PARTURITION SCARRING AS A CONSEQUENCE OF FLEXIBLE PELVIC ARCHITECTURE

by

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Parturition Scarring as a Consequence of
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ABSTRACT

Adaptation for upright bipedalism and childbearing has influenced the architecture of the human pelvic girdle. Assessment of childbearing in human skeletal remains is a major concern in paleodemography and forensic anthropology. Knowledge of childbearing is also important to archaeological and anthropological analysis. This study addresses the implications of parturition stress and excessive pelvic motion during locomotion to the bony pelvis.

The bony pelvis of 226 individuals from the Hamann-Todd Collection were examined. Included in the study were 87 males, 43 Black and 44 White as well as 151 females, 74 Black and 77 White. Parity status for all females were determined from comprehensive medical records provided by autopsy and dissection.

The occurrence of scars found at attachment sites in the bony pelvis previously thought to serve as indicators of childbirth, were examined to test the hypothesis that differential fertility can be accurately determined by analysis of "scars of parturition". The results of this study show that parity is not significantly associated with pelvic pits, cavities and/or depressions. The nulliparous female may have scarring, the multiparous female may have none, and males also can exhibit pelvic scarring. Thus, the hypothesis that fertility can be determined by skeletal pelvic analysis is rejected.

The results of this study show that pelvic flexibility and sex are significantly associated with pelvic scarring. Females have a significantly greater range of motion, rotation of the sacrum and expansion of the pelvic articulations, than do males. Tightly articulated pelvic girdles show significantly less scarring than the more loosely articulated pelves. Males have tighter pelves and show less scarring than females. Relaxation or stretching of the supporting soft tissue may allow excessive movement for pelvic articulations not tightly maintained by bone. It is determined that sex and flexibility of the bony pelvis are most important in pelvic scarring and that parity is not a significant factor. This study suggests that pelvic scars at attachment sites are a consequence of excessive pelvic movement beyond the optimum during locomotion and are, "scars of excess motion".

DEDICATION

This Ph.D. thesis is dedicated to

LAWRENCE LIMUAL CAGE

a scholar and gentleman from Missouri by his grandaughter.

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I

INTRODUCTION

Two important selective forces, upright bipedalism and childbearing, have played a major role in shaping the architecture of the human pelvic girdle (Derry 1912; Todd 1923; Brooke 1924; Waterman 1929; Schultz 1930; Reynolds 1931; Elftman 1932; Willis 1933; Kuhns 1935; Reynolds and Hooton 1936; Stewart 1938; Broom and Robinson 1950; Mednick 1955; Robinson 1972; Campbell 1979; Wolpoff 1980; Kelso and Trevathan 1984). This study addresses the implications of parturition stress and excessive pelvic motion during locomotion to the bony pelvis.

The adaptation of the pelvis to upright bipedalism and childbearing is not teleological, but has been produced in the past by natural selection (Muller 1949; Mayer 1962,1983; Bock and Wahlert 1965; Dobzhansky 1968; Lewantin 1978; Bock 1980). Selection is one of the forces of evolution (Mayr 1963,1970; Dobzhansky et al. 1977; Campbell 1979; Wolpoff 1980; Stebbins and Ayala 1981; Templeton 1982; Kelso and Trevathan 1984), and has been described as "the result of individuals' having differing numbers of offspring survive to parent the next generation" (Wolpoff 1980:18). Thus, human selection is exemplified by observing differential fertility (how many offspring are born to individuals during their lifespan) and differential survivorship (how many of those offspring survive to adulthood in order to reproduce) which cause differences in contribution to the next generation thereby changing the gene frequencies represented within the gene pool. The ability to derive "differential fertility" from female skeletons is important in the study of adaptation and micro-evolution because differential fertility is a measure of fitness (Kelson and Trevathan 1984). Fitness is a measure of adaptation by a population to a particular econiche. If an archaeological population could accurately be analyzed to answer the question, of who lived to reproduce and how many offspring were produced, a significant contribution would be made to our understanding of micro-evolution and human adaptation. This information is extremely important to the analyses of anthropologists, archaeologists and paleodemographers.

The differential reproduction of a past population is a crucial puzzle piece in a complex set of data needed to reconstruct the picture of a past population. Using individual skeletons from past populations paleodemographers attempt to reconstruct the population from which the skeletons came (Angel 1969; Nemeskéri 1972; Acsádi and Nemeskéri 1970). In order to make "useful guesses at the composition of a living prehistoric population " (Angel 1969:432) accurate attempts must be made to infer more than age, sex, mortality curves, and sex ratios from each skeleton. To infer differential fertility is desirable because it is needed to determine a measure of fitness or reproductive success.

In 1969, Angel proposed a method to determine differential fertility from human skeletal remains. He pointed out that fecundity (the potential ability to reproduce) data are a prerequisite for such a determination. He said that fecundity could be estimated by observing marked bony changes around the pubic symphysis of the pelvis. At the time this article was written (1969) no specific term was given to this complex of bony changes, although childbirth was proposed as the cause. Angel (1969:432) explained that these changes were most evident at the pubic symphysis because of the stresses of parturition. Stress of "the muscle and tendon attachments of the central belly wall" (1969:432), and stretched and torn arcuate and interpubic ligaments are cited as causal factors. Exostoses and a "spiral fossa below the pubic tubercle begins to develop even after one or two births" (1969:432). Also small fossae from haemorrhages and cysts develop posteriorly, parallel to the symphyseal margin. After perhaps four to eight births the fossa may coalesce into a deep groove on the symphyseal face. Angel stated that "clear cut development of these changes occurs after more than three births" (1969:432). This was the first time anyone had proposed that differential fertility could be determined by studying these characteristic, although unnamed, bony changes on the dorsal pubis.

According to Stewart (1970), Angel had based his findings on Putschar's (1931) autopsy material, Stewart's Eskimo pelves (1957), (neither of which had known parity) and four pubic bones of U.S. women (with known parity). Stewart (1957) noticed the same changes Angel had seen on the pubis of a predominately female Eskimo collection he was studying. Just prior to the Eskimo analysis, Stewart had been studying the effects of age changes on American male pubic bones (McKern and Stewart 1957) and having just seen so many male pubic bones had fixed the concept of the "normal" pubic symphysis in his mind. Stewart saw immediate differences between the male and female pelves, particularly abnormal changes on the dorsal pubis, and cautioned anthropologists not to mistake these abnormal changes as a result of aging. He felt that, "abnormalities of the pubic symphysis confined to females must be connected with child-bearing" (Stewart 1957:16). To test this possibility Stewart (1970) examined the Terry Collection, and was surprised when he found only about half of the female sample showed any scars at all and perhaps only about 17% showed definite scarring. This was far less than expected showing that some women could obviously bear children without any or with a minimal amount of scarring. Stewart (1970) regarded the deduction that dorsal pubic changes were a result of childbirth as tentative, and suggested that Angel (1969) surely did also. Not surpisingly, Stewart suggested further study.

In 1970, Stewart named these characteristic bony changes, "scars of parturition". Parturition scars have been described as pits, depressions, grooves, craters, and/or cavities in the bone at specific locations on the pelvic girdle (Angel 1969; Stewart 1970, 1979; Putschar 1931, 1976; Houghton 1974, 1975; Ullrich 1975). The scars most frequently appear at the pubic symphysis and the preauricular sulcus. It has also been suggested that they may be found on the interosseous groove (Kelley 1979) (a.k.a. postauricular sulcus), and the sacrum (see Figures 1, 12a-17b).

Angel (1969) has suggested that by the analysis of scars of parturition an accurate estimate of differential fertility can be produced. Today most investigators use these scars to make inferences about the fertility of the individual, and by extrapolation to the population from which the individual came (Gejvall 1970; Ullrich 1975; Houghton 1975; Ashworth et al. 1976; Owsley and Bradtmiller 1983). However, although scars of parturition are being used as indicators of fertility, some investigators do not agree that parturition scars have been proven to be indicators of differential fertility (Gilbert and McKern 1973; Holt 1978; Suchey et al. 1979; Kelley 1979; Spring et al. 1984).

Figure 1

Right Innominate Bone

Pelvic Landmarks

A - Iliac crest

B - Iliac fossa

C - Ilio-pubic ramus

D - Pubic tubercle

E - Articular area for the pubic symphysis

F - Obturator foramen

G - Ischial-pubic ramus

H - Ischial tuberosity

I - Greater sciatic notch

J - Preauricular groove

K - Auricular surface

L - Postauricular groove

M - Iliac tuberosity

Parturition Scars Location

1 - dorsal pubis

2 - preauricular groove

3 - postauricular groove

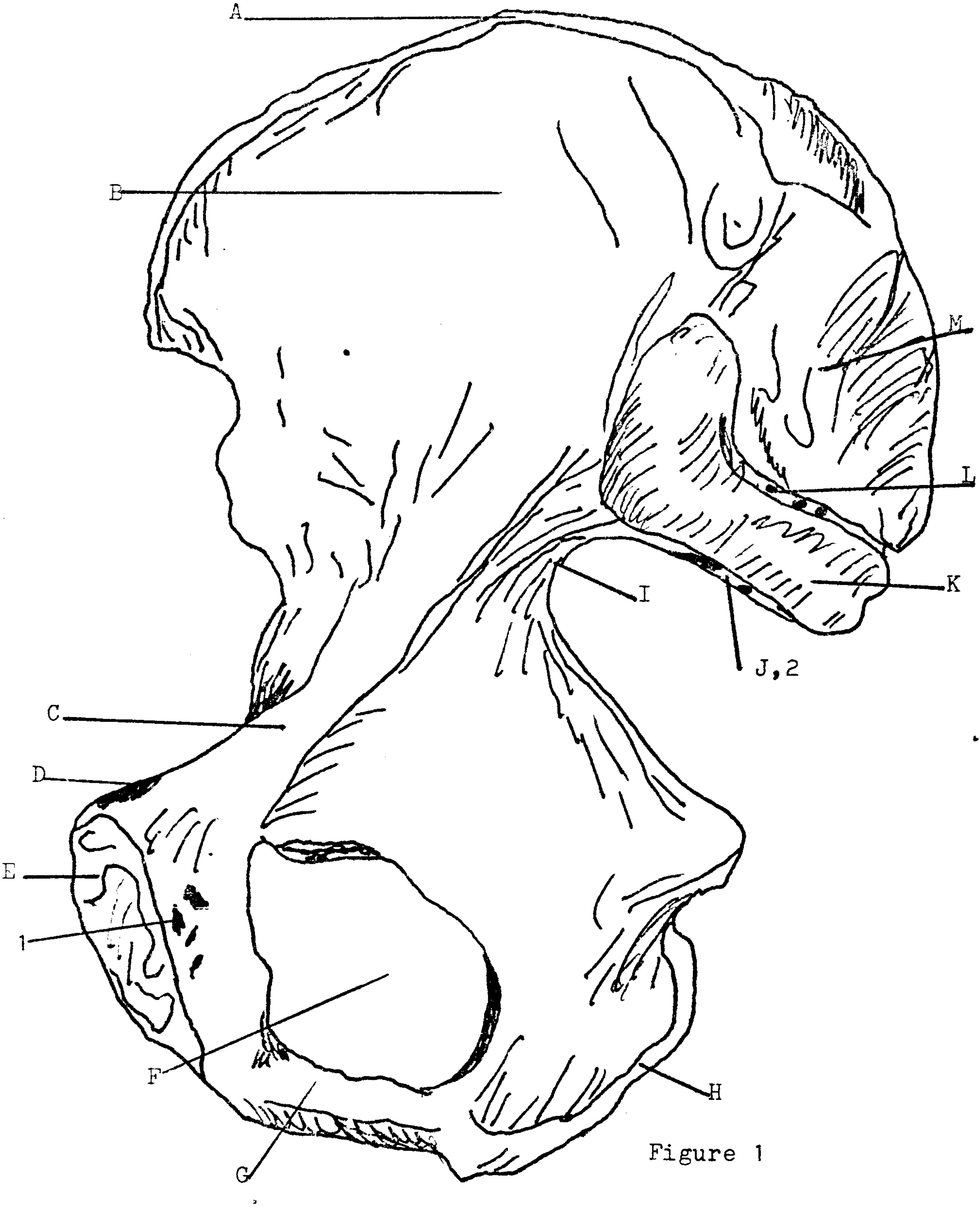


Figure 1

This research will examine stress of the bony pelvis in females due to childbirth. Because the architecture of the pelvic girdle provides the possibilities and limitations to the mechanics of reproduction, the biomechanics of the pelvic girdle during childbirth will be reviewed. Male and female pelves will be examined macroscopically for comparison and markers of parturition will be examined on female skeletons of known parity. These data will be applied to increase the understanding of the biomechanics of the pelvic girdle, in particular, the bony limits set by architectural design regarding movement of the girdle and its consequences. These data will also be used to test the hypothesis that differential fertility can be determined by analysis of the scars of parturition. If the hypothesis is accepted then a 'model of parity' will be devised to provide a framework for analysis. If the hypothesis is rejected an alternative explanation for scars of parturition will be proposed. Thus, the aim of this research is to provide a better assessment of fertility for past populations, to better understand pelvic girdle morphology in childbirth and thereby provide a better understanding of micro-evolution and human adaptation.

