| | Nulligravid | Para | | $\chi^2$ Values | |
|---|---|---|---|---|---|
| Pregnancy sulcus absent | 6 | 3 | 9 | Corrected test value | = 8.346 |
| Pregnancy sulcus present | 3 | 24 | 27 | .01 level significance value | = 6.635 |
| | 9 | 27 | 36 | | |

Table 18. Chi Square Test Comparing the Pregnancy Sulcus with Parity on First Sample*

| | Nullipara | Para | | $\chi^2$ Values | |
|---|---|---|---|---|---|
| Pregnancy sulcus absent | 6 | 6 | 12 | Corrected test value | = 3.038 |
| Pregnancy sulcus present | 7 | 30 | 37 | .05 level significance value | = 3.841 |
| | 13 | 36 | 49 | | |

*This sample includes all individuals for whom parity is available from physician or obituary sources.

relationship exists between gravidity and preauricular sulcus morphology. The second sample includes only those individuals for whom physician reported gravidity and parity is available. Test results on this second sample of 36 females are reported in Tables 8 and 19.

Table 19. Chi Square Test Comparing the Pregnancy Sulcus with Parity on Second Sample*

| | Nullipara | Para | | $\chi^2$ Values |
|---|---|---|---|---|
| Pregnancy sulcus absent | 6 | 3 | 9 | Corrected test value = 5.280 |
| Pregnancy sulcus present | 5 | 22 | 27 | .05 level significance = 3.841 |
| | 11 | 25 | 36 | |

*This sample includes all individuals with physician reported gravidity and parity.

No significant relationship exists between parity and preauricular sulcus measurements. However, parity and preauricular sulcus morphology are significantly related.

## Degenerative Joint Conditions

Since the preauricular sulcus (as a ligament attachment site) is an integral part of the sacroiliac joint, it may be affected by degenerative joint conditions of the sacroiliac and adjacent joints. The sacroiliac joint, the L5/S1 articular facets and the L5 and S1 vertebral bodies are available for the majority of the specimens. Therefore, preauricular sulcus morphology was compared with osteoarthritis, spondylosis deformans and osteochondrosis at the appropriate joint locations.

Osteoarthritis, as defined by Lewin (1964) was evaluated at the sacroiliac joint and the L5/S1 apophyseal joint. Each joint surface was scored as none, slight, moderate, or heavy (numerically: 0, 1,

2, or 3). The numerical scores for each joint were added and the subsequent division for the 2 x 2 contingency table was 0-3 and 4-6.

Spondylosis deformans, as defined by Nathan (1962) and Schmorl and Junghanns (1971) was evaluated on S1 and L5 by a numerical score of 0, 1, 2, or 3 (respectively: none, 0.1-3mm, >3-10 mm, >10 mm) similar to the fashion of Swedborg (1974). The area of maximum osteophyte projections from the epiphyseal ring margins was scored for both sides of the sagittal plane. In other words, an L5/S1 score consists of the sum of four separate observations: left and right inferior L5 epiphyseal ring margin scores, and left and right S1 epiphyseal ring margin scores. An L5/S1 score may range from 0 to 12. The division for the 2 x 2 contingency table was 0-6 and 7-12.

Swedborg (1974) evaluates osteophyte incidence and degree in a 45° anterior location and left and right antero-lateral locations. In this study, of course, only two available adjacent vertebrae were evaluated, and it was evident that the dominant pattern of osteophyte incidence occurs antero-laterally in these two vertebrae. Furthermore, on the basis of dissection of the soft anatomy in this region of the spine and consideration of the etiology of spondylosis deformans (Schmorl and Junghanns, 1971), it is unlikely that antero-sagittal annulus fibrosus lesions followed by osteophyte formation would occur before degenerative conditions in other areas of the disc tissue. L5 spondylolysis was seen in five female and two male specimens in the cadaver collection under study. In this anomalous condition in which anterior displacement of the vertebral body was

no longer prevented by the vertebral arch articular facets, anterior osteophyte formation was not encountered. The greatest development of osteophytes in these specimens was laterally and antero-laterally, as in the remainder of the cadaver specimens under study.

Osteochondrosis is the degenerative process which commences in the intervertebral disc. Fibrillation, dessication, necrosis, and tissue diminution gradually effect subchondral bone changes. Osteochondrosis in the bone is characterized by perforations, sclerosis, and calcification of fibrocartilagenous transformations of intrusive vascularized connective tissue. Evaluation and scoring of osteochondrosis at the L5/S1 disc level was carried out with independent consideration of the cranial surface of the first sacral body and the caudal surface of the fifth lumbar body. Each surface was scored as none, slight, moderate, or heavy (numerically: 0, 1, 2, or 3). Their adjacent surfaces' scores for each specimen were added and the 2 x 2 contingency table divisions were 0-3 and 4-6.

When the three aforementioned degenerative joint conditions were compared with preauricular sulcus morphology, there was no significant relationship. See Table 20. Preauricular sulcus morphology is therefore probably not related to degenerative joint conditions. In a few specimens, it appears that osteoarthritis at the sacroiliac joint has masked the pregnancy sulcus (see Plate 6) and, of course, the ligament sulcus may or may not be interpreted as a pregnancy sulcus irrespective of the availability of obstetrical history. The tendency for the ligament sulcus to appear in older individuals who

Table 20. Chi Square Test Values on Degenerative Joint Conditions

| | L5/S1 Osteoarth. Same Side | L5/S1 Osteoarth. Opp. Side | L5/S1 Spondylosis Deformans | L5/S1 Osteo-chondrosis | L5 Cranial Spondylosis Deformans | L5 Cranial Osteo-chondrosis | Sulcus Morphology | Age | Body Weight |
|---|---|---|---|---|---|---|---|---|---|
| SI Joint Osteo-arthritis Same Side | 56† .269 | 56 .269 | 57 4.982* | 56 6.649** | 62 2.870 | 62 .516 | 65 .306 | 65 5.354* | 42 .428 |
| SI Joint Osteo-arthritis Opposite Side | 56 .173 | 56 .173 | 57 5.465* | 56 1.018 | 62 3.715 | 62 1.885 | 64 .905 | 64 1.150 | 42 .000 |
| L5/S1 Osteo-arthritis Same Side | | | 55 2.943 | 54 .047 | 55 2.796 | 54 .471 | 57 1.096 | 57 19.638*** | 38 2.752 |
| L5/S1 Osteo-arthritis Opposite Side | | | 55 2.943 | 54 .194 | 55 2.796 | 54 1.350 | 56 .157 | 56 10.380** | 38 2.752 |
| L5/S1 Spondylosis Deformans | | | | 55 4.562* | | | 57 .391 | 57 1.020 | 39 1.648 |
| L5/S1 Osteochondrosis | | | | | | | 56 .113 | 56 .620 | 37 .119 |
| L5 Cranial Spondylosis Deformans | | | | | | | 62 .504 | 62 14.307*** | 42 .525 |
| L5 Cranial Osteochondrosis | | | | | | | 62 .493 | 62 5.923* | 42 .110 |

†Upper whole number is n and lower number is $\chi^2$ test value for each 2 x 2 contingency table. df = 1; .05 critical value = 3.841; .01 critical value = 6.635. .001 critical value = 10.827. The ligament sulcus specimens are included in these tests.

* $p \leq 0.05$
** $p \leq 0.01$
*** $p \leq 0.001$

are also likely to be undergoing advanced degenerative changes in the joint suggests that the ligament sulcus may be part of the degenerative process. However, a chi square test comparing sacroiliac joint osteoarthritis with the ligament sulcus of the same side revealed no relationship in the females. See Table 21.

Table 21. Chi Square Test Comparing the Ligament Sulcus with Sacroiliac Joint Osteoarthritis on the Same Side

| | Sacroiliac Joint Osteoarthritis | | | $\chi^2$ Value |
|---|---|---|---|---|
| | 0-3 | 4-6 | | |
| Ligament sulcus absent | 17 | 37 | 54 | $\chi^2$ corrected test value = .271 |
| Ligament sulcus present | 2 | 9 | 11 | Critical value 1df, .05 significance level = 3.841 |
| | 19 | 46 | 65 | |

One can therefore conclude, on the basis of the analysis of the cadaver specimens in this study, that the ligament sulcus is not related to degenerative joint conditions. It also appears that preauricular sulcus morphology, in general, is not related to degenerative joint conditions, except perhaps in severe cases of sacroiliac joint osteoarthritis, where the masking of a pregnancy sulcus may occur.

The degenerative conditions under consideration compare with age and with each other in a manner not unexpected from the literature on the subject (Sashin, 1930; Stewart, 1976; Nathan, 1962; Lewin, 1964; Schmorl and Junghanns, 1971; and Swedborg, 1974). See

Table 20. Osteoarthritis is generally more severe with age. Spondylosis deformans and osteochondrosis are less clearly related to age. The latter two degenerative phenomena at the L5/S1 disc appear to be related to age whereas the same phenomena do not appear to be related at the L5 cranial level. Swedborg's (1974) archeological sample of lumbar vertebrae tends to support this observed difference in degenerative phenomena and age cranially and caudally to the L5 body. The difference may be related to the large loads in this area of the spine and the increased range of axial rotation allowed at the L5/S1 level compared to the superior lumbar articulations (White and Panjabi, 1978).