II

THE BONY PELVIS

The human pelvis resembles a bony basin (pelvis is the latin word for basin) and consists of four bones: two hip bones called the os coxae or innominate bones, the sacrum, and the coccyx (Figure 2). (This, and all of the remaining discussion in the Bony Pelvis Chapter are based on: Francis 1952; Basmajian 1970; Grant 1972; Kapandji 1974; Gray 1977; Anderson 1978; Snell 1978; Gunn 1984) The innominate bones and the sacrum are joined by three joints: the symphysis pubis and the two sacro-iliac joints forming a "closed osteo-articular ring" (Kapandji, 1974). Thus, the posterior portion is made up of the sacrum and coccyx and the innominate bones are joined by the pubis symphysis forming the anterior border.

THE INNOMINATE

The os coxae or innominate bone is actually composed of three bones: the ilium, ischium and the pubis which are separate bones joined by cartilage in the immature

Figure 2

Articulated Pelvic Girdle

Pelvic Landmarks

A - Innominate bone

B - Symphysis pubis

C - Coccyx

D - Sacrum

E - Sacro-iliac joint

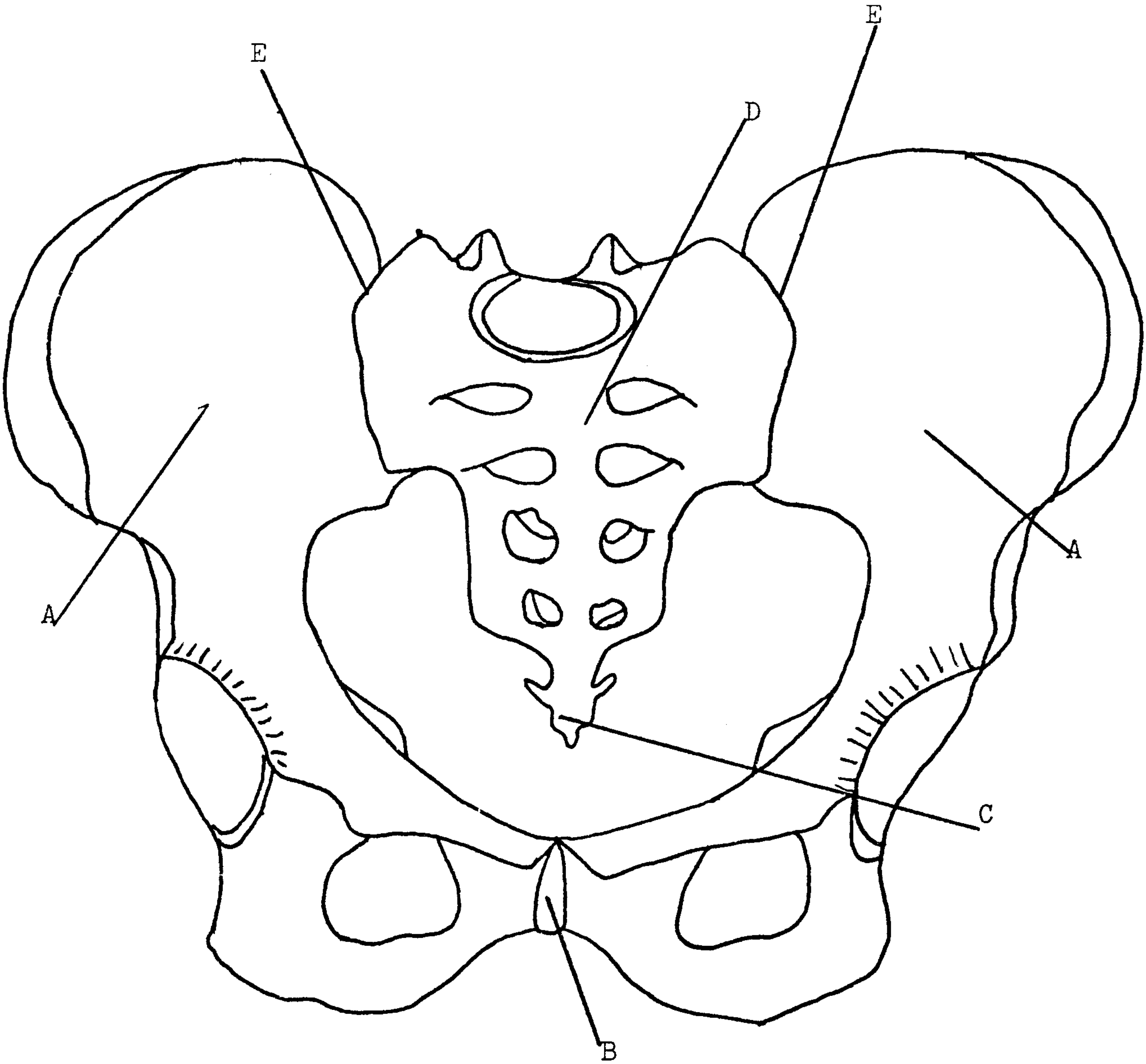


Figure 2

individual and fused by adulthood into one large irregularly shaped bone (Figure 3). The acetabulum is a hollow hemisphere which forms the socket for the head of the femur on the body of the innominate. It is at the acetabulum that portions of the ilium, ischium and the pubis meet and join to form the fused adult innominate (Figure 3).

The ilium is the flat portion of the innominate that lies superiorly, mainly above, and forming the upper two-fifths of the acetabulum (Figure 4). The iliac crest from the posterior superior iliac spine to the anterior superior iliac spine forms the thick anterior margin. The inner surface of the iliac blade is called the iliac fossa (Figure 4). Below this fossa is the ilio-pectineal (arcuate) line that extends from the promontory of the sacrum to the symphysis pubis. On the dorsal posterior aspect of the iliac blade is the iliac tuberosity which is uneven and sometimes quite thick.

Inferior to the iliac tuberosity and superior to the auricular surface is a cleft-like groove called the postauricular sulcus or interosseous groove (Figure 4) (Cleland 1889; Hoyme 1963; Stewart 1979; Kelley 1979; Işcan

Figure 3

Three parts of the innominate bone united along a Y-shaped line at the acetabulum.

Pelvic Landmarks

A - Ilium
B - Posterior superior iliac spine
C - Acetabulum
D - Ischium
E - Ischial tuberosity
F - Pubis
G - Anterior superior iliac spine
H - Iliac spine

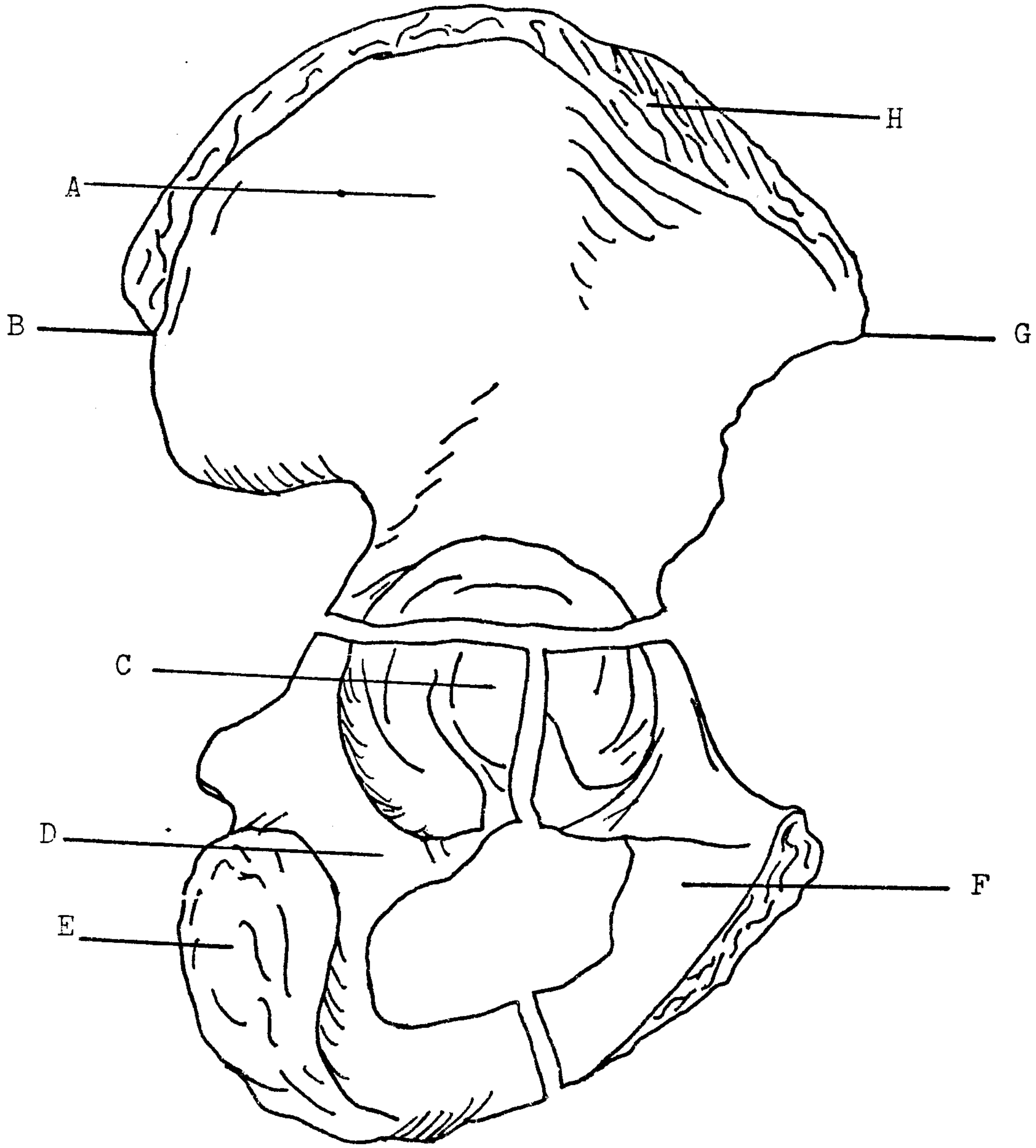


Figure 3

Figure 4

Right Innominate Bone

Pelvic Landmarks

A - Iliac crest
B - Iliac fossa
C - Anterior superior iliac spine
D - Anterior inferior iliac spine
E - Ilio-pectineal line
F - Ilio-pubic ramus
G - Pubic tubercle
H - Pubic crest
I - Articular area for the pubic symphysis
J - Dorsal pubis
K - Obturator foramen
L - Ischial-pubic ramus
M - Ischial tuberosity
N - Lesser sciatic notch
O - Ischial spine
P - Greater sciatic notch
Q - Preauricular groove
R - Posterior inferior iliac spine
S - Auricular surface
T - Postauricular groove
U - Posterior superior iliac spine
V - Iliac tuberosity
W - Assessory articular facet

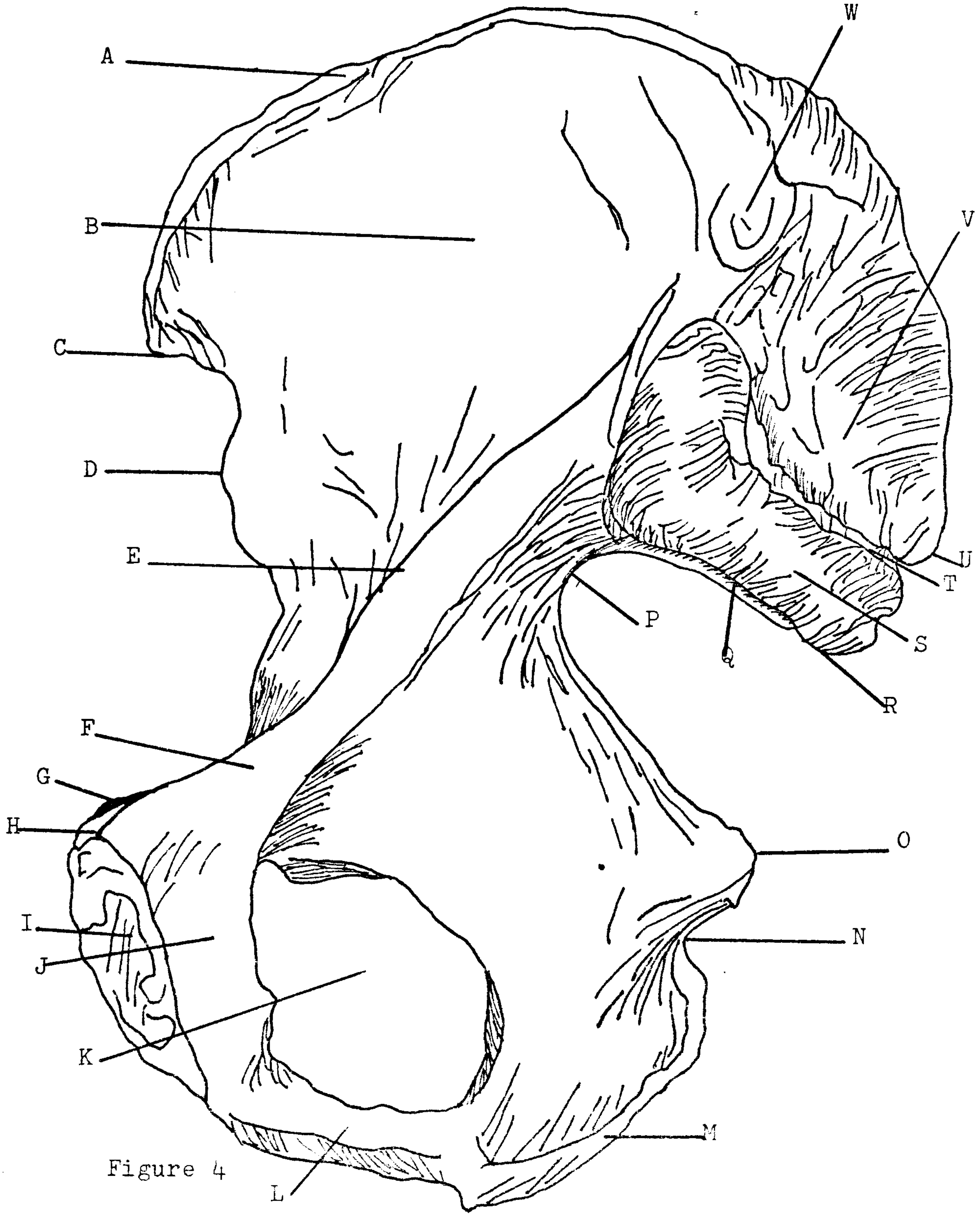


Figure 4

and Dunlap 1983; Iscan and Derrick 1984). Located between the posterior superior iliac spine and the posterior inferior iliac spine and abutted to the postauricular groove is the ear shaped auricular surface of the ilium which articulates with the auricular surface of the sacrum to form the sacro-iliac joint of the pelvis (Figure 4). Sometimes a preauricular sulcus will be present as a horizontal groove which is below the inferior border of the auricular surface of the ilium (Zaaijer 1866; Lohr 1894; Derry 1911b, 1909; Houghton 1974, 1975). The posterior border of the ilium sweeps down and forward forming the greater sciatic notch. The ilium joins the ischium just below the angle of this notch.

The ischium forms the posterior and inferior portion of the innominate and is the strongest bone in the pelvis (Figure 4). The ischium forms the lower two-fifths of the acetabulum and terminates the greater sciatic notch by the pointed ischial spine. The ischial tuberosity is a large rough pillar of bone which supports the body weight when sitting upright and is a main feature of the ischium. From the tuberosity a much thinner bar of bone, the ischial ramus joins with the pubic ramus.

The obturator foramen is a large hole between the acetabulum and the pubic symphysis formed by the rami of the pubis and ischium (Figure 4).

The pubis completes the acetabulum and moves medialwards as a bony bar called the superior (or ilio-pubic) ramus (Figure 4). The symphysis pubis articulates the body of the left and right pubic bones. A bar of bone called the inferior (ischio-pubic) ramus runs from the lower part of the symphysis inferiorly and posteriorly to meet the ischium.

THE SACRUM

The sacrum is a symmetrical triangularly shaped solid piece of bone resulting from fusion of five sacral vertebrae (Figure 5). It is larger above than below and articulates superiorly with the body of the fifth lumbar vertebra to form the lumbosacral joint, inferiorly with the base of the coccyx to form the sacrococcygeal joint, and on both sides with the auricular surface of the innominate to form the sacro-iliac joint. The base is the most superior part of the sacrum with the sacral promontory located at the highest most center point on the ventral

Figure 5

Right Innominate Bone

Pelvic Landmarks

A - Sacro-iliac joint

B - Iliac crest

C - Iliac fossa

D - Arcuate line (ilio-pectineal line)

E - Acetabulum

F - Ischial spine

H - Ilio-pectineal line (arcuate line)

I - Obturator foramen

J - Symphysis pubis

K - Ala

L - Sacrum

M - Base

N - Lumbro-sacral joint

O - Sacral promontory

P - Sacro-coccygeal joint

Q - Coccyx

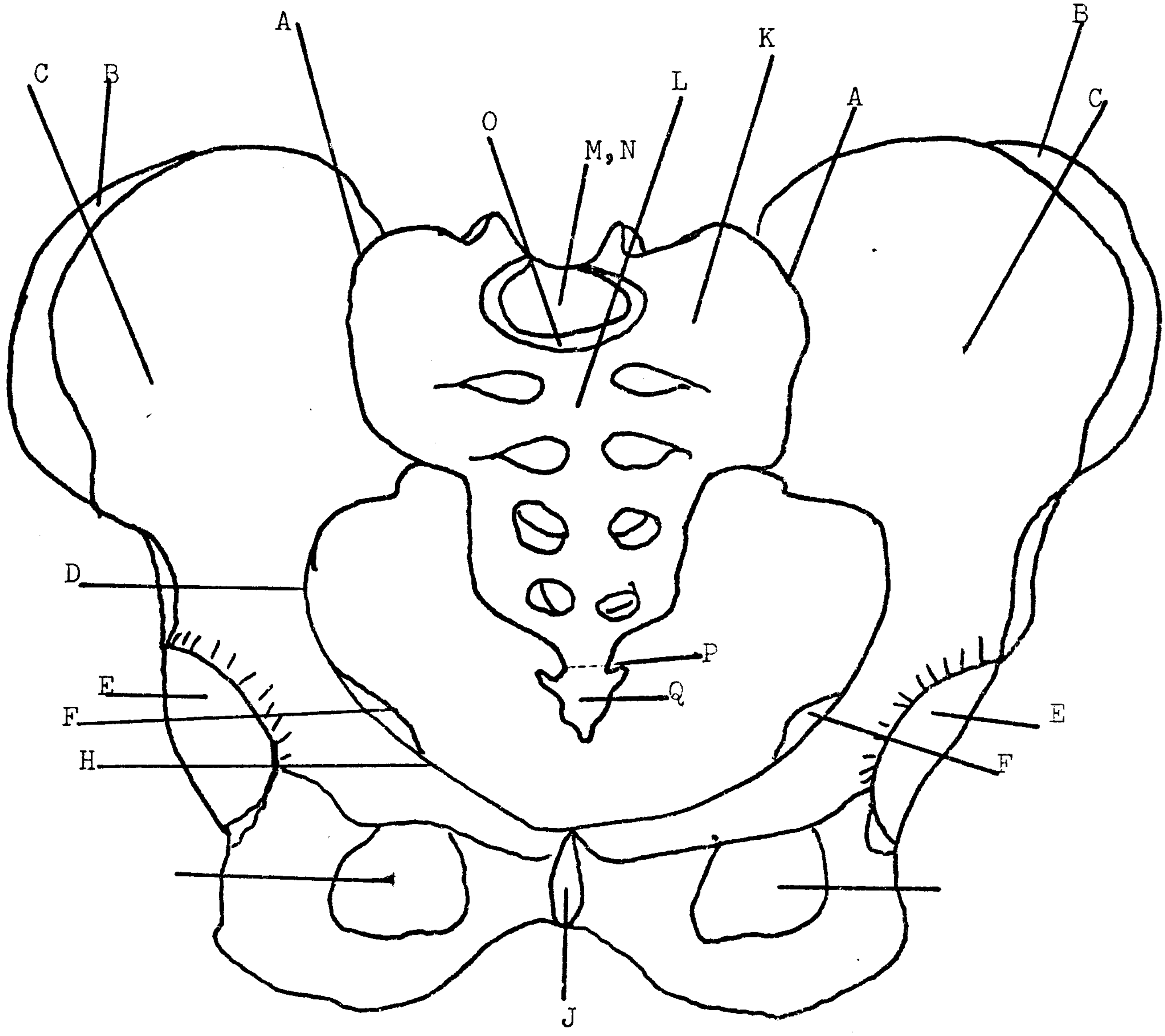


Figure 5

margin of the base.

The coccyx articulates with the apex of the sacrum (Figure 5). This bone is composed of four greatly reduced vertebrae diminishing in size from above downward, sometimes only nodules of bone. The coccyx may or may not be fused.

THE PELVIC GIRDLE

The bony pelvis is divided into two parts: the greater (false) pelvis and the lesser (true) pelvis (Figure 5). It is the larger upper portion of the pelvis that is referred to as the greater pelvis. It lies above an oblique plane called the pelvic brim passing through the sacral promontory, the ilio-pectineal (arcuate) line, and the upper margin of the symphysis pubis and forms part of the abdominal cavity. The lesser (true) pelvis lies below the pelvic brim. The pelvic inlet (bounded by the pelvic brim) opens into the pelvic cavity formed by the pubis and the interior wall of sacrum and coccyx. The outlet forms an angle of approximately 75° with the plane of the inlet bounded by the symphysis pubis, the ischio-pubic rami, the sacro-tuberous ligaments and the coccyx.

JOINTS OF THE PELVIC GIRDLE

The pelvic girdle is joined by three joints: the symphysis pubis and the two sacro-iliac joints.

The Pubis Symphysis (Figure 5)

The intermediate structural category of joints is,

> "the amphiarthrosis (= both + joint) which allows some motion in response to compression, tension, or twisting, yet is tough. The surfaces of the adjoining bones may be covered by hyaline cartilages which, in turn, are joined by a pad of collagenous fibers or by fibrous cartilage. The union between the bones of such a joint is called a symphysis instead of a suture" (Hildebrand 1974:450).

The symphysis pubis is a secondary cartilagenous joint (amphiarthrosis) and is formed when the two pubic parts of the innominate bone are articulated.

The articular surface of each pubic bone is oval in shape and covered with articular hyaline cartilage.

Articular cartilage is the weight bearing surface in this joint (Swanson 1980). The cartilage is firmly attached to the osseous tissue by interlocking processes and depressions between the two. A thick disk of fibrocartilage (interpubic fibrocartilaginous lamina, interpubic disk, and interosseous ligament) connects the two hyaline cartilage ends. This disk can vary in thickness and sometimes project beyond the bones especially on the dorsal surface. There is usually a slit like cavity on the upper part of the articulation. Snelling (1870) said that "this space is found at all periods of life, both in male and female" (569), yet later it was found to appear between the seventh and tenth years and is attributed to the breaking down of the interpubic lamina" (Boland 1933:432), and is larger in the female (Francis 1952).

The joint is supported and strengthened on all sides by ligaments. The superior ligament is a thick and fibrous band attached on either side to the crest and tubercle of the pubis. The inferior ligament (subpubic arched ligament, arcuate) supports and forms the apex of the pubic arch. The very thick and strong anterior ligament closes the joint anteriorly. It is composed of transverse and oblique fibers whose aponeurosis blend with the origin of the muscles in the area: (transverse abdominis, rectus abdominis, pyramidalis, internal oblique abdominis and adductor longus). The fourth ligament of the periarticular pubic ligaments is the weaker posterior ligament. This ligament is a fibrous membrane crossing behind the joint and is continuously joined with the periosteum.

The Sacro-Iliac Joint (Figure 5)

The sacrum and the ilium articulate together in a synovial and fibrous attachment called the sacro-iliac joint. This joint is sometimes classified as an amphiarthrosis joint yet Brooke (1924) suggests that "the old description, that the joint was an amphiarthrosis, was the description of a pathological change. The normal joint is of the diarthroidal type and in all probability takes part in movements backwards and forwards of the lumbar spine" (p. 305). Francis (1952) suggests that the reason the joint is sometimes classified as an amphiarthroidal joint is that, "In later life there are frequently fibrous bands crossing the joint cavity, fibrocartilage may be present in the articular cartilages, or there may be a complete obliteration of the joint cavity" (Francis 1952:43). Within the general structural category of joints is,

> "the freely movable joint or diarthrosis (=2+joint). The articulating surfaces of the bones are covered by extremely smooth hyaline cartilage. Where not bordered by the cartilage-covered bones the cavity is enclosed by a joint capsule...the capsule is lined by a cellular synovial membrane which is more or less folded... Ligaments binding a diarthrosis may be within or partly outside the capsule, or may be inside the joint cavity, as at the hip and knee of mammals...Bathing joint cavities is a small quantity of synovial fluid, apparently produced by the synovial membrane" (Hildebrand 1974: 452-453).