Again, when the degenerative conditions are compared with each other, the results compare favorably with the literature available. Swedborg (1974) reports low positive correlations exist between apophyseal joint arthritis and spondylosis deformans. These two degenerative phenomena do not originate from the same causal factors (Schmorl and Junghanns, 1971; and Lewin, 1964). In this study sample, comparisons between spondylosis deformans and osteochondrosis at the L5/S1 level, indicate a significant relationship exists. Swedborg (1974), who has made similar comparisons in archeological remains, found moderate correlations between these two degenerative phenomena in the lumbar region of aged females.

Studies of degenerative joint conditions in the human vertebral column do not include the sacroiliac joints. Nevertheless, the sacroiliac joints should be included, as evidence in the medical literature suggests they are involved in compensatory movements

of the spine (Schmorl and Junghanns, 1971; Coventry and Tapper, 1972; and Grieve, 1976).

In this study, comparisons of sacroiliac joint osteoarthritis with degenerative conditions of adjacent joints revealed that a significant relationship exists only when L5/S1 spondylosis deformans is compared. This single result may reflect similar etiological factors. However, a larger sample including young adults should be studied in order to determine if the relationship observed here is spurious.

## Sacroiliac Joint Location

### The Cuneate Index

Derry (1909, 1911) discusses the contributions which biomechanical considerations might play in affecting preauricular sulcus formation in women. He suggests that a more horizontally oriented sacrum in females would cause a weight distribution difference. Additionally, females have more mobile sacroiliac joints, especially during gestation. A larger ligament attachment in the area of the preauricular sulcus would counteract the forward rotation of the sacrum (see Figure 2). Derry (1923) has also shown that some degree of sexual dimorphism is present in the location of the sacroiliac joint area of the ilium. Females tend to have more posteriorly located auricular surfaces compared to males because of a proportionally greater length of iliac bone along the iliopectineal line from the sciatic notch apex to the auricular surface (Derry, 1923; and Howells and Hotelling, 1936). See Figure 5.

Straus (1927) also found sexual dimorphism in the human ilium in his index which expresses the upper iliac height as a percentage of lower iliac height. Figure 13, adapted from his Figure 1, illustrates the measurements he took using sliding calipers. The sexual dimorphism of the ilium, expressed by a relatively greater iliopectineal portion, is not remarkable (Straus, 1927; and Hausermann, 1926).

The above discussion indcates that females tend to have more posteriorly located sacroiliac joints compared to males. The obvious functional significance of this lies in the obstetrical requirements of the female true pelvis. The true pelvis in females must be large enough to allow for the passage of full term infants regardless of the size of the whole pelvis.

The female pelvis is adapted to perform obstetrical functions as well as to support body weight. These two functions are not necessarily mutually compatible, particularly during pregnancy. Pelvic joints undergo significant ligamentous changes which are reflected in bone resorption adjacent to the joints. These changes occur during conditions when the load on the rotational moment arm about the sacroiliac joint is increased. The preauricular sulcus, which reflects the bone resorption at the sacroiliac joint, is related to obstetrical events but not body weight in the sample under study. Sacroiliac joint ligament hypertrophy and growth, along with pre-auricular sulcus formation is undoubtedly, in part, related to increases in body weight during pregnancy. However, data is not available to study the relationship. Sexual dimorphic characteristics

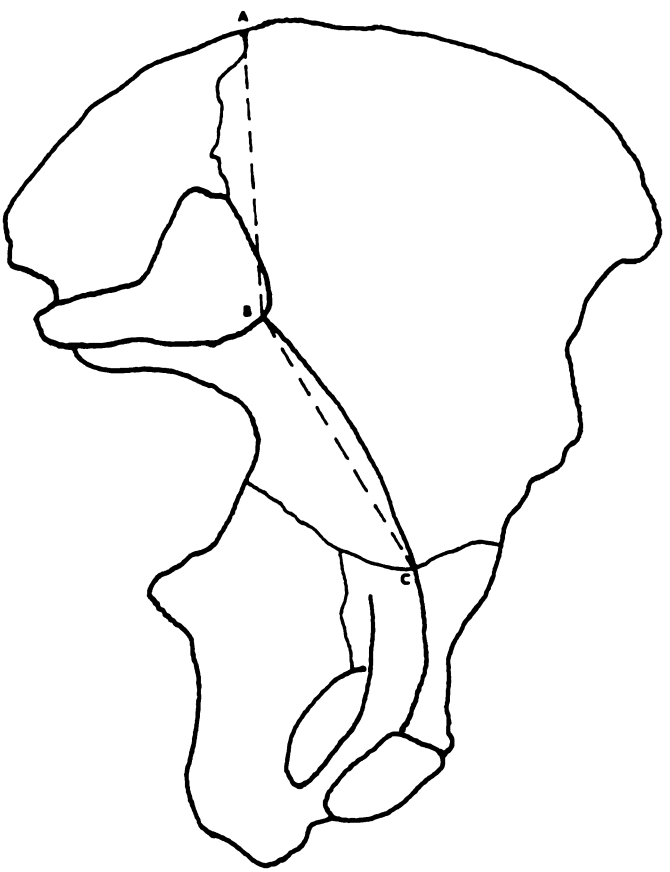


Figure 13. Innominate: Adapted from Straus' Figure 1 (1927)

AB = upper iliac height; BC = lower iliac height.

also constitute a source of variation in the load on the rotational moment arm about the sacroiliac joint which might effect preauricular sulcus formation.

Chi square tests were performed comparing the Cuneate Index with preauricular sulcus morphology, length, width, depth, area and body weight. Test results (see Tables 8 and 14) indicate the Cuneate Index is not related to preauricular sulcus morphology, length, width, depth, area or body weight.

The Sciatic Notch

It is generally assumed that the sacrum lies closer to a horizontal position in the female than in the male pelvis in the standing position (Derry, 1912; Howells and Hotelling, 1936; and Solonen, 1957). The larger sciatic notch angle in female innominates may be associated with the more horizontal sacrum position. In the cadaver sample of 19 female and 8 male pelves in which the sacra and innominates may be articulated and oriented in the lateral anatomical position, there is no evidence for more horizontal sacra being associated with larger sciatic notch angles. See Figure 14. Nevertheless, since the sciatic notch is a sexually dimorphic feature of great value which may also effect biomechanical relationships in sacroiliac joint function, it is worthwhile to compare its angle measurement with preauricular sulcus morphology and measurements.

The angle of the sciatic notch has been measured in a variety of ways in the past. Most of these techniques have involved measurements of an angle produced by a triangle composed of straight lines joining

The Innominate and sacrum are the same individual illustrated in Figure 5. Orientation under the dioptograph was accomplished after articulating the sacrum and innominate, by rotating the superior S1 epiphyseal surface into a vertical plane with the posterior epiphyseal surface margin tangent in a vertical orientation.

The resulting drawing was oriented so that a straight line through the anterior superior iliac spine and the pubic tubercle would be parallel to a line through the center of gravity (Young and Ince, 1940). The maximum load point is the point on the acetabulum articular surface where maximum load is transferred from the ilium to the femur head (Strange, 1965).