The upper posterior portion of the joint on the iliac blade is bounded by the iliac crest and the posterior superior iliac spine (Figure 4). Over this area the sacrum and ilium are not in direct contact but are filled by numerous fibers such as short and long dorsal sacro-iliac ligaments, superior and inferior bands of the ilio-lumbar ligament and on a deeper level the very strong interosseous sacroiliac ligament. Other dorsal ligaments, although more inferiorly located, are the secondary ligaments, sacrospinous and sacrotuberous. The iliac tuberosity is highly variable in form ranging from a fossa shape to a pointed, mound or crest (Işcan and Derrick 1984), and is found in the posterior iliac region inferior to the iliac crest and superior to the auricular surface. Accessory sacro-iliac articulations sometimes are present as a facet superior and posterior to the auricular surface generally resulting from stabilizing articulation with the sacrum (Derry 1911; Seligmann 1935; Trotter 1937, 1967; Stewart 1938).

The postauricular sulcus (interosseous groove) is between the iliac tuberosity and the auricular surface, being generally closer to the posterior edge of the auricular surface (Figure 4). When present, it is variable in size and may extend along the horizontal ramus of the auricular surface from the articular vertical ramus superior to the posterior inferior iliac spine (Işcan and Derrick 1984). This is the site of the insertion of the very strong interosseous sacroiliac ligament, and superficially the long and short dorsal sacroiliac ligaments.

The main function of the sacro-iliac area is to transmit the weight of the body to the hip. Thus, this joint is under constant weight strain unless the body is supine. An additional function of this joint is to buttress and maintain the integrity of the synovial joint "(which is helpless alone, in spite of its interlocking character, to sustain weight)" (Basmajian 1970: 104).

The auricular surface of the sacro-iliac synovial joint lies on the medial postero-superior portion of the iliac bone (Figure 4). It is posterior to the ilio-pectineal line and is part of the pelvic brim. Although the surface is highly variable in form, it is generally considered to be concave postero-superiorly and is covered with smooth articular hyaline cartilage. "Articular cartilage is the tissue which forms the bearing surfaces in the synovial joints of mammalian skeletons" (Swanson 1980:377). The shape of the auricular articular surface resembles the outline of an ear, or a kidney bean, or to the two arms of an L. The corresponding surface on the sacrum is a mirror image of the iliac surface although is lined with fibrocartilage. "The sacral articular facet is subject to wide structural variations from person to person" (Kapandji 1974:60). The highly variable L shaped articular surface (Brooke 1924) has been shown by Weisel (1954) to exhibit a cranial segment that is longer and narrower than the caudal segment. At the junction of the two segments is a slight elevation known as Bonnaire's tubercle (Weisel 1954). Attached to the margins of the articular cartilage is a continuous layer of synovial membrane. It is only the lower half of the entire sacroiliac joint that is lined by synovium (Vayas, et al 1981).

Due to upright bipedalism the sacro-iliac joint is larger in man than other mammals in order to provide stability, "including more segments of the sacrum and presenting greater surfaces for attachment of ligaments" (Willis 1933:149-150). "The sacrum and ilium are held in apposition by a capsular ligament and a number of accessory ligaments dorsal to it" (Weisl 1954a:211). The capsular ligament (short axial or interosseous ligament) is the deep layer of the ligaments and is attached laterally to the iliac tuberosity region and medially to the sacral tuberosities of S1 and S2. This interosseous ligament is the strongest of all the sacro-iliac attachments consisting of many very strong interlaced fibers sometimes filling the entire postauricular area. The other peripheral ligaments which wrap around the joint are reinforcements to this main articulatory attachment. They are the anterior sacro-iliac ligament, posterior sacro-iliac ligament, sacro-tuberous ligament and the sacro-spinous ligament. These ligaments are the stabilizers of the sacro-iliac joint. The interosseous anterior and posterior sacro-iliac ligaments help prevent forward displacement of the sacrum during weight bearing, and the sacro-tuberous and sacro-spinous ligaments help prevent backward rotation of the sacrum with the longitudinal fibers of the anterior sacro-iliac ligament also restraining lifting or rotation of the posterior end of the sacrum (Derry 1911b).

The anterior (ventral) sacro-iliac ligament consists of superficial and deep bands originating at the third sacral vertebra and inserting into the preauricular sulcus (Zaaijer 1866; Lohr 1894; Derry 1911b). The antero-superior band is more superficial with the antero-inferior the stronger deep band inserting into the floor of the preauricular sulcus. The anterior sacroiliac ligament covers the anterior and inferior aspects of the joint.

The posterior (dorsal) sacroiliac ligament is strong and is divided into short and long sections. Both sections are heavy fibrous bands running from the iliac tuberosity to the sacral tuberosity. These bands cover the posterior aspect of the joint and merge with the sacrotuberous ligament.

The sacrospinous ligament runs from the ischial spine to the lateral border of the sacrum and coccyx, whereas the sacrotuberous ligament is attached superiorly to the posterior border of the iliac bone and to the first two vertebra of the coccyx, subsequently inserting into the ischial tuberosity and the ascending ramus of the ischium. Thus, these two ligaments divide the sciatic notch into two sciatic foramina, (greater and lesser).

MOBILITY OF THE PELVIC JOINTS

The pubic symphysis is of minimal mobility. Forces on the symphysis pubis produce tension and compression. This joint is under tension, because when sitting upright weight is borne by the ischial tuberosities which tend to be forced apart. Compression arises due to weight distribution in standing which tends to buckle the acetabular margin inward (Basmajian 1970). It is the symphysis pubis joint which resists these tendencies and, is thus subjected to both tension and compression. A shearing force is also brought to bear on the pubic symphysis when a step is taken (Kapandji 1974). Thus, the normal non-pregnant female and male pubic symphyses experience little movement because it is the function of the surrounding soft tissue to maintain a firm union (Goel and Svensson 1977).

Movement of the sacroiliac joint does occur although slightly (Zaglas 1851; Duncan 1854, 1868; Weisel 1954, 1955). During standing the body weight tends to tilt the promontory of the sacrum, as does flexing of the hips, and can initiate nutation (a nodding movement).

The movement of nutation is limited by the sacrotuberous and sacrospinous ligaments and both bands of the anterior sacroiliac ligament. Classically it was assumed that nutation of the sacrum occurred around the axis of the interosseous ligament. Another view (Bonmaire's theory) suggested that the axis of nutation passed through the tubercle located between the cranial and caudal segments of the sacral articular facet. Weisel (1954, 1955) has proposed that movement at the sacroiliac joint consists of a linear displacement with a sliding motion along the caudal portion of the articular facet, and a rotational movement with the axis slightly anterior to the articular facet.

Counter nutation is movement wherein the promontory of the sacrum moves inferiorly and anteriorly as the iliac bones tend to move apart and the ischial tuberosities move together. "The movement of counternutation is limited by the tension developed in the sacroiliac ligaments both in the anterior and posterior planes" (Kapandji 1974:64).

Nutation and counter nutation occur normally in standing and walking and the range of movement is very small. Nutation also occurs during flexing of the hips, as in childbirth. This movement increases the diameter of the pelvic outlet. "During a change of position from hip extension to hip flexion, the mean range of displacement of the promontory is 5.6mm" (Kapandji 1974:70). The normal shearing force at the pubic symphysis is also produced by the shift of weight on the sacroiliac joint during standing and walking. The resistance to movement of the bony pelvis resides in the ligaments of the pelvic joints.

The movements of the pelvic joints, and changes of pelvic dimensions in women during pregnancy and parturition have been studied (Zaglas 1851; Duncan 1854; Snelling 1870; Lynch 1920; Brooke 1924; Thoms 1936; Heyman and Lundqvist 1932; Abramson et al. 1934; Roberts 1934; Young 1940; Weisl 1955; Borell and Fernstrom 1957, 1967; Russell 1965, 1969; Ohlsen 1973). By 1870 it was generally accepted that relaxation of the pelvic articulations occurs during pregnancy and parturition (Snelling 1870).

In the pregnant female hypertrophy and relaxation of the pelvic ligaments and cartilages causes the joints to become looser and permit shearing as the pubic bones slide on each other. Some separation of the union occurs as they move apart (Snelling 1870; Putschar 1931, 1976; Heyman and

Lindqvist 1932; Abramson et al. 1934; Thoms 1936, 1938; Thorp and Fray 1938; Young 1940; Berezin 1950).

As early as 1929 Hisaw observed the relaxation of the pubic symphysis in pregnant guinea pigs, due to a secretion from the corpus luteum. It was suggested that relaxin, produced by the corpus luteum (Weiss and Steinetz 1976), and estrogen produce relaxation of the articular ligaments and seperation of the pelvic joints during pregnancy and labor (Hisaw 1932). Weiss and Steinetz (1976) showed that increased progesterone secretion was accompanied by and associated with, an increase in relaxin secretion. Hall (1950) studied the effects of oestrone and progesterone on the pubic symphysis of casterated mice and found similar changes and relaxation of that joint. Berezin (1950) suggested that the presence of estrogen is obligatory for the expression of the other hormones: relaxin, progesterone, or doca, and that estrogen is the only one of the hormones to have an effect when acting alone. "That estrogen alone can affect pelvic girdle relaxation is shown by X-ray demonstrations of articular diastasis during menstruation and the frequent association of the catamenia with sacral backache" (Maxwell 1938:1166). Thus relaxation and pelvic changes can occur due to the hormonal influence or influences of estrogen, progesterone, relaxin or doca during pregnancy. Maxwell (1938) pointed out that relaxation may occur because of estrogen at times other than pregnancy, such as during menstruation. In 1980 Oxorn discussed the role of progesterone and relaxin in producing hyperemia and softening of the ligamentous tissue of the pelvic girdle.

Studies support movement of the pelvic articulations when there is a change of body position during parturition which causes a change of pelvic diameters (Walcher 1889; Young 1940; Duncan 1854; Williams 1911; Thoms 1915; Borell and Fernstrom 1957, 1967; Russel 1969). Movement of the pelvic articulations independent of the change in maternal position have been demonstrated and are important because "clearly, a small and rigid pelvis is less adequate for delivery than a pelvis of identical size which is mouldable" (Borell and Fernstrom 1967:76).

Widening of the sacroiliac joints but not increased separation of the pubic symphysis, was reported by Lynch (1920).

Brooke (1924) noted clearly in a study of the sacroiliac joint in postmortem subjects that the range of movement of that joint is increased two and one-half above the maximum for non-pregnant woman. In addition to range of movement, actual separation of the joint surfaces was proposed with an autopsied case as an example, "the ligaments and capsule were so lax that the anterior margin of the joint surfaces could be separated from each other in a horizontal plane for a distance of almost a quarter of an inch on each side" (Brooke 1924:302).

Heyman and Lundqvist showed that an "increase in the width of the symphysis apparently occurs in all pregnant women" (1932:216). They noted that though diastasis did occur, no significant increase of the pubic symphysis during the early stages of labor could be demonstrated.

Boland (1933) stated that separation of the pubic symphysis is not as common as generally believed, and occurs in about one out of every 685 deliveries. Cause of separation was grouped into two classes: 1) severe external trauma, and 2) result of parturition. Boland described the mechanics of separation, "the descent of the fetal head against the pelvic ring produces separation of the symphysis which spreads at its weakest point" (Boland

1933:432).

Abramson et al. (1934) and Roberts (1934) agreed that the width of the pubic symphysis did not significantly increase during parturition. Eventhough, Abramson et al. acknowledged that an average widening of 7-8 mm did occur, and Robert's sample was small and inconclusive.

Conflicting evidence was presented by Thorp and Fray (1938) when they used systematic X-ray techniques and demonstrated definite diastasis in 43.6% of the pubic symphyses studied with a mean increase of 5mm and a maximum of 12mm (N=78). Separation was not confined to the pubic symphysis as it was generally expressed in the sacro-iliac joints as well.

By the 1940s (Young, 1940) it was accepted that the pubic symphysis did widen slightly (Heyman and Lundqvist 1932; Abramson 1934; Roberts 1934; Ince and Young 1940), and that there appeared to be wide variation in the amount of separation. In addition, there was evidence for similar change in the sacroiliac joints.

In pregnant and puerperal women, Borell and Fernstrom (1957) demonstrated that "the movements at the sacroiliac joint resulted in upward and downward displacement of the symphysis pubis, the distance moved by the latter measuring between 2 and 3 cm in some cases" (1957:56). This demonstrates a shearing displacement of pubic bones normally in lateral aposition. They also showed that the sagittal diameter of the outlet increased on average by 10 mm, and in one case by 20 mm. They felt that these changes were significant and that they were due to a rotation of the sacrum in relation to the ilium.