Figure 14. Medial View of Right Innominate and Sacrum

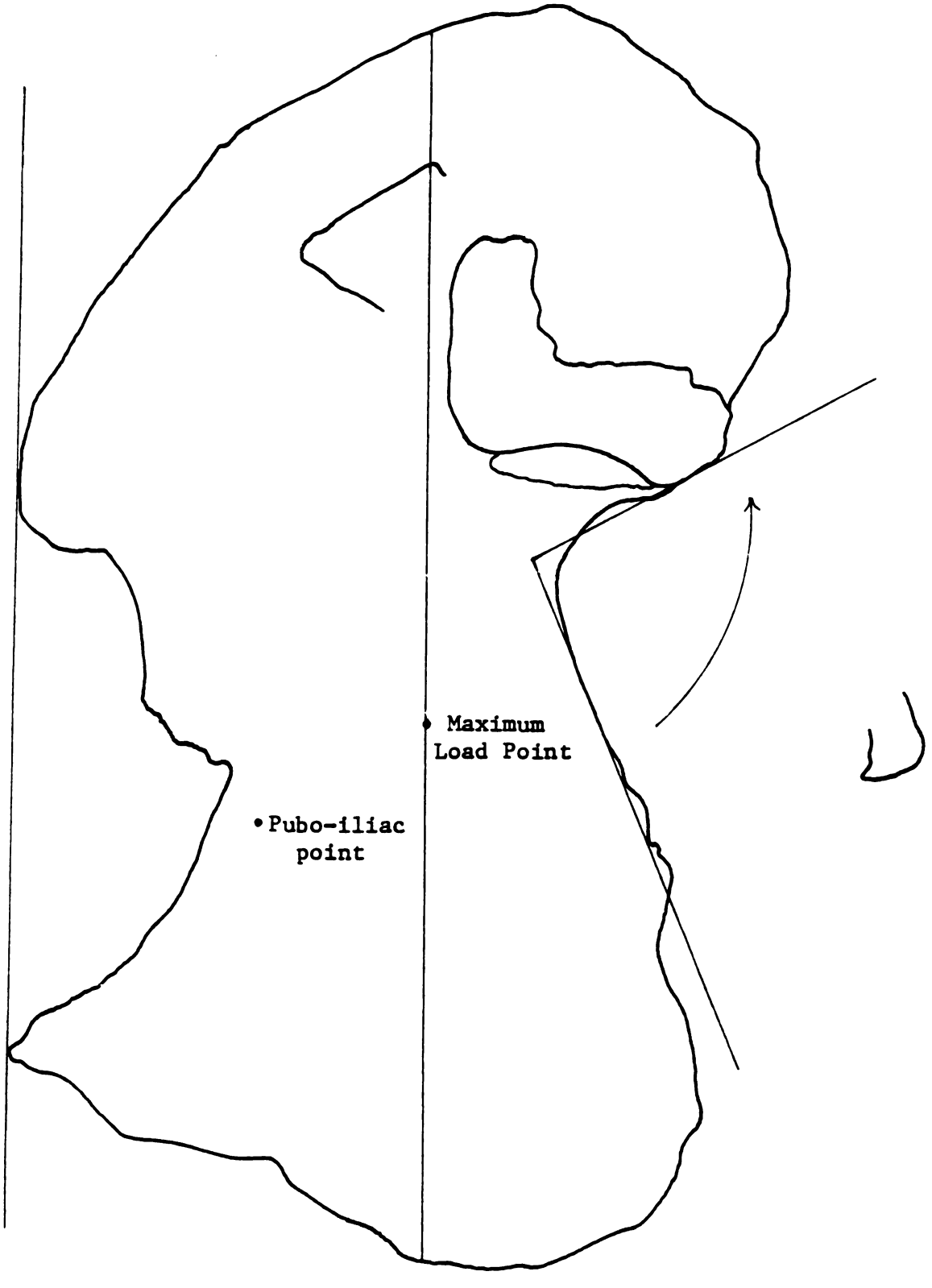


Figure 14. Medial View of Right Innominate and Sacrum

points in the vicinity of the ishial spine, the deepest portion of the notch, and some point in the area of the pyriformis tubercle or posterior inferior iliac spine. Different angle measurements have yielded different results in distinguishing male and female specimens. (Straus, 1927; Hanna and Washburn, 1953; Stewart, 1954; Howells and Hotelling, 1936; and Singh and Potturi, 1978). A few attempts have been made to produce the sciatic notch angle by anteriorly projecting tangents to the ishial and iliac margins of the notch. The angle produced by the intersecting tangents is measured (Howells and Hotelling, 1936; and Hanna and Washburn, 1953). The sciatic notch angle measurement used in this study was similar to the latter attempts. See Figures 5 and 8. Since the location of the tangent involves an estimate (Stewart, 1954), particularly in the usually more curved ilial border, the measurement used in this study has been designed to remove some of the subjectiveness.

Chi square tests were performed comparing the sciatic notch angle with preauricular sulcus morphology, length, width, depth, area, body weight and the Cuneate Index. Test results indicate the sciatic notch angle is significantly related to preauricular sulcus area when the ligament sulci are included (Table 8) in the sample and significantly related to preauricular sulcus area and width when the ligament sulci are not included (Table 14) in the sample. The sciatic notch is not related to any of the other tests of preauricular sulcus morphology, body weight or the Cuneate Index.

# CHAPTER IV

# DISCUSSION

## Sex

The morphology and measurements of the preauricular sulcus clearly indicate this structure is sexually dimorphic as previous investigations have suggested (Derry, 1909, 1911; and Houghton, 1974, 1975). The preauricular sulcus is small and indistinct in males. In females, it is usually well developed. When males exhibit a sulcus which could be confused with a pregnancy sulcus, it is invariably associated with severe degenerative and/or pathological changes in the lower back, pelvis and/or lower limbs.

Derry (1913, 1923) briefly mentions such a case. A similar case exists in the human remains from the Fletcher site (Sauer, 1974) and the known male specimen in this study with ankylosing spondylitis constitutes a third case.

In 1913, Derry described the skeletal remains of a Roman period Egyptian adult male who had suffered from a hydrocephalus condition. The left side of the postcranial remains were severely atrophied. See Figure 15. The left innominate " . . . exhibited a tendency to the formation of a pre-auricular sulcus, a female character." (Derry, 1923) Derry attributed the female characteristics generally seen in the left innominate as resulting from body weight being carried on

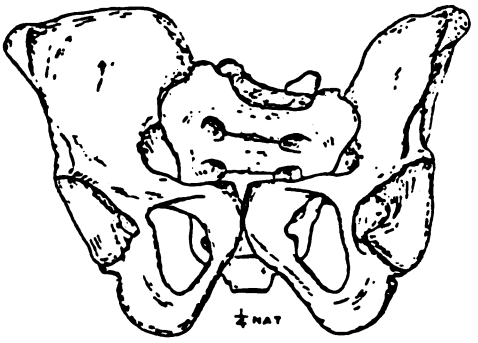

Figure 15. Pelvis Illustrated by Derry (1913)

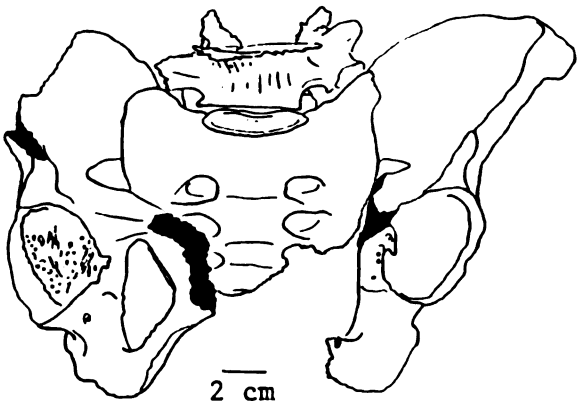


Figure 16. Pelvis of Fletcher Site Male.

the right side. The pelvis was tilted to the left and there is evidence for a lack of right adductor use.

A similar case was examined in this study from the human skeletal remains from the Michigan Indian historic contact Fletcher Site in Bay City (Sauer, 1974). An adult male skeleton exhibits an unusual preauricular sulcus on the right innominate which could be confused with the typical female sulcus associated with pregnancy. See Plate 7. The examination of the spinal column, pelvis and lower limbs reveal this male suffered from severe spondylosis deformans and osteoarthritis. These degenerative conditions are most severe in the right limb and innominate compared to the left. The lateral compensatory curves of the spinal column suggest weight bearing on the left leg more frequently than the right. On closer examination of the right preauricular sulcus, it is clear that the appearance of a female sulcus is due to ligament ossification and not the characteristic pitted and scooped nature associated with bone resorption. Therefore, confusion of this sulcus with the typical female sulcus associated with obstetrical events is unlikely after one has examined a large number of female sulci. Unfortunately Derry does not publish any illustrations of the hydrocephalous male's sulcus so comparison is limited. However, this author's drawing of the Fletcher site male pelvis in Figure 16 may be compared with Derry's hydrocephalous male's pelvis. The right acetabulum exhibits severe osteoarthritis with eburnation and sclerotic alterations of the acetabular surface and lipping of rim. There is right lumbo-sacral apophyseal joint ankylosis and a left L5 transverse process/sacral-ala joint.

It does appear clear from the few cases discussed above that sulcus formation and possibly ligament enlargement are likely to occur in the male sacroiliac joint when the joint's normal function is altered by severe degenerative and/or pathological conditions affecting the bony pelvis and lower limbs.

## Age

Derry (1911) observed that larger preauricular sulci were more likely to be seen in older women. This supported the early notion that preauricular sulcus formation was related to pregnancy. Houghton (1979) also reported that larger sulci tend to be found with increasing age. The chi square tests in this study clearly indicate that age and preauricular sulcus morphology and measurements are not related, irrespective of the disposition of the ligament sulci in the samples tested. Since the collection in this study is from individuals beyond their reproductive life, any relationship would most likely be due to some degenerative phenomena associated with advanced age. Some evidence for this relationship may be found in the fact that nearly all the ligament sulci in females come from individuals 70 years of age or older.

The chi square test comparing the female ligament sulci with lumbo-sacral anomalies indicated that a significant relationship exists. Although 33% of the male specimens exhibit some form of the lumbo-sacral anomalies, none of them have ligament sulci as seen in females. Males have less mobile sacroiliac joints than females. Fibrous and occasionally bony ankylosis begin at an earlier age in males and progress more rapidly. (Brooke, 1924; Sashin, 1930; and

Stewart, 1976). These anatomical considerations reasonably account for the lack of preauricular sulcus variation so commonly seen in female innominates.

## Body Weight

The sacroiliac joints serve as transfer points for body weight between the lumbo-sacral junction and the hip joints (Solonen, 1957). Derry (1909, 1911) argued that the more horizontally oriented female sacrum shifts body weight passage through the more anterior portion of the sacroiliac joints. This produces rotational sacral motion which is checked by the ligaments that originate from the preauricular sulci. Since these joint ligaments relax during pregnancy, the well-developed ligaments that originate from well-developed preauricular sulci are particularly important in maintaining pelvic joint stability during pregnancy. Houghton (1974) noted that the preauricular sulcus is more likely to bear the bone resorption signs of pregnancy than the pubic bones since " . . . the sacroiliac joint is in the direct line of transfer of body weight and its ligaments are under greater stress at all times, and especially during pregnancy . . . " (p. 383).

In this study, preauricular sulcus morphology and measurements were found to be unrelated to body weight. However, it should be emphasized that weight gain and body posture changes during pregnancy may be related to preauricular sulcus variation.

## Obstetrical Events

At least three factors have influenced the differential results obtained in the chi square tests on gravidity and parity:

1. The inclusion of gravid, nulliparous females in the pregnancy sulcus versus parity test.

2. The possibility of "pregnancy sulcus" formation under conditions other than gestation.

3. The possibility of inaccurate reporting of obstetrical histories and incomplete obituary information.

There are two individuals exhibiting pregnancy sulci who were gravid yet nulliparous. See Table 2. One, aged 82, had two spontaneous abortions (dates unknown) and a hysterectomy at age 39. See Plates 3 and 4. The other, aged 60, had one abortion (date unknown). See Plate 8. These specimens indicate that the bony changes are not simply "birth scars" but are related to the physiological process which alters the structure and function of the pelvic joints during gestation. The early literature on pelvic joint changes suggests that the relevant physiological process begins during the first half of pregnancy (Lynch, 1920; Brooke, 1924; Heyman and Lundquist, 1932; Abramson et al., 1934). The hormone relaxin, which plays a key role in the physiological process, was discovered in 1926 (Hisaw). Subsequently, relaxin has clearly been shown to effect significant ligamentous changes in pelvic joints, and its secretion in human females commences in the first month of pregnancy (Quagliarello, 1979).

Secondly, two individuals who exhibit classic pregnancy sulci in both innominates and also demonstrate dorsal pubic bone changes characteristic of past pregnancies both have obstetrical histories indicating they are nulligravid. See Plates 9 and 10. These two

individuals also exhibit slight sulcus formation on the sacrum, a rare occurrence in the cadaver specimens under study. One of these females, aged 80, has the largest set of sulci observed in this study. Notwithstanding the present scarcity of knowledge about the physiological processes involved in pregnancy sulcus formation, it can be assumed that these females had at least experienced pregnancies. Given the ages of the individuals under study, it is entirely possible that obstetrical histories had been lost.

Examination of the skeletal remains of younger women from forensic sources, presumably nulligravid, indicate unmistakeable pregnancy sulci. Recently, this author has worked on two forensic cases involving the skeletal remains of one 30 year-old woman and one young adult female. The families of these women had been asked for medical histories and x-rays for use in the identification process. Both families indicated the women had never been pregnant. It should be noted that the families were made aware of the importance of accurate obstetrical information. Both women had pregnancy sulci. The 30 year-old woman's sulci were particularly well developed. See Plate 14. Her skeletal remains were positively identified by other bony features so the questionnable obstetrical information or the questionnable significance of "pregnancy sulci" remains an academic issue. The young adult female, aged in the early 20's, has not been identified.

Finally, adopted children may be included in the parity information, particularly in those instances where the obituary was the only

source of information. Conversely, there is no way to include abortions or stillbirths in the sample. Therefore, the analysis has accepted all the obstetrical histories and obituaries at face value.

These three factors have certainly affected the outcome of the parity/pregnancy sulcus comparison. Obviously, any gravid, nulliparous individuals exhibiting pregnancy sulci would affect the outcome of a simple chi square test for parity. Any analysis of unknown skeletal material which included an attempt at parity or fertility assessment should consider that a small percentage of the females with pregnancy sulci may be gravid and nulliparous. Far from negating the relationship between parity and pregnancy sulci, specimens from gravid, nulliparous females provide corroborating evidence that the bony and ligamentous changes occur during pregnancy and survive into old age.

Nevertheless, the several nulligravid individuals who exhibit classic pregnancy sulci still require discussion. It is not enough to simply accept the inadequacies of the obstetrical information and claim that classic pregnancy sulci clearly indicate the occurrence of past obstetrical events. The physiological processes involved in the ligamentous and bony changes are poorly understood at the present time. Pregnancy sulci formation is most probably associated with the pelvic joint ligamentous changes which occur during pregnancy. However, clinical findings indicate women experience pelvic joint laxity during menstruation. This suggests that pelvic joint laxity and the concomitant ligamentous changes could effect pelvic joint margin changes in the bone during menstruation similar to the

formation of pregnancy sulci.

Female steroid sex hormones are also known to produce ligamentous changes under experimental conditions. Although the peptide hormone, relaxin, in conjunction with the steroids, produces ligamentous changes far more rapidly and extensively, it is rarely present in the peripheral blood stream of menstruating women (O'Byrne et al., 1978, Quagliarello et al., 1979). An additional factor which could explain nulligravid individuals who exhibit pregnancy sulci is spontaneous abortions. The percentage of fertilized eggs which spontaneously abort is generally very high in mammals. Spontaneous abortion rates in humans are reported to be ten percent or greater (Potter and Craig, 1975). Since spontaneous abortions nearly all occur during the first and second trimesters, and the physiological processes responsible for pelvic joint relaxation commences in the first month of pregnancy, many nulligravid women, particularly habitual aborters, may exhibit pregnancy sulcus morphology.

Statistically, the pregnancy sulcus, as described by Derry (1909, 1911) and Houghton (1974, 1975) and utilized in this study, is associated with past obstetrical events. Obstetrical history prediction on unknown human pelvic remains is obviously problematic. Figures 17, 18, and 19 illustrate the relationships between preauricular sulcus morphology and obstetrical events. The variability expressed in these figures suggests that accurate obstetrical event prediction is not possible.

As discussed, ligament sulci appear to form in response to a variety of anomalous biomechanical configurations in the pelvic area.