Russel (1969) suggested that pelvic moulding does increase all the pelvic diameters in parturition and that these changes can best be explained by postural changes rather than being due to diastasis of the joints.

Ohlsen's (1973) reexamination of the films that Borell and Fernstrom collected between 1955-1957 support the view that movement occurred in the sacroiliac joint. In 25 out of 26 cases the intersacro-iliac distance showed a mean increase during labor of 4.2mm (range of 0-9.1mm) suggesting a backward displacement of the sacrum (Weisl 1954, 1955; Borell and Fernstrom 1957, 1967). A slight increase in the width of the pubic symphysis during labor was also shown.

Thoms (1936) concluded that pelvic joint relaxation is a normal feature of pregnancy and that pelvic instability is far more common than previously supposed. It was determined that pelvic type did not play a role in the amount of pelvic relaxation.

Kuhns (1935) pointed out that hormonal and bony structure changes are not the only major factors to be considered. "It is well known that the stability of joints is dependent to a large extent upon their controlling musculature" (Kuhns 1935:17).

PELVIC SUPPORT

There are a great number of muscles and connective tissues attached to the pelvic girdle. Only those intimately associated with the pelvis is reviewed here (Elftman 1932; Francis 1952; Mengert 1956; Ulfelder 1956; MacConaill and Basmajian 1969; Weed 1972; Wilson 1973; Basmajian 1974; Goel and Svensson 1977). "The structures which form the pelvic girdle and close the outlet are made of bone, striated muscle, smooth muscle, or of connective tissue in all its variants" (Ulfelder 1956:861). Striated muscle or voluntary muscle can effectively resist stretching and loss of tonus to gravity or pressure. Smooth muscle or involuntary muscle does not maintain original length or fiber direction when under constant stress, and thus may relax and lengthen in response to gravity or pressure. Connective tissue such as fascias, aponeuroses and ligaments are composed of collagenous and elastic fibers. Generally their function is to prevent or limit motion. When a force is applied that exceeds the tissues stress limits a fracture may result. A sustained pull results in a permanent increase in connective tissue length (Ulfelder 1956). Thus, smooth muscle and connective tissue lengthens or is injured by constant pressure, while striated muscle is not.

Mengert (1936) showed fluctuating pressures created within the abdominal cavity ranging from 2 - 3 1/2 pounds per square inch by normal straining. The pelvic cavity walls are necessarily of striated muscle tissue. An abnormal rise in intra-abdominal pressure can be caused from excessive weight gain, smokers cough, lifting of weights, prolonged straining at stool, perineal injuries to the levator and sphincter muscles, and parturition (Wilson 1973). Borell and Fernstrom (1967) showed that intra-abdominal pressure in labor is not uniform because the deformation or moulding of the fetal head is a result of strong axial compression by the uterus. This non-uniform pressure of labor accompanies the constant pressure of the added weight and pelvic tilt of the pregnant female. Weed (1972) agreed that pelvic relaxation can be caused by 1) childbirth, 2) increased abdominal pressure, and added 3) change of posture with aging. Ulfelder (1956) pointed out that most of the pressure produced by the intra-abdominal musculature is absorbed by the pubis, anterior pelvic girdle and the iliac bones. Due to the constant pressure of gravity in addition to the frequency and magnitude of pressure changes within the pelvic girdle, relaxation or lengthing of tissue can occur and cause the loss of integrity of the support system (Mengert 1936, 1956; Ulfelder 1956; Weed 1972; Wilson 1973).

Bone is an ideal support because it is rigid and dependable for transfer of weight in bipedalism and is perfect for the pelvis in man. "Man subjects the pelvic floor to great stresses not only in the liberal use of his hands but especially by walking with a fully erect body" (Elftman 1932:333). Yet a compromise in structure must be made for perpetuation of the species. Ulfelder (1956) says, "the skeleton of man contributes to the support of the pelvis chiefly by keeping as much bone as possible under the contents and still permitting delivery of the fetus" (858). Yet Nicholson (1945) points out that, "for the erect posture there can be no doubt that the male pelvis is architecturally sound...the female pelvis has been compelled to sacrifice some of its architectural soundness because of its necessary use as a birth canal" (Nicholson 1945:133). Thus, the pelvic floor of the female must be considered as a functional link in the support system of an integrated pelvic girdle. "The pelvic floor or pelvic diaphragm is mostly muscular, very important in parturition, and generally misunderstood" (Basmajian 1974:348).

The pelvic diaphram is composed of the levators. The pubococcygeus and the iliococcygeus can be lumped together and called the levator ani. The levator ani and the coccygeus are the chief sources of the strength of the pelvic floor (Elftman 1932; Weed 1972). The pyriformis reinforces the coccygeus and closes the sacro-iliac foramen. The levators originate from the pubic bone and the fascia overlying the obturator internus muscle. Because of the bilateral nature of this group it forms a sling of striated muscle punctuated by the anus, the vagina, and the urethra. Separation of the levators are caused by sexual activity, parturition, delivery of large infants, rapid labor or injury (Weed 1972). Because the levators are of striated muscle they can be exercised to retain their tone. However, relaxation can occur in virginal women or women who have never given birth due to a loss of integrity of the supporting soft tissue of the pelvis.

The urogenital diaphram (the sphinctor group) consists of the striated sphincter of the urethra and the deep transverse perineal muscle (Francis 1952), the bulbocavernosus, ischiocavernosus, and transversus perinei. The urogenital diaphram effects the spincture of the vaginal orifice (Weed 1972). The urogenital diaphram gets support from the fascia of the pubococcygeus. "fascia takes the form of suspending sheets and ligamentous condensations, which attach the pelvic viscera to the pelvic walls" (Wilson 1973:1154). There are sex differences in this group because of the great variability of the deep transverse perineal muscle in the female "sometimes being almost absent" (Francis 1952:97). The ischiopubic muscle is sometimes present and is considered part of this group. It originates at the pubis passing around the dorsal vein of the penis or clitoris.

There are many smooth muscle fibers that join the rectum, bladder and pubic symphysis. Two smooth muscles attach the gut to the vertebral column: the paired muscle, caudo-analis, and a single sheet, caudorectalis. The cardinal, smooth and uterosacral ligaments are composed of smooth muscle and areolar tissue that carry all the vascular and hypogastric vessels from the organs of origin and are capable of stretching to great lengths. These blend with the endopelvic fascia arising from the fasia of the levator ani muscle. The supporting ligaments function as stays to maintain the cervix in normal position. The round ligaments hypertrophy during pregnancy and contract with the laboring uterus (Mengert 1956), and in the non-laboring female support the vaginal vault.

The chief support of the normal pelvis is striated musculature. If this muscle tissue is weakened or injured then the responsibility of support falls to the fibroelastic tissue. The fibroelastic tissue can stretch and lose its elasticity by forces as small as the constant pressure of the abdominal contents. In addition, tearing and overstretching of muscle and connective tissue can cause extensive damage weakening the pelvic floor (Oxorn, 1980). As a result, the relaxation of the pelvic floor breeches the integrity of the entire pelvic girdle and contributes to pelvic instability.

CHARACTERISTICS OF THE PELVIS

After the basic anatomy of the pelvis was established, other early studies began to explore the utility of bony pelvic analysis in determining sex, race, aging, and projected obstetrical outcome (Turner 1886; Cleland 1889; Matthews and Billings 1891; Thomson 1899; Derry 1909, 1911, 1912, 1923; Williams 1911, 1922; Thoms 1915, 1936).

Sex

There is no certain method to determine the sex of an individual skeleton, but the pelvic girdle provides the most reliable clues to sex determination (Meindl et al. 1985; Krogan and Işcan 1986). When comparing accuracy for sexing the human skeleton by skull morphology versus pelvic morphology, Meindl and Lovejoy concluded that the "primary reliance should be placed on the pelvis for the determination of sex of the adult skeleton" (1985:205).

Additionally, Meindl and associates (1985) determined that pelvic assessment for sex determination is superior to other analyses of skeletal elements in terms of frequency and overall bias of error. However, they pointed out that completeness of skeletal remains decreases the bias in sexual estimation because all elements may be examined, including the skull, adding to accuracy.

In 1922, Williams described the typical characteristics of the male and female pelves. Male pelvic characteristics were described as: 1) heavy and rugged, 2) with less iliac flare, 3) the superior strait narrow, 4) descending rami of the os pubis forms an angle of less than 70°, 5) narrow outlet, 6) narrow sacrosciatic notch, and 7) oval obturator foramen. The female pelvis: 1) is lighter and thinner than that of the male, 2) exhibits more flare of the ilia, 3) has a superior strait which is elliptical and wider in all diameters than the male, 4) the descending rami of the os pubis forms an arch of 70° to 100°, 5) wide outlet, 6) wide sacrosciatic notch, and 8) triangular obturator foramen. When Gunn (1984) also described typical pelvic characteristics, the list of characteristics was not too dissimilar from the generally described characters of Williams, 62 years earlier (Table 1).

Diagnostic sexual characteristics develop at puberty because of hormonal changes (Hisaw 1925; Morton 1942; Thoms 1942a, 1942b; Gagon 1986): whereas, conflicting opinions state that sex differences are present from fetal life onward (Thomson 1899; Reynolds 1945, 1947; Krogman 1962).

One of the first to attempt skeletal sexing by standard measurements was by Matthews and Billings (1891) who demonstrated the value of the pubo-ischiatic and sacral length indices in sex determination. As Hoyme (1957) pointed out, Matthews and Billings' (1891) work should have sparked more contributions to methods of determining sex from pelvic characteristics, yet few were forthcoming. Straus (1927) expressed the opinion that, "the only reliable guide to the sex of an ilium is to know the body from which it has been taken" (p. 10). Though, according to Straus (1929), a human is the only primate whose greater sciatic notch is larger in the female.

When Washburn (1942) showed definite differences

TABLE 1

"Differences between the male and female pelvis"

(Gunn 1984:86).

	Male	Female
General shape	Narrow, deep	Wide, shallow
Bone structure	Heavy	Light
Pelvic cavity	Long, tapering downwards	Short, cylindrical
Sacrum	Narrow, long, curved	Wide, short, less curved
Pelvic inlet	Heart shaped	Circular
Ischial tuberosities	Close	Wide apart
Pubic arch	Less than 90°	More than 90°
Greater sciatic notch	Acute, narrow	90°, wide
Symphysis pubis	Limited movement	More flexible

between the two sexes of the non-human primate (similar to Schultz 1930), new interest in pelvic analyses for human sexual determination arose. Washburn (1948) cautioned that some characteristics of the pelvis may not be good sex indicators because of their high degree of variability as shown by Howells and Hotelling (1936), Young and Ince (1940) and Nicholson (1945). Hrdlička (in Stewart 1952) also suggested that sexual characteristics are highly variable and produce large ranges with a great deal of overlap between the sexes.

There are two general methods of sexing the pelvis. One method uses visual inspection of morphological differences between pelvic features (Derry 1911; Hrdlička 1939; Stewart 1954, 1968, 1979; Phenice 1969; Işcan and Derrick 1984; Krogman and Işcan 1986). Visual assessment is advantageous because, assessment can be made quickly and on fragmented osteological material.

Phenice (1969) proposed a quick and accurate visual method composed of three criteria, the ventral arc, the subpubic concavity, and the medial aspect of the ischiopubic ramus. This new method of sexing the os pubis had a high degree of reliability.

In a test of Phenice's method Lovell's (1985) results showed a sexing accuracy of about 83% compared to the 95% reported by Phenice. Even though the accuracy rate was lower, Lovell confirmed reliability and ease of application. The discrepancy may partly be a function of the fact that accuracy decreased as the individual age increased.

In 1984, visual assessment was again utilized when Işcan and Derrick proposed that a visual examination of "the posterior iliac bone and its articulation with the sacrum can be used to determine sex" (1984:98). Three structures were considered including the iliac tuberosity, postauricular sulcus and postauricular space. A high degree of accuracy was attained and the postauricular space was the most reliable of the three. Işcan and Dunlap (1983) determined that a visual examination of the perimeter and face of the posterior sacral auricular surface was also an accurate and valuable means of sexing fragmentary remains.

The second method of sex determination requires measurement of pelvic markers (Matthews and Billings 1891; Derry 1923; Straus 1927; Howells and Hotelling 1936; Washburn 1942, 1948, 1949; Krukierek 1951; Torpin 1951; Işcan 1980, 1981; Kimura 1982; Dibennardo and Taylor 1983; Schulter-Ellis and Hayek 1984). Accurate measures require the bone to be relatively complete and can be time consuming to perform when an entire collection is examined.

Davivongs (1963) examined characteristics of 100 pelves and discovered that the most reliable sex determinants were: 1) the ischium-pubis index, 2) the diameters of the acetabulum, 3) the length of the sciatic notch and, 4) the sciatic notch index.