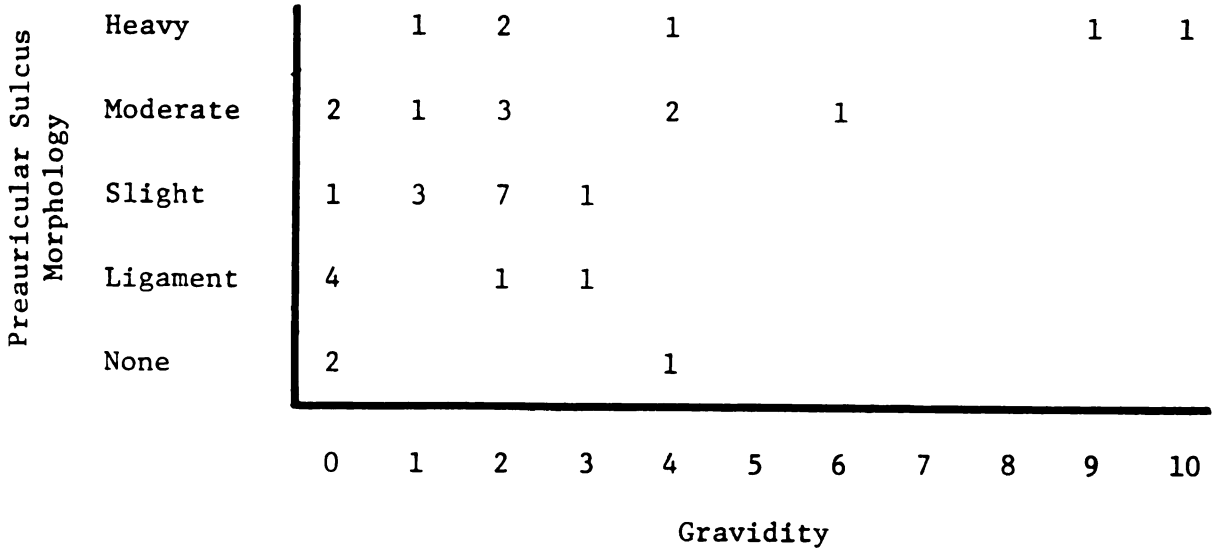


Figure 17. Preauricular Sulcus Morphology Versus Gravidity

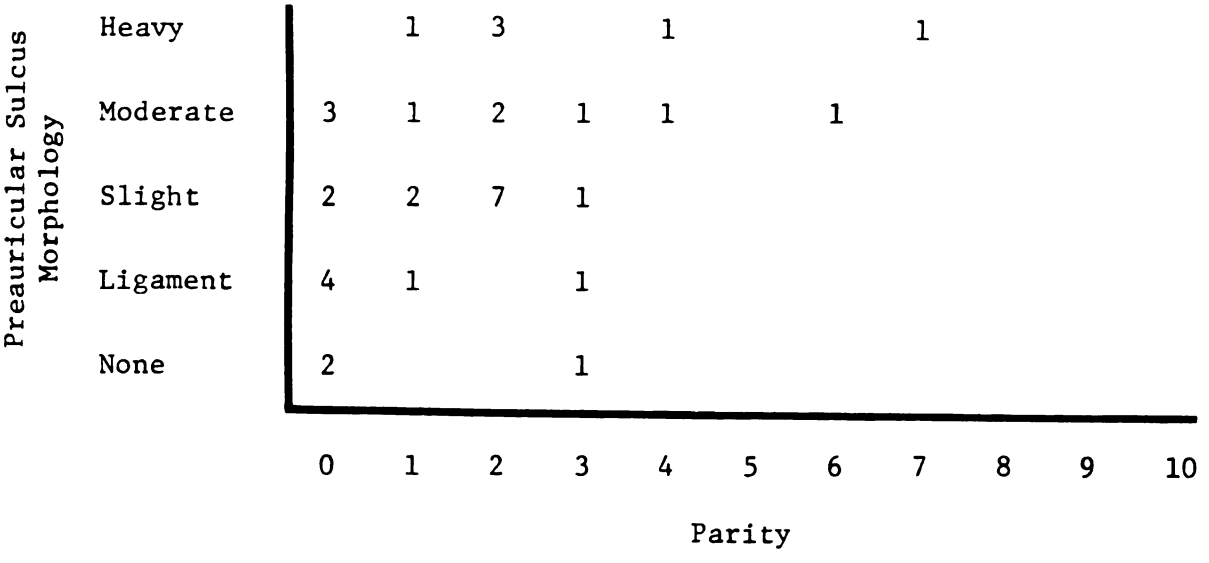


Figure 18. Preauricular Sulcus Morphology Versus Parity

Including only specimens with physician reported gravidity and parity.

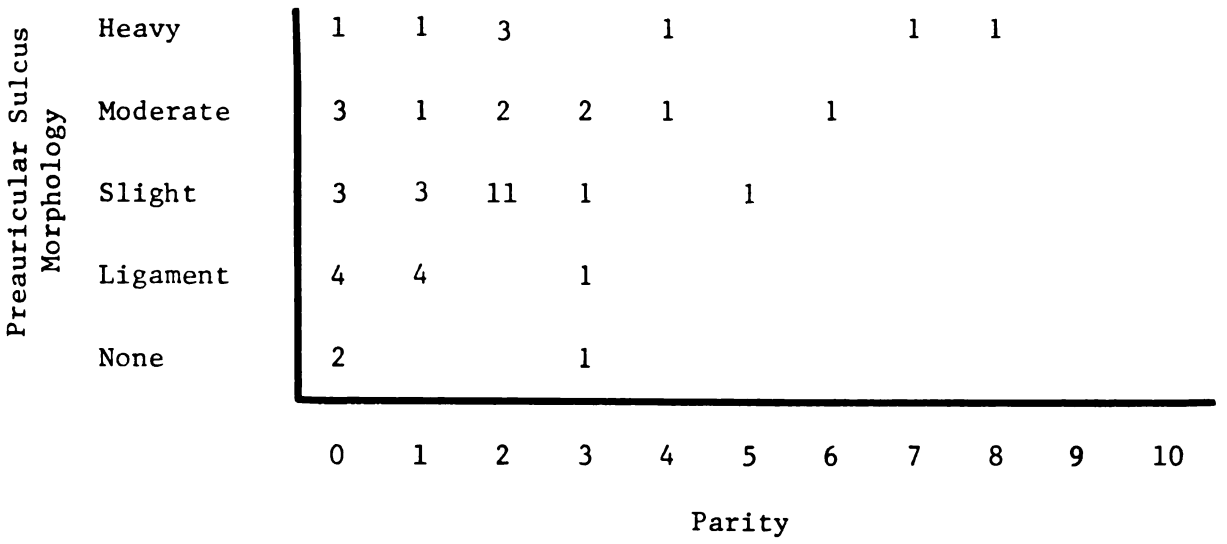


Figure 19. Preauricular Sulcus Morphology Versus Parity: Including Specimens with Obituary Information.

A number of the ligament sulci specimens also have histories of low parity. These specimens effect the outcome of the chi square test. The ligament sulcus in females is typically a shallow, rough floored often wide structure never seen in males. It is usually seen in older and nulliparous or low parity females. The female ligament sulcus also tends to occur when lumbo-sacral anomalies and pelvic joint destruction are present. One-third of the male cadaver specimens exhibit lumbo-sacral anomalies and pelvic joint destruction without any occurrence of the large but shallow ligament sulcus. The unusual load conditions which these anomalies may subject the more mobile female sacroiliac joints to are probably responsible for the formation of the ligament sulcus in females.

Distinguishing between ligament sulci and slight pregnancy sulci is frequently difficult. This problem is well illustrated in Figure 10 and Table 7. The slight pregnancy sulci which tend to be

associated with low parity females may be obliterated due to the formation of ligament sulci often in response to lumbo-sacral anomalies. However, the ligament sulcus may indicate past obstetrical events. Two low parity females in Figure 10 do not have lumbo-sacral anomalies associated with ligament sulci. These two are shown in Figure 20 which is a repeat of Figure 10 with the 26 anomalous individuals identified by squares. The problem of scoring the lesser developed preauricular sulci is also illustrated by Table 7 which lists the 12 females with different scores between the left and right sides. Seven of the specimens involve differences between slight, ligament and none. Four of these, or 33% of the 12, display slight preauricular sulci on one side and ligament sulci on the other.

## Degenerative Joint Conditions

Female preauricular sulcus morphology and measurements are not related to any of the degenerative joint conditions studied in the sacroiliac joints, lumbo-sacral joint complex, or the superior joint surfaces on the fifth lumbar vertebra. However, it appears that some masking of the pregnancy sulcus may occasionally occur due to ligament ossification. Pseudo pregnancy sulci may form in males but it appears to be invariably associated with severe degenerative or pathological conditions effecting the sacroiliacs and adjacent joints.

The variations within and interrelationships between the osteo-arthritis, spondylosis deformans and osteochondrosis examined in this study conform with the literature on the subject.

Numerical score is parity. X denotes specimen of unknown parity. Circled scores denote ligament sulcus specimens. Squared scores denote specimens exhibiting lumbo-sacral anomalies or pelvic joint destruction.

Figure 20. Preauricular Sulcus Depth Versus Preauricular Sulcus Area: Lumbo-Sacral Anomalies Denoted

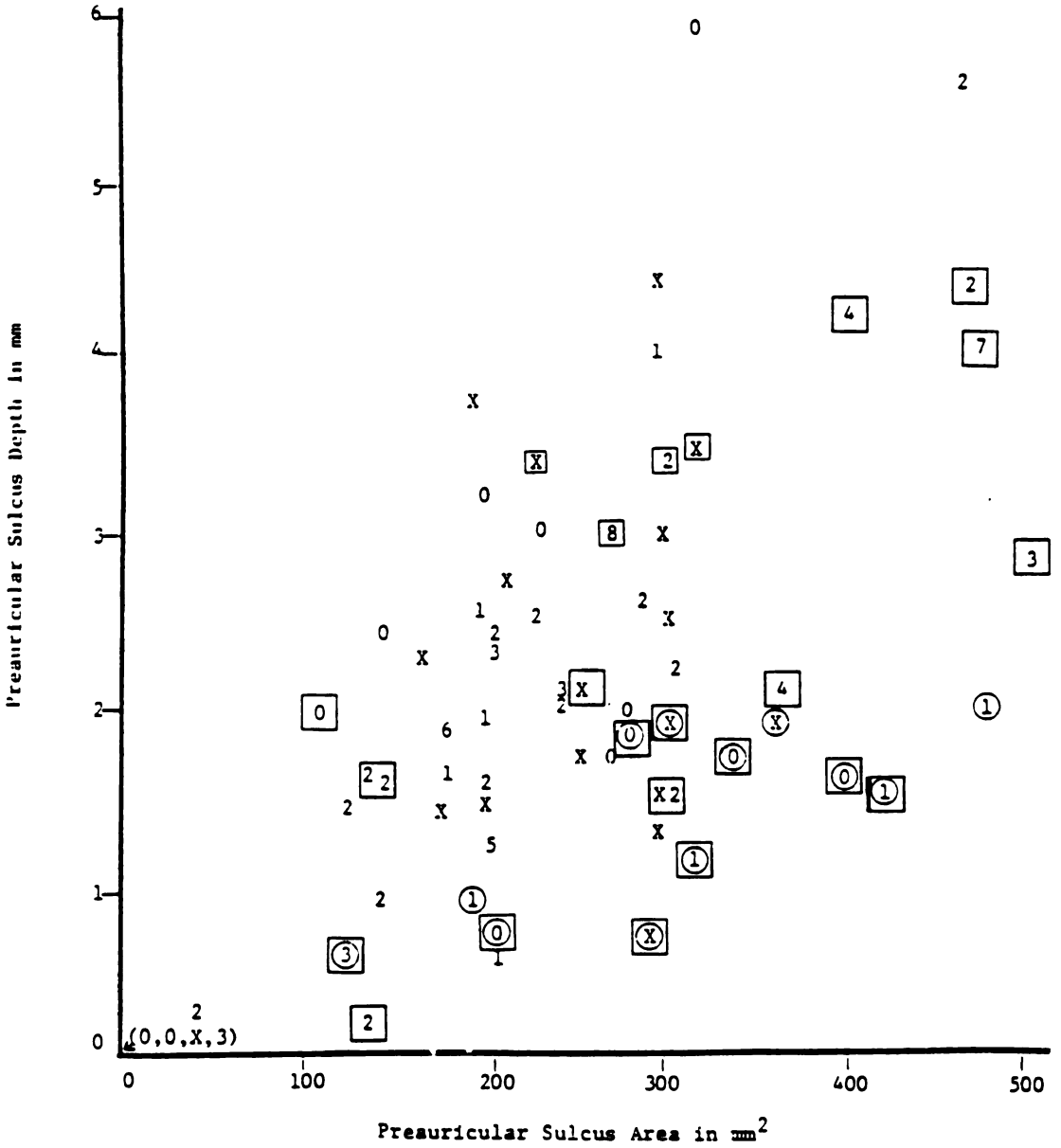


Figure 20. Preauricular Sulcus Depth Versus Preauricular Sulcus Area: Lumbo-Sacral Anomalies Denoted