However, Schulter-Ellis and Hayek (1985) correctly sexed 96% of a sample from the Terry Collection using a discriminant function analysis of an acetabulum/pubis index. Using this same index plus ischial height and femoral length, 36 Arikara skeletons were 91% correctly sexed, while the ratio alone classified 75% of the sample.

Miles (1986) also described a sexually diagnostic pubic index which is very accurate, useful in fragmentary bone identification, and is easy to perform. The index is "the computed ratio of the ischium-pubis ramus width to the length of the pubic body" (1986:241).

Studies testing sex differences of the sacrum had been few and mostly inconclusive when Flander (1978) proposed testing methods for sexing the sacrum (Turner 1886; Thomson 1899; Derry 1909, 1911; Trotter 1926; Fawcett 1938; Davivongs 1963). Davivongs (1963) examined characteristics of 100 pelves and found that one cannot determine sex by the sacrum alone because of the wide range for every measurement and the extensive overlap between the sexes. Then in 1982, Kimura developed a base-wing index for sexing the sacrum. Flander (1978) determined that race differences between white and black may affect sex assessment by the sacrum, suggesting that if race is known, sex is easier to determine.

Race

Race assessment is an important component of anthropological and forensic investigations (Turner 1885; Derry 1923; Todd and Lindala 1928; Todd 1929; Howells and Hotelling 1936; Torpin 1951; Krogman 1962; Stewart 1968, 1979; Işcan 1980, 1981, 1982, 1983, 1985; DiBennardo and Taylor 1983; Krogman and Işcan 1986).

Until the 1980's, race determination of skeletal remains was generally performed by analyses of cranial features (Stewart 1979; Işcan 1983; Krogman and Işcan 1986). DiBennardo and Taylor's (1983) study showed that race discrimination could be performed by a discriminant function analysis of postcranial features. The extensive investigations by Işcan (1980, 1981, 1982, 1983, 1985) and

Işcan and Cotton (1985) have determined that features of the pelvic girdle can also be used to assess race accurately.

Işcan's (1983) discriminant function analysis of Black and White articulated pelvic girdles showed the transverse pelvic breadth, biiliac breadth and the antero-posterior height to render accuracy of assignment to be as high as 88%. Advantages of Işcan's technique are: 1) determination of race on only three variables, 2) simple and readily performed, and 3) based on pelvic bones alone. It has been shown that the age of the individual affects various pelvic dimensions (Işcan 1980, 1983). Even though accuracy for determining race is reduced when controlling for age this reduction was not found to be significant (Işcan and Cotton 1985).

Age

After ten years of examining skeletons of known age Todd (1920, 1923) felt that the pubic symphyseal area could help to determine approximate age. Although Todd could not show rate of change he did propose 10 phases for age determination from pubic changes. Later, McKern and Stewart (1957) developed a new system of age determination by examining the pubis. Two major characteristics were examined, the change of the pubis and the articular face of the pubic symphysis. Following the method of McKern and Stewart (1957), Gilbert and McKern (1973) developed a method for aging the female pubis, and they noted that the development of the pubis of the female is so different from the male that age scores (McKern and Stewart 1957) should be created especially for the female (Gilbert and McKern 1973). This method became widely used for age determination in forensic anthropology (Kerley 1978; Stewart 1979). Other sexing methods are provided by Krogman (1962), Brothwell (1963), Stewart (1968, 1979), and Kerley (1978; Krogman and Işcan 1986).

Işcan (1980, 1981, 1983) determined that, as age increased the biiliac breadth and the sacral angle also increased in black females, whereas, in the white females the brim surface area and brim angle decreased. As indicated earlier, Işcan and Cotton (1985) determined that age changes did not significantly change race classification although accuracy was decreased.

Type

Obstetrical concerns regarding the shape of the pelvis and successful obstetrical outcome, prompted anatomists to consider patterning of pelvic shapes and the recognition of "pelvic type" came to be accepted (Turner 1886; Williams 1922; Derry 1923; Straus 1927; Caldwell and Moloy 1933, 1938; Caldwell et al. 1934; Greulich and Thoms 1938; Young and Ince 1940; Thoms and Greulich 1940; Torpin 1951; Arthur 1974). Francis (1952) pointed out that there is a great deal of variation in pelvic types yet they are of particular importance to obstetricians, anatomists, anthropologists and paleodemographers.

The four commonly accepted types are: 1) gynecoid type, female with a round inlet, 2) android type, male with a wedge-shaped inlet, 3) anthropoid type, long narrow oval inlet resembling anthropoid apes, 4) platypelloid type, transverse oval inlet with a long transverse diameter and a short anteroposterior (Caldwell 1933, 1938; Caldwell et al. 1934).

Thom's (1942a) classificatory system also includes four types: 1) dolichopellic or elongated type, 2) mesatipellic or round type, 3) brachypellic or oval type, and 4) platypellic or flat type.

There are many variations of pelvic types due to the multiplicity of factors contributing to pelvic form

(Francis 1952). Brinker (1985) suggested that pelvic form differs with social status. It may be that nutritional differences are reflected in the form of the pelvic inlet (Nicholson 1945; Krukierek 1951; Angel 1976; Işcan 1981). If socio-economic level and nutritional status can be equated then differences in pelvic form may indicate social status. The sample in this study was not large. Only 48 individuals were sampled, 33 male and females of high status, and 15 male and females of low status. Thus, the number of females with a high status and/or females with low status may be so small that sample error may preclude a significant statistical statement. Certainly a study of this kind with a large enough sample could contribute to the understanding of the social structure of paleopopulations (Angel 1969; Acsádi and Nemeskéri 1970; Nemeskéri 1972).

III

PARTURITION SCARRING

In The Bases of Paleodemography (1969), Angel suggested that pregnancy and childbirth left a record of the event on the bony pelvis in the form of characteristic changes and that from these changes, fecundity could be estimated. These changes have since been described as parturition scars, pits, depressions, grooves, craters, and/or cavities in the bone (Angel 1969; Stewart 1970, 1979; Houghton 1974, 1975; Ullrich 1975; Putschar 1976). Parturition scars are most often found at three locations of the pelvic girdle: 1) the dorsal pubis near the pubic symphysis, 2) the preauricular sulcus, 3) the interosseous groove (Kelley 1979) also known as the postauricular sulcus (Işcan and Dunlap 1983; Işcan and Derrick 1984), and sometimes at a forth location 4) the sacrum (see Figures 1, 4, 9a-14b). A review and critque of research pertaining to parturition scarring is presented from the historical perspective in the remainder of this chapter.

Putschar (1931)

From autopsy material, Putschar (1931) described pelvic articulations with special attention to possible effects of pregnancy and parturition. He observed changes to the connective tissue, soft tissue surrounding the joints, and in bone adjacent to these joints. At that time he suggested that perhaps the changes were because of 1) function, 2) age, and/or 3) pregnancy and childbirth. Putschar concluded that the cleft in the pubic symphysis of multiparae, nulliparae and males were the same, and that loss of ligamentous structure occurs only in multiparae, and that fatty degeneration and calcium deposits in the ligaments are changes due to pregnancy.

Wiltse and Frantz (1956)

Wiltse and Frantz (1956) described a condition they called non-suppurative and non-inflammatory osteitis pubis in the female. They reported a remarkable similarity to the generally male condition known as periostitis, osteochondritis, osteomyelitis, symphyseal osteoarthropathy, and most often osteitis pubis. In females, characteristics of this condition include spotty demineralization of bone a few centimeters laterally from the symphysis, widening of the symphyseal gap, and gradual development of sclerosis and narrowing. In males, characteristics of osteitis pubis include resorptive bone changes in the anterior portion of the pelvic girdle usually limited to the pubis, and low grade osteoperiostitis. Symptoms in both male and female were 1) discomfort in the area of the pubic symphysis, 2) painful and difficult walking, 3) usually no fever, 4) spotty resorption of pubic bones, 5) lifting and fraying of the periosteum at attachment sites, and 6) self-limiting in time period. Of the 13 women described, symptoms occurred during pregnancy for five, two months after delivery for five others, after pelvic surgery for one, and after an injury for two. Thus, 77% of the women had symptoms possibly related to pregnancy or parturition and 23% did not. The authors believed that the female cases they described and the male disease known as osteitis pubis are, "variants of the same disease and that both originate from the same basic cause" (Wiltse and Frantz 1956:512). The basic cause was attributed to trauma to the pubis of both male and female. Sources of trauma were 1) trauma from motion because of walking with relaxed ligaments during pregnancy, 2) trauma of birth, 3) trauma as a result of injury from pelvic surgery, and 4) trauma from some known injury other than surgery. Wiltse and Frantz also suggested that when "predisposing changes" (1956:515) were present the trauma was more likely to produce this condition. "Predisposing changes" refers to the presence of hormones similar to those found during pregnancy although which hormones might be involved was not specificaly stated.

Boland (1933)

It was pointed out by Boland (1933) that trauma to the pelvis always occurs from parturition. Trauma includes 1) tears parallel to the bony ends, 2) calcium deposits in the ligaments, and 3) sometimes the formation of cystic structures. Boland suggested that because of these changes the normally rigid pelvic girdle becomes more mobile at the sacro-iliac joint which can be stressed on one or both sides. In addition, while studying age changes of the pubis, Stewart (1957) found that dorsal pubic changes in females were confounding age estimations and suggested that perhaps childbearing was the confounding factor.

Boland (1933), Wiltse and Frantz (1956), and Putschar (1931) had all indicated that pregnancy and parturition produced changes in the pelvic girdle yet their work was relatively unnoticed until Angel (1969) proposed that pits or scars on the dorsal pubis were the result of pregnancy and childbearing. Thus, the generally proposed mechanism for scar and pit formation is that hormonal secretions such as progesterone, prolactin, estrogen and/or relaxin cause swelling and relaxation of the ligaments of the pelvic joints during pregnancy. Subsequently, childbirthing stresses the softened and relaxed tissue causing tears and small hemorrhages at attachment sites. After tearing and hemorrhaging tiny cysts and knots of fibrocartilages follow the insult to the soft tissue. Angel suggested that "a clear cut development of these changes occurs after more than three births" (1969:432).

Stewart (1970)

Stewart (1970) cautioned, that because Angel determined that pubic pits or cavities were evidence of childbearing from a sample containing perhaps as few as four females of known parity, that parity interpretations in forensic sciences and paleodemography should be tentative. He stated that accuracy in determining parity from the bony pelvis would best be achieved by study of an adequate series of autopsied pelves with documentation of parity.

At the same time that Stewart (1970) was cautioning that parturition scars were tentative evidence for parity determination, Angel's proposition was already being accepted. Acsádi and Nemeskéri (1970) developed a five stage classification of pregnancy and childbirth changes at the dorsal pubis. Nemeskéri (1972) modified the five stage plan of Acsádi and Nemeskéri two years later.

After studying Eskimo, Black, and White pelves from the Terry Collection (parity unknown) Stewart (1970) reported that pits or cavities on the dorsal pubis were extremely rare in young adult males and not uncommon in females. He classified the amount of scarring on the dorsal pubis into three categories 1) absent, 2) trace to small, and 3) medium to large. It was found that "only about half of the female sample for each race shows any scars of this sort, and that quite likely not more than 17% show unmistakable scars" (Stewart 1970:131). He concluded that 1) Eskimo females show more scarring than modern White and Black females, 2) some women have children with minimal or no scarring, 3) only medium to large scars seem to indicate parturition, and 4) that it will probably be impossible to determine the number of complete pregnancies by degree of scarring.

Gilbert and McKern (1973)

Gilbert and McKern (1973) examined 140 pelves of known parity and agreed with Stewart (1970). They stated that because of the numerous variables such as size of fetus, pelvic size, pelvic shape, and obstetrical practices, "it does not presently seem possible to determine the number of pregnancies an individual has experienced simply by noting the degree of damage done to the os pubis" (Gilbert and McKern 1973:37).

Houghton (1974, 1975)

In 1974, Houghton discussed the relationship of the preauricular groove to pregnancy. He determined that two forms of the preauricular groove can be defined. The GP form is a groove composed of a series of pits coalescenced together with an uneven floor and wavy margins, and the GL form is commonly a short, narrow, straight-edged and shallow groove with a flat even floor. The series of pelves studied had no known parturition records. The results of this study showed 81% of the males had grooves and all were GL. Ninety-two percent of the females had grooves and of these 71% were GP and 21% were GL. Houghton dismissed the groove as a racial characteristic based on his own study and those of Derry (1909, 1911) and Davivongs (1963). While GL occurred in both sexes only GP was associated with dorsal pubic changes which he assumed to be "changes of pregnancy" (1974:382), citing Angel (1969) and Stewart (1957, 1970). He concluded that "GL is the normal imprint of a strong ligament on bone in both the male and female pelvis" (Houghton 1974:383), that GP is the result of pregnancy and labor and is the mark of a female who has borne one child, and that changes of pregnancy are expected to be more marked at the preauricular sulcus than at the dorsal pubis. Houghton assumed these changes to be marks of pregnancy from the work of Angel (1969) and Stewart (1957, 1970). Stewart (1970) cautioned that "scars of parturition" as the explanation of dorsal pubic changes was a tentative explanation only, due to lack of adequate data on parity. In Houghton's series information on parity is again missing. Thus, to state that "the pelvis must be of a female who has borne at least one child" (1974:383) is perhaps premature.