## Sacroiliac Joint Location

The Cuneate Index and the sciatic notch angle are two of many sexually dimorphic characteristics of the female true pelvis which reflect obstetrical adaptations. These two measurements probably also reveal changes in the location of the sacroiliac joints with respect to the center of gravity, which are inimical to sacroiliac joint stability particularly during pregnancy. Ligamentous changes during pregnancy relax pelvic joints, and the larger ligaments originating from the female preauricular sulcus provide joint stability. Chi square tests comparing preauricular sulcus morphology and measurements with the Cuneate Index indicated no relationship exists. It is not surprising that the index for the relative posterior location of the sacroiliac joint is not related to any of the other variables under consideration. Although the index constitutes a reasonable measurement for sacroiliac joint location on posterior ilia, there is no way to reliably orient these partial specimens in a lateral anatomical plane. Such a plane would allow for a reasonable location of the vertical line through the center of gravity from which sacroiliac joint location might then be more biomechanically relevant. When dioptograph drawings of the 19 whole innominates with articulated sacra are produced in a lateral anatomical plane, there is no suggestion that preauricular sulcus morphology or measurements are related to sacroiliac joint location. The chi square test results indicated that the sciatic notch angle is related to preauricular sulcus area and width measurements. The measurements for a larger preauricular sulcus are more frequently

found in ilia with larger sciatic notch angles. The ligaments across the sacroiliac joint in the area of the preauricular sulcus may be larger in ilia with larger sciatic notch angles in order to check forward rotation of relatively more horizontal sacra. However, the articulated sacra in the 19 whole innominates viewed in the lateral anatomical plane do not appear to be more horizontal in the females with larger sciatic notch angles.

Figure 21 is a plot of sciatic notch angle versus preauricular sulcus area. The ligament sulci are denoted in the plot. The relationship between these metric variables does not appear to be particularly significant in spite of the chi square test results.

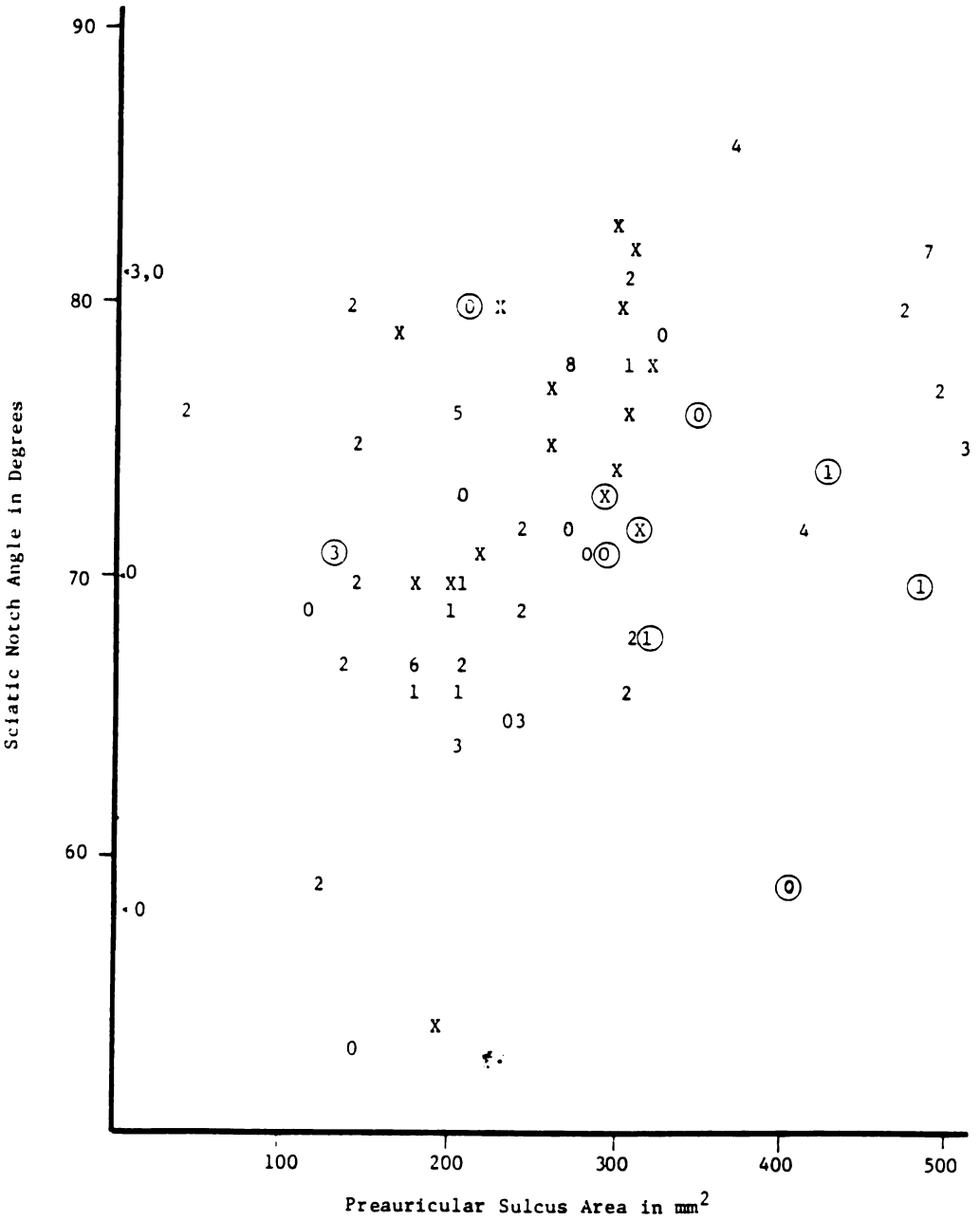


Figure 21. Sciatic Notch Angle Versus Preauricular Sulcus Area.

Numerical score is parity. X denotes specimen of unknown parity. Circled scores denote ligament sulcus specimens.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

In this study, I examined the preauricular sulcus in a small sample of post-reproductive aged cadaver specimens. Analyses of preauricular sulcus morphology and measurements revealed that sex differences are clear and distinct. Although well-developed sulci are virtually always associated with female ilia, their absence does not necessarily indicate male ilia. Obstetrical events explain the well-developed sulci which bear the characteristic scooped-out pitting or grooving of bone described in this study and previously by Derry (1909, 1911) and Houghton (1974, 1975). However, some low parity women may not exhibit sulci, and classic pregnancy sulci are occasionally seen in nulligravid women. There appears to be no compelling physiological reason to explain the reported nulligravid women exhibiting classic pregnancy sulci other than that they experienced pregnancies which were not reported. Of course, further elucidation of the problem will occur as the physiological processes involved in pelvic joint changes associated with pregnancy become better understood and preauricular sulcus variations are examined in a reproductive aged sample with available medical history.

Preauricular sulcus morphology and measurements are not significantly related to the number of obstetrical events. Therefore, preauricular sulcus morphology and measurements may not be reliably

employed to predict the exact or approximate gravidity and/or parity of any particular female skeletal remains. However, upon examination of such remains, the likelihood of any particular individual having experienced pregnancy may be stated with a reasonable degree of accuracy. The assessment of the obstetrical history of unknown pelves requires further research of other aspects of pelvic anatomy which may influence preauricular sulcus morphology. For the 19 whole female pelves in this study, obstetrical histories are known for only 10. This sample size is too small for analysis of sacroiliac joint location, sciatic notch angle and other biomechanically relevant variables independent of obstetrical events.

The sacroiliac joint area is a very plastic region of the skeleton. Some of the muscles of locomotion are associated with the sacroiliac joints. The joints function as transfer points for body weight and are an integral part of the vertebral column. Stability and mobility are simultaneous functions of the female sacroiliac joints during gestation and parturition. It is therefore not surprising that many metric and nonmetric sexing techniques which involve this area tend to be unreliable. The preauricular sulcus is an excellent sexing aid. This study has shown that its distinctive formation in the female ilium, the pregnancy sulcus, is most reasonably explained by obstetrical events.

Future research may indicate a closer relationship between sulcus morphology and gravidity and parity. Such research should be conducted on a large sample of reproductive aged specimens. The physiological processes involved in preauricular sulcus formation should be

better understood in order to substantiate or negate the relationship between sulcus visual morphology and gravidity/parity. Medical histories and especially obstetrical information should be obtained from a physician. These above-mentioned areas and aspects of future research are particularly important as other research reveals that dorsal pubic bone pitting occurs frequently in nulliparous females (Angel, 1969; Stewart, 1970; Gilbert and McKern, 1973; Putschar, 1976; and Suchey et al., 1978). According to Gilbert and McKern (1973) and Stewart (1970), about 140 pubic bones with physician reported obstetrical information are available for study. In Suchey's study (1978), which included 486 pubic bones from medical examiner autopsies, obstetrical histories were obtained directly from family members or friends. Because of the problems of unreported and unwanted pregnancies, it seems reasonable that obstetrical histories obtained from a family physician would be less likely to contain errors in gravidity and parity. Large pelvic joint collections from reproductive aged females with physician-reported obstetrical histories will provide the necessary data in order to evaluate the relationship between bone resorption at the joint margins and gravidity and parity. From this study, the preauricular sulcus variations appear to be more closely related to obstetrical events than the the dorsal pubic bone pitting studied in the past.

Occasionally, female cadaver specimens deviate significantly from the relationship this study has demonstrated between the preauricular sulcus and obstetrical events. Three of the 36 gravid females, or 8.3% (Figure 17), show no bone resorption at the

preauricular sulcus attributable to obstetrical events. The same three females are also parous (Figure 18). However, one exhibits a slight pregnancy sulcus on the opposite side and dorsal pubic bone pitting; a second exhibits slight dorsal pubic bone pitting; and the third has a right superior pubic ramus fracture and pubic symphysis ankylosis so any signs of former pregnancies are obliterated. Although the sample is small, there is no compelling reason to believe age or degenerative conditions have effected preauricular sulcus morphology in these females, aged 51, 71, and 93.

There are five nulliparous females (Figures 17 and 18) who exhibit pregnancy sulci bone resorption at the preauricular sulcus attributable to obstetrical events. Two of these nulliparous females are gravid. They suggest that significant ligamentous alterations and bone resorption may occur in women who never experience full term pregnancies or parturition. Examination of the three nulligravid females indicate other physiological factors besides pregnancy and parturition may occasionally be responsible for the formation of a well-developed preauricular sulcus which has been identified as a pregnancy sulcus in this study. Again, although the sample is small, there is no compelling reason to believe age or degenerative conditions have effected the preauricular sulci in these three females, aged 68, 78, and 80.

No significant relationships existed when female preauricular sulcus morphology and measurements were compared with age, body weight, and degenerative joint conditions in the sacroiliac joints, lumbo-sacral joints, and fifth lumbar vertebras' cranial joints.

However, the large, shallow ligament sulcus which tends to appear in the oldest females is associated with lumbo-sacral anomalies and pelvic joint destruction. Its formation is probably related to sacroiliac joint instability occuring because of lumbo-sacral anomalies and greater sacroiliac joint mobility in females than males. Even though 33% of the male cadaver specimens exhibit some form of lumbo-sacral anomaly or pelvic joint destruction, none have the large, shallow ligament sulci occasionally encountered in the females. Since the female ligament sulcus is most commonly found in nulliparous or low-parity individuals, it is difficult to evaluate slight pregnancy changes at the preauricular sulcus.

Measurements of the sciatic notch angle and the relative posterior location of the auricular surface were compared with preauricular sulcus morphology and measurements in an attempt to assess any relationships between sexual dimorphic characteristics and the preauricular sulcus. The only significant comparisons were between the sciatic notch angle and preauricular sulcus width and area. The chi square test employed in these comparisons is not a particularly powerful analytical method. Figure 21, which is a plot of the sciatic notch angle and preauricular sulcus area illustrates that the relationship between these variables is not particularly significant. Nevertheless, research would be valuable on a larger sample of whole pelves for which gravidity and parity could be held constant. The results of this study suggest that the larger ligament originating from the larger preauricular sulcus functions to check sacral rotation particularly in females with larger sciatic notch angles.

In this study, three factors have been identified which may produce preauricular sulcus morphology seen only in females. These three factors are obstetrical events, lumbo-sacral anomalies, and the sciatic notch angle. They have a common characteristic which would explain the appearance of a large preauricular sulcus. That common characteristic is the possibility of sacroiliac joint instability. In the case of obstetrical events, the chance of sacroiliac joint instability results from the ligamentous changes associated with pregnancy and the increased load on the joints due to weight gain in pregnancy. In the case of lumbo-sacral anomalies and pelvic joint destruction, these conditions are assumed to effect sacroiliac joint instability due to abnormal load conditions on the joints over an extended period of time. The larger sciatic notch angle in females is a part of the complex of obstetrical adaptations in the female pelvis. These adaptations are probably not in the best interests of the body weight transfer function of the sacroiliac joint. More of the load at these joints is passed through the more anterior portion of the joint, thus increasing the rotational moment about the joint.

From an examination of forensic case specimens, Hammon-Todd collection specimens and archeologically-derived specimens, nothing inconsistent was found with the findings presented in this study of the post reproductive-aged cadavers. The majority of the forensic, Hammon-Todd and archeological specimens are from reproductive-aged adults.

Two of the 33 female forensic cases shed some light on the relationship between the preauricular sulcus and the sciatic notch angle. These are the same two females discussed on page 71 whose families indicated they were nulligravid. At the time of examination of these two females, it was noted that they had particularly wide and large angled sciatic notches. This supports the suggestion that the shape of the sciatic notch may be a contributing factor in pregnancy sulcus formation.

From the examination of forensic, Hammon-Todd and archeological specimens, it is evident that the large, shallow ligament sulcus is occasionally present in the reproductive-aged females. However, its presence has not been evaluated.

Even though there is a poor understanding of the physiological processes involved in the ligamentous and bony changes which occur in gestating women, Wolff's law (Enlow, 1975; Weinmann and Sicher, 1955) can be invoked to explain preauricular sulcus formation. Wolff's Law simply states that the morphology and structure of bone are influenced by its functional stresses. Current research on relaxin indicates that this hormone is a significant factor in effecting ligamentous changes (Schwabe et al., 1978). Although the hormones involved in pelvic joint ligament hyperplasia and bone resorption are the female steroids and relaxin peptide hormone, the entire physiological process may be analogous to the maintenance of ligament and tendon attachments on resorptive bone surfaces during bone growth in subadults (Enlow, 1975). The microscopic structure of the cortical and subcortical bone of the preauricular sulcus in

gestating females or nongestating, multigravid females may also differentiate these women from the same bone in nulligravid females and males, just as does preauricular sulcus morphology.

The significance of this research on the preauricular sulcus transcends its use in sexing and parity assessment of human skeletal material from forensic and archeological contexts. An obvious follow up study to this preauricular sulcus investigation would be a biomechanical comparison of sulcus morphology in whole pelves with obstetrical measurements and history. The more we understand about pelvic anatomy, the better will be our interpretation of historic, prehistoric and early hominid discoveries. From an evolutionary standpoint, the hominid pelvis was a very early development.

Since this research provides new information about pelvic joint anatomy, it will be useful in a variety of related studies, such as the controversy of pelvic joint mobility in gestating and parturient women (Ohlsen, 1973), the physiology of the corpus luteum peptide hormone, relaxin (Schwabe et al., 1978), and degenerative and pathological conditions in the pelvic joints. Study of the preauricular sulcus and relaxin lead to inquiry about the nature of bone resorption and ligament attachment. The sulcus is one of the few ligament attachment sites where an envagination of the attachment surface rather than tubercle formation occurs to allow for continuous attachment of an enlarging ligament.

This research also emphasizes the sexual dimorphism in pelvic joints and links the dimorphism to obstetrical adaptations in the pelvis. Since the birth process in humans is not well understood

as evidenced by the radically different obstetrical practices employed by physicians and midwives, obstetrical care would benefit from a greater understanding of obstetrical adaptations.

This research also offers the scientific historian new material. The lack of follow up on Derry's work (1909, 1911) for more than 60 years (Houghton, 1974, 1975) is interesting particularly in light of the 1926 discovery of the ovarian hormone, relaxin (Hisaw), a possible physiological mechanism for pelvic joint changes. Research on this hormone has only just begun to increase.

In summary, this research is an enlightening aspect of current research on pelvic anatomy and physiology which will provide anthropologists and other investigators with new and relevant information upon which a better understanding of the pelvis will result.