One year later Houghton (1975) stated that "pregnancy does leave an imprint on the bones of the pelvis and that this imprint is clear, easily recognised, and rarely equivocal" (1975:655). Evidence of pregnancy includes pits on the dorsal pubic bone and a, "modification of the preauricular groove of the ilium" (1975:655). Additionally, erosion of bone may occur where the interosseous ligament attaches to the ilium. However, Houghton felt that the preauricular sulcus is first in importance as evidence of childbirth due to the continued transfer of weight at the sacroiliac joint even while the ligaments are relaxed during parturition. He indicated that the relaxation of the ligaments permits the joints of the pelvic girdle to open and the sacrum to rotate. He pointed out that active resorption of bone occurs adjacent to the hypertrophied and relaxed ligaments as did Boland in 1933. At delivery the ligaments are stretched and sometimes fibers may rupture (Putschar 1931). Repair and replacement of bone follows, and thus, the pits become shallower with age. Houghton found that contemporary western women have less scarring than those of prehistoric or developing populations, probably citing Stewart's (1957, 1970) series of pelves. Houghtons statement that determination of parturition is "rarely equivocal" (1975:655) and the "only conclusive evidence of sex" (1975:655) cannot be documented by the data available at this time.

Ullrich (1975)

Ullrich (1975) accepted the premise that fertility can be ascertained by examining parturition scarring and recounted two successful investigations in such determinations. Failing to note the cautionary statements by Stewart (1970) and Gilbert and McKern (1973), Ullrich stated that Angel had "determined the fertility of several prehistoric populations of Greece" (1975:24). Also based on Putschar (1931), Stewart (1957), and Angel (1969), Gejvall (1970) showed that a Mesolithic skeleton was indeed female and had had many children. Ullrich examined skeletal materal from the late Slavic cemetery of Sanzkow including 63 pubes, 70 ilia, and 49 sacra from 77 individuals. A few individuals were juvenile out of the 39 males and 38 females. Using a five stage analysis (Acsádi and Nemeskéri 1970; Nemeskéri 1972), Ullrich (1975) determined that 1) "childbirth alterations at the pubis, the ilium, and the sacrum can be diagnosed with adequate certainty" (1975:34), 2) the dorsal pubis and the ilium produced the most reliable information, thus changes in these two areas were considered most important, 3) these changes provide reliable sexing criteria, and 4) the different stages of alterations should correspond to the number of childbirths. The estimation of fertility of the Sanzkow material is mainly based on the assumptions and conclusions of Angel (1969), Putschar (1931), Stewart (1957), Acsádi and Nemeskéri (1970), Nemeskéri (1972), and Houghton (1974). Because the Sanzkow material has no known parity data it could not be used to test assumptions regarding parity determination. Unsurprisingly, Ullrich's (1975) results reinforce the assumptions and conclusions on which the study was based.

Ashworth and associates (1976)

Ashworth et al. (1976) reported on "the pubic scars of gestation and parturition in a group of Pre-Columbian and Colonial Peruvian mummies". Ashworth and associates visually examined the os pubis of the Peruvian mummies and used evidence for scars of parturition (Angel 1969) and osteitis pubis (Wiltse and Frantz 1956) as evidence of fertility. They recognized the similarities between Angel's and Wiltse and Frantz's description of pubic changes and stated that pubic scars of parturition are one of a number of disorders of the pubic symphysis and bone commonly called osteitis pubis. They determined that this form of osteitis is valuable as a diagnostic tool when determining probable parturition.

There were 35 mummified adults from the colonial period of which 33 were female and 2 male. Of the females, 57.6% showed scarring and 42.4% had none. The two males exhibited no evidence of scarring. There were 30 Pre-columbian mummies, of which 18 were female and 12 male. Scarring was shown on 72.3% of the Pre-columbian females whereas, the males had none. The colonial group experienced the poorest environmental conditions of the two; yet, the Pre-columbian female exhibited the highest frequency of scarring. However, the sample size of the Pre-columbian group was rather small. No explanation was made for the high frequency of scarring in Pre-columbian Peruvian females compared to the colonial Peruvians, Eskimos, Blacks, and Whites (Stewart 1957, 1970).

Putschar (1976)

In 1976, Putschar published a review article based on his earlier histological research on pelvic joints in 198 cases (1931). It was not stated whether parity data were available for this series. The symphyseal cleft, osteocartilaginous border, retropubic eminence, pregnancy changes, age changes and arthritic changes were discussed. He concluded that effacement of ridges and degenerative "arthritic changes are more continuously time related in the male than in the female" (p. 594). He also noted that because of upright bipedalism both sexes showed age related degenerative changes, and due to mechanical trauma in parturition, females generally appear older than males of the same age.

Holt (1978)

Holt (1978) was the first investigator to attempt to systematically test the validity of parturition scarring on the dorsal pubis or as he said "birth scarring" (p. 92). The 68 female pelves were from the Hamann-Todd Collection. All of the pelves examined had a statement of parity determined at autopsy, such as "definitely has had children", "definitely has not had children", "definitely has had one child", "probably has had children", and "probably has not had children". Holt concluded that scarring occurred in a number of females who had never given birth, and a number of females who had had children did not exhibit scarring. In addition, no differences in scarring could be found between scarred pelves of nulliparous and multiparous females. Therefore, scarring may occur for a number of reasons and pelvic scarring is not the unique marker of parturition. He suggested that, "one should use extreme caution when using the presence of 'birth scarring' as a forensic or paleopathological indicator or for demographic studies (p. 94).

Suchey and associates (1979)

Suchey et al. (1979) were the first investigators to examine a large sample (N=486) of pubes, (not entire pelvic girdles) from contemporary autopsied females of known age (range of 13 to 99 years) and parity. Data on parturition, and number and spacing of children had been obtained from relatives and/or friends. Analyses of dorsal pits on the pubes were based on Stewart's (1970) three stage system. Ullrich's (1975) six stage system was considered but not used because "the observed data do not fall into these classes" (p. 518). Suchey and co-workers investigated the relationship between dorsal pitting and, the number of full term pregnancies, the interval since last pregnancy, and the age of decedent. The results showed that the number of full term pregnancies and dorsal pitting were associated though the relationship is weak. "Females who had their last child 15 or more years prior to death are more apt to have 'medium to large' dorsal changes than are females who have more recently given birth" (p. 517). Finally, age is an important variable because pits in nulliparous females are more frequently found over 30 years. It was concluded that the number of pregnancies could not be inferred from the size of the dorsal pits. However, age is an important variable because there appears to be an increase in scarring over time. This contradicts the conclusion suggested by Stewart (1970). Also, morphology of dorsal pubic changes is extremely variable and negates a rigid system of classification. Suchey et al. suggested that further research may reveal factors other than pregnancy and childbirth to be responsible for dorsal pubic changes.

Kelley (1979)

In the same year, Kelley (1979) examined a sample of 198 Black and White female pelves with known parity from the Hmann-Todd collection in order to determine degree of reliability in parturition assessment. Changes on the dorsal pubis were recorded according to Stewart's (1970) three descriptive categories and the preauricular region as well as the interosseous groove were described according to Houghton (1974). After preliminary analysis dorsal pubic lipping was found to occur indiscriminately indicating age-progressive changes (Putschar 1976), and sacral pitting proved to be too rare (12 out of 198 cases) to be of utility, therefore were not included in further analyses. Three features were found to be significantly related to parturition dorsal pubic pitting, preauricular groove, and the interosseous groove. Results showed that there were no significant differences between Black and White females. Dorsal pubic pitting was not commonly found among either nulliparous or parous females, yet women experiencing parturition had a high percentage of presence (20.9%). The presence of a developed preauricular groove in parous women (43.9%) "was still unexpectedly high in nulliparous females (20.6%)" (Kelley 1979:543). Kelley reported that neither the interosseous groove, the preauricular groove, nor the dorsal pubis alone could determine parity status. This finding supports the work of Stewart (1970), Gilbert and McKern (1973), Holt (1978), and Suchey et al. (1979). Kelley then examined the three traits in combination to see if patterning developed. From this study Kelley concluded that pits or grooves in two or more of the three features increased the reliability of parity assessment. The preauricular groove is the most reliable indicator of the three "but is occasionally well-developed in nulliparous women" (p. 546). In addition, aging tends to obscure marks of parturition supporting Stewart's (1970) suggestion that as age increases, scarring decreases. Finally, it is impossible to correctly categorize "parturition" or "no parturition" in all females. If a positive statement of parity cannot be made, then an inference regarding number of pregnancies and/or number of children born to an individual also cannot be made.

Owsley and Bradtmiller (1983)

In Owsley and Bradtmiller's (1983) study of female mortality in Arikara villages cautiously determined trauma associated with parity by analysis of parturition scars and Schmorl's nodes. Schmorl's nodes ("erosion of the bodies of the vertebrae due to pressure" (Gunn 1984:127) were considered by the authors as the most tentative indicator of parturition. But the possibility exists that the increased lumbar lordosis and the thoracic kyphosis in the pregnant female (Wallace and Wilk 1979) may predispose the vertrebral bodies to form Schmorl's nodes. Owsley and Bradtmiller felt that whereas one feature alone was insufficent, the presence of both parity pits and Schmorl's nodes may indicate a prior pregnancy or that the pregnancy in progress was stressful. This supposition may support the deduction that adult males lived longer in this population than females due to the mortality associated with pregnancy and parturition.

Spring and associates (1984)

Spring et al. (1984) studied 70 radiographs of the preauricular sulcus of females with known parity. They were specifically testing for the deep, scooped contour of the sulcus which has been proposed to indicate parturition (Houghton 1974, 1975). Twenty-seven percent were nulliparous, 73% had been pregnant at least once. Additionally, six films were from before and after pregnancy. Deep radiographic preauricular grooves were present in 6.3% of those who had been pregnant at least once and 11.8% of the nulliparous females. No difference could be demonstrated in the sulcus between six pre- and post-pregnancy. They concluded that "the presence of a deep radiographic preauricular sulcus does not appear to be associated with a history of past pregnancy" (Spring et.al. 1984:221).

Tague (1985)

In 1985, Tague studied bone resorption (pitting) at the pubis and preauricular area by testing the hypothesis that dorsal pubic pitting and preauricular pitting are related to fertility. The sample population was collected from three Amerindian skeletal populations Indian Knoll, Libben, and Pecos Pueblo. Statistical analysis indicated that dorsal pubic pits were associated with fertility but not with age. Results also suggest that severity of pits at the dorsal pubis and the preauricular groove are independent. Unfortunately, Tague chose archaeological material of inferred sex and age with no known parity data to test the hypothesis that pits at the pubis and preauricular area are the result of childbearing. The sample population seems to be inappropriate for proving his hypothesis.

Summation

Despite the studies which suggest caution or question the validity of the assumption that scarring in the pelvic girdle is the result of parturition (Stewart 1970; Gilbert and McKern 1973; Holt 1978; Suchey et al. 1979; Spring et al. 1984) the assumption that pelvic girdle pitting is evidence for pregnancy and childbearing is still accepted by investigators in anthropological, archaeological, forensic, paleopathological, and paleodemographical investigations (Angel 1969; Acsádi and Nemeskéri 1970; Gejvall 1970; Nemeskéri 1972; Houghton 1974, 1975; Ullrich 1975; Ashworth et al. 1976; Kelley 1979; Owsley and Bradtmiller 1983; Tague 1985).

The above literature review indicates that only four studies have ever addressed the topic of parturition scarring with a population sample of known parity (Holt 1978; Suchey et al. 1979; Kelley 1979; Spring et al. 1984). Holt and Suchey et al. both examined the dorsal pubic region only. Holt could not demonstrate that dorsal pubic scarring is a positive indicator of fertility yet did not provide an alternative etiology. Suchey et al. concluded that number of pregnancies could not be inferred from the size of dorsal pits and claimed..."that there are factors other than pregnancy which produce alterations in the dorsal region of the os pubis" (Suchey et al. 1979:522).

Spring et al. (1984) examined the preauricular sulcus radiographically and could not find any relationship between the preauricular sulcus groove and parity.

Kelley (1979) demonstrated a relationship between pelvic scars and parturition. No one feature was diagnostic; an assessment of the entire pelvic girdle gave the highest degree of reliability. Yet even when considering the pelvic girdle as a whole he added that it was "not possible to correctly label all females within the broad categories of 'no parturition' and 'parturition'" (Kelley 1979:546).