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# APPENDIX

# PLATES

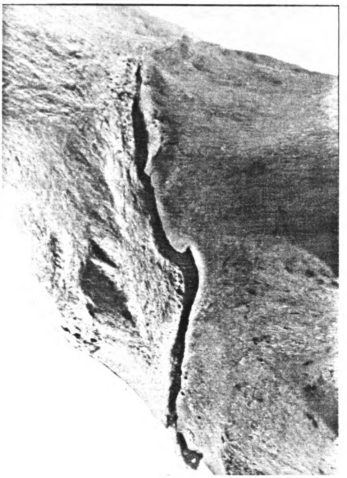

Plate 1. Right Heavy Preauricular Sulcus. Female: 65 years old, Gravid 10, Para 4, Body Weight 90.7 kilograms

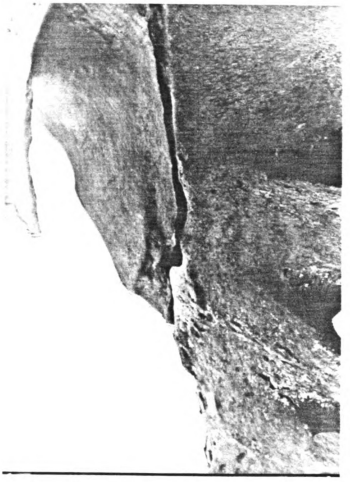

Plate 2. Right Ligament Preauricular Sulcus. Male: 59 years old, Body Weight 68 kilograms

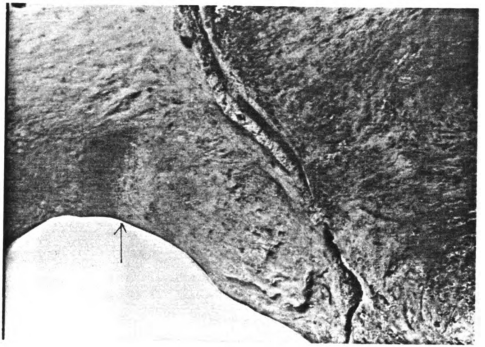

Plate 3. Right Moderate Preauricular Sulcus. Female: 82 years old, Gravid 2, Para 0, Body Weight 70.3 kilograms, Arrow--Superior Gluteal Artery Groove

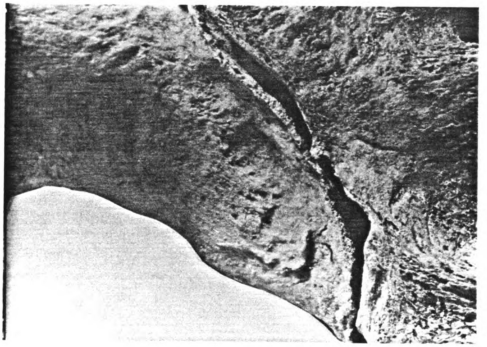

Plate 4. Same as Plate 3 but with Different Lighting

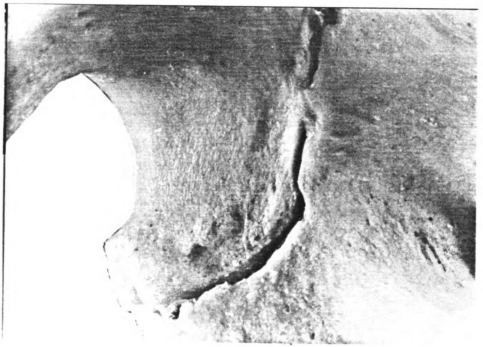

Plate 5. Right Pseudo Pregnancy Sulcus. Male: 65 years old, Body Weight 95.4 kilograms

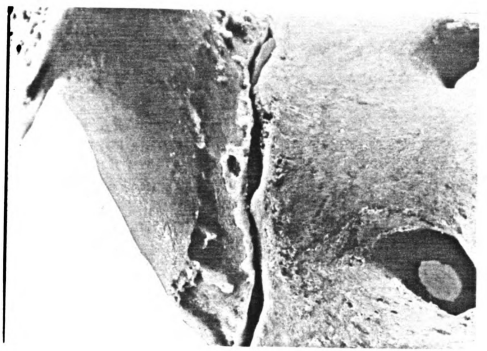

Plate 6. Right Heavy Preauricular Sulcus. Female: 78 years old, 8 Children Listed in Obituary, Body Weight 63.5 kilograms

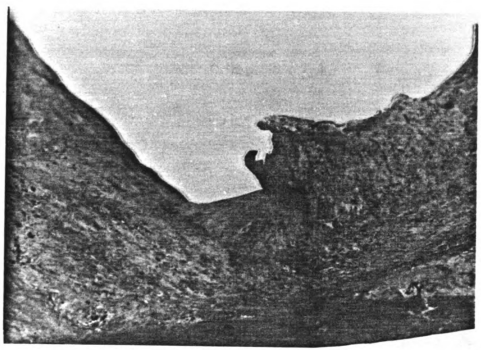

Plate 7. Right Ligament Sulcus. Male: Fletcher Site (20BY28)
Bay City, Michigan

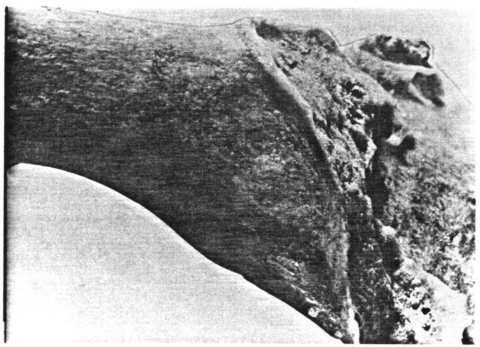

Plate 8. Right Slight Preauricular Sulcus. Female: 60 years old, Gravid 1, Para 0

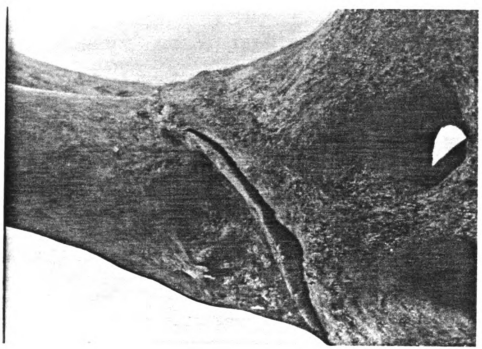

Plate 9. Right Heavy Preauricular Sulcus. Female: 80 years old, No Children in Obituary, Body Weight 56.7 kilograms

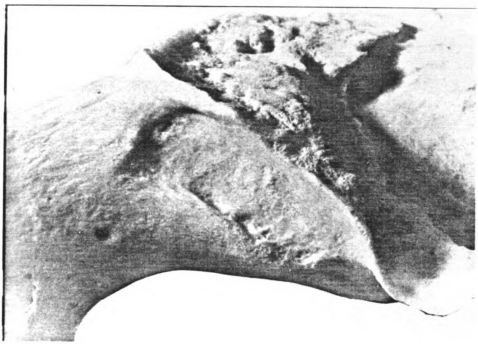

Plate 10. Right Heavy Preauricular Sulcus. Female: 47 years old, Body Weight 49 kilograms

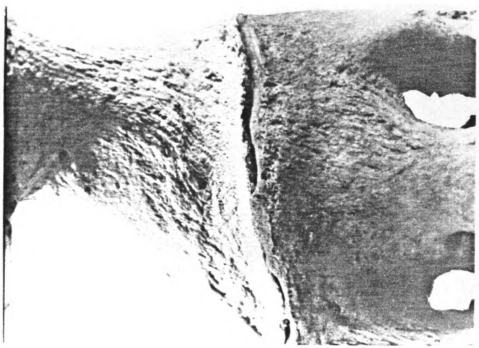

Plate 11. Right Ligament Sulcus. Female: 82 years old, Nulligravid, Body Weight 52.2 kilograms

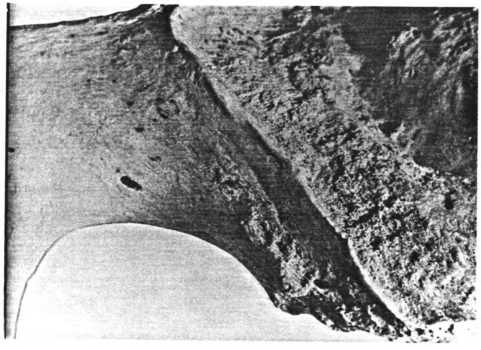

Plate 12. Right Ligament Sulcus. Male: 59 years old, Body Weight 90.7 kilograms

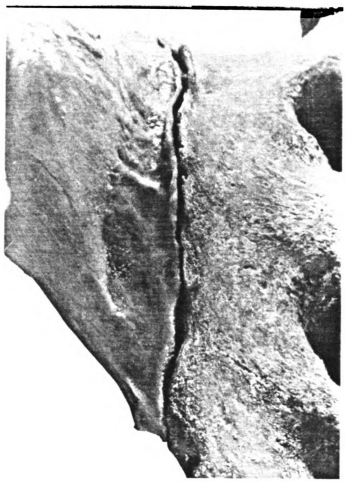

Plate 13. Right Ligament Sulcus. Female: 70 years old, Nulligravid


Plate 14. Left Heavy Preauricular Sulcus. Female: 30 years old, Nulligravid