Purpose of the present research

The present research is designed to examine stress of the bony pelvis in females due to childbirth. Because the architecture of the pelvic girdle provides the possibilities and limitations to the mechanics of reproduction, the biomechanics of the pelvic girdle during childbirth were reviewed.

Male and female pelves are observed macroscopically for comparison and markers of parturition are examined on female skeletons of known parity. The data are used in order to increase the understanding of the biomechanics of the pelvic girdle, in particular, the bony limits set by architectural design regarding movement of the girdle and its consequences. These data are also used to test the hypothesis that differential fertility can be determined by analysis of the scars of parturition. If the hypothesis is accepted then a "model of parity" will be devised to provide a framework for analysis. If the hypothesis is rejected an alternative explanation for scars of parturition will be proposed.

IV

METHODS AND MATERIALS

THE SAMPLE

The skeletal material used in this research is from the Hamann-Todd Collection which resides in the Cleveland Museum of Natural History, Cleveland, Ohio. The Hamann-Todd osteological material, collected between 1912 and 1930 and originally housed at the Western Reserve Medical School contains 3300 individuals, of which, over 400 are adult females (Cobb 1959).

Cleveland in 1912 was a "melting pot" city with a growing industrialized community augmented by immigrants from abroad (Cobb 1959). The deceased individuals given to the collection were unclaimed by family or friends and were probably indigent or of lower socioeconomic class. This does not automatically denote poor nutrition but low nutritional status is likely. Dr. T. W. Todd saw the desirability of complete documentation for each of the unclaimed deceased in the anatomical laboratory. Thus, each skeleton is accompanied by a complete file containing information such as name, sex, parity, age, race, birthplace, nationality, occupation, cause of death, somatological observations and 86 anthropometric measurements, photographs and any special notations about that particular individual.

In addition to the complete soft tissue analyses performed at the dissection, T. W. Todd, W. M. Cobb, and associates utilized all accompanying hospital and/or autopsy records available in the assignment of parity. The assignment of parity was stated as "certainly has (or has not) had children," "probably has (or not had) had children," or "no data". Information pertaining to presence of a hymen, caesarean section scars, perineal tears or scars, cervical scars, state of the fourchette and uterus, nipple appearance and presence or absence of abdominal striations were noted and supported the assignment of parity. Examples of parity assessment and assignment from the Hamann-Todd Osteological Collection records are given in Appendix 1. The biologically determined "definite" categories are probably as reliable, as self-report of parity by a living mother before death. The descriptions are also as reliable as a report of parity by relatives or friends of a deceased female who for a number of reasons may not know of past pregnancies or deliveries (Suchey et al. 1979). From this skeletal collection there is no way to discover the total number of children borne by an individual female. There are no known human skeletal collections with complete pelvic girdles, which document the number of children borne by an individual. At the present time the Hamann-Todd Osteological Collection has the most complete parity information on pelvic material (Cobb 1933; Işcan 1985).

Sample size consists of 238 individuals chosen from the Hamann-Todd Collection record section. Forty-three Black and 44 White males were randomly selected for a total of 87 males. Females were not randomly selected from the records as were the males, because only females with a recorded parity notation were chosen and, of those, a preference was shown for women between the childbearing ages of 18 and 50 years. Seventy-four Black and 77 White females for a total of 151 females were sampled. Of the total number of females, 95 were between the preferred ages of 18 and 50 years.

DATA COLLECTION

Of the original 238 sampled individuals, 12 could not be tested due to absence of one or more bony parts of the pelvic girdle. Thus, only 226 individuals were available for analysis. Forms in Appendix 2A - 2J are used for data collection. A total of 85 males which included 43 Black and 42 White males were tested. Seventy-four Black females and 67 white females with known parity were tested for a total of 141 females. The parity distribution consisted of:

41 definitely had child/children,
45 definitely did not have child/children,
25 probably had child/children,
30 probably did not have child/children.

All 226 individuals, male and female, were examined and measured using the same techniques. Each pelvis was examined for marks on and about the joints of both the left and right sides of the sacroiliac region. The most extensive pubic symphyseal markings noted were used for the pubic joint analysis. All measurements were performed with the same sliding and spreading calipers made by Tesa and a GPM Gneupel osteometric board. Sixty individuals were randomly selected and remeasured in order to check for observer error.

Background information on each individual collected included catalogue number, sex, age, height, weight, cause of death, parity status, racial category, and description of autopsy observations regarding determination of parity and/or lesions. The data form illustrated in Appendix 2A is used for this purpose.

Dorsal pubic changes were recorded using Stewart's (1970) three descriptive categories 1) absent, 2) trace to small, and 3) medium to large, including the location of such marks. According to Kelley (1979), trace to small is either shallow, poorly demarcated depressions or are small pits not exceeding two millimeters in diameter. Suchey et al. (1979) suggested that in reality these marks form a continuum and that no rigid system is adequate. However, at this time no other model exists with which to replace Stewart's system. Computer notation for the dorsal pubis begins with the letters DPUB. As shown in Appendix 2B sketches were made of each dorsal pubis examined and lesions were noted.

The preauricular groove of the left and right ilium was examined and measured. Computer notation for the preauricular groove area begins with the letters PAG. The size of the groove was noted on a scale of one (small) to five (large). The description of the preauricular sulcus consisted of five categories (Houghton 1974; Kelley 1979)

1) broad-shallow = absent to poorly demarcated, broad and shallow,
2) narrow shallow = short straight-edged and shallow, flat even floor,
3) developed = one or more deeper and well demarcated pits in the preauricular region,
4) scooped-wavy = elongated pits joined as though bone scooped out with wavy margins,
5) extended = extension of groove superiorly on the anterior surface of the adjacent surface of the ilium.

A notation was made recording the appearance of the groove as GP or GL (Houghton 1974). GP is defined as a groove formed by coalescence of a series of pits, uneven floor and wavy margins. GL is defined as a narrow, short straight-edged and shallow, flat even floor sometimes resembling scratches. The depth (at the deepest point) and the length were measured in millimeters. Three sketches were made showing different views and and all conditions were noted using the forms in Appendix 2C and 2D.

The interosseous groove (Kelley 1979) or postauricular sulcus (Işcan and Derrick 1984) of both right and left ilia were examined and measured. Computer notation for the interosseous groove begins with the letters IG. Descriptions of this area were:

0) none,

1) shallow, poorly marked,

2) shallow defined = shallow straight-edged even floor,

3) developed = deeper well defined platform,

4) developed-pitted = developed with one or more pits in sulcus,

5) irregular = irregular floor and/or margins,

6) projecting = projecting dorsal margin.

The depth (at the deepest point) and the length were measured in millimeters with a sliding caliper. All conditions were noted and sketches were made of the groove (Appendix 2E,F,G).

The thickness of the left and right iliac tuberosities and accessory articular surfaces (Trotter 1937, 1967) were measured by spreading calipers. Computer notation for the iliac tuberosity and accessory articulation begins with the letters IT. Tuberosity size was noted on a continuum from one (small) to four (large). Tuberosity shape (Işcan and Derrick 1984) was described as 0) absent, 1) fossa, 2) mound, 3) pointed mound, 4) crest. Accessory size was noted as: zero (absent) to five (extra large). Accessory articulation shape was noted by the same criteria as tuberosity shape. Two sketches were made and abnormalities were noted (Appendix 2E,F,G,H).

The sacroiliac joint is classified as a synovial joint but in fact only the lower portion, the auricular articular surface, has synovial fluid. Weisl (1954) has been the only investigator to attempt to quantitatively describe the auricular articular surface. Weisl devised a method to construct a contour map and obtain average lengths and widths of the sacral auricular surface in order to study movement of the sacro-iliac joint. Weisl's mapping and measurement techniques are given in Appendix 3A. Thus, a new simpler triangulation technique has been devised to determine minimum surface area of the articular auricular surface of the ilium (Figure 6, Appendix 3B).

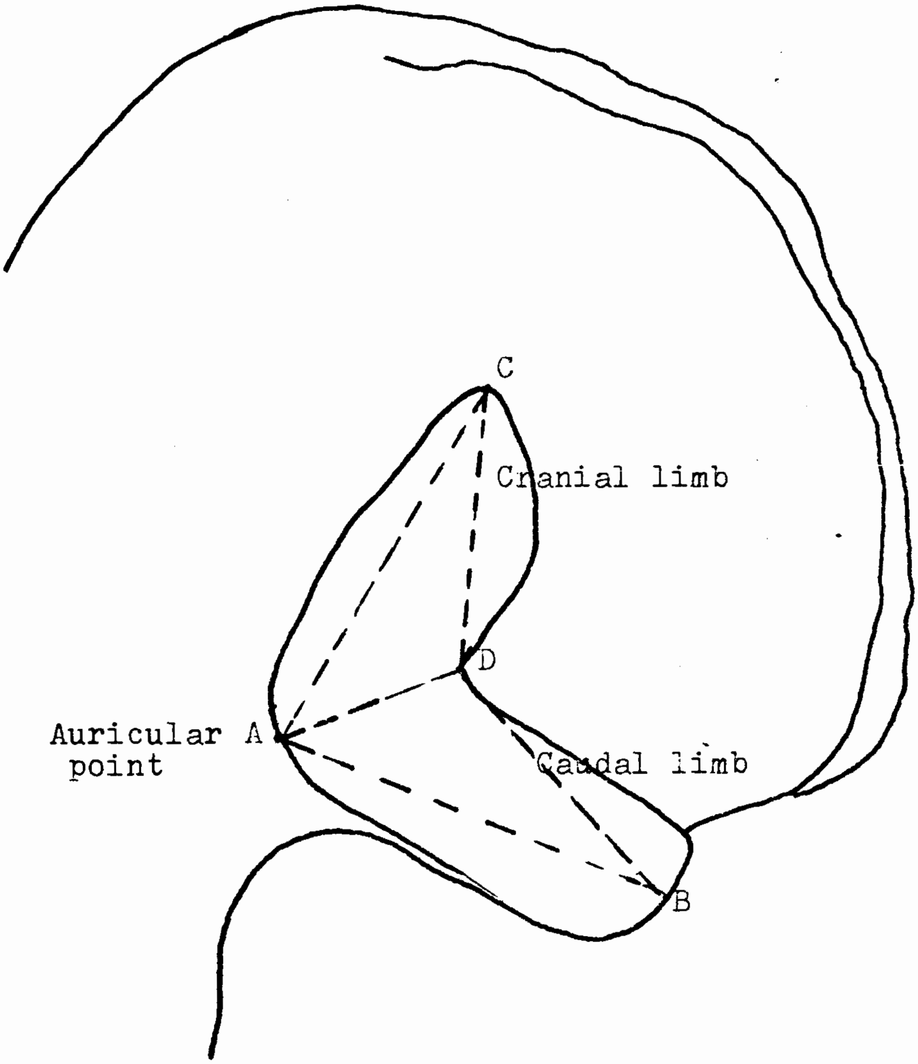


Figure 6 POSTERIOR AURICULAR SURFACE
POINTS A,B,C,D (see Appendix 3B)

The measurements were taken with a sliding caliper in millimeters. Computer notation for the articular area begins with the letters PAS. The articular surface was divided into two sections (Derry 1923; Weisl 1954), the caudal limb and the cranial limb (Figure 6). Points A,B,C,D, were determined after Weisl (1954). The method of determination is demonstrated in Appendix 3A. Line AD, from the auricular point to the deepest concavity of the dorsal border forms the base of each of the two triangles within the surface. Lines AD, AC, and CD are joined to form the cranial triangle. Lines AD, AB, and BD join to form the caudal triangle. The area of a triangle can be calculated, knowing three sides, with Heron's formula (Selby 1973) as shown in Figure 7. All sides of each triangle were measured in millimeters and the area calculated. The area of the cranial and caudal triangles were then added to give a total minimum area of the auricular articular surface.

It is readily apparent that a good deal of the area information is lost when measured by the straight sides of a triangle. Thus, it was important to test the accuracy of the triangulation technique and to determine approximately

HERON'S FORMULA

$S = \underline{A + B + C}$ = semiperimeter

$$\text{Area} = \sqrt{S\ (S-A)\ (S-B)\ (S-C)}$$

(Selby 1973).

FIGURE 7

how much information is lost on average.

The test sample consisted of 33 iliac auricular surfaces from the National Heritage Osteological Collection which reside in the Provincial Museum of British Columbia, Victoria, Canada. The pelves examined were dated circa 2000 B.P.

A cast of each surface was made using Jeltrate and Unijel-II impression material. Dental impression material provided a fine grain medium for excellent reproduction. The caudal and cranial limbs were noted on the cast at the time of casting. Two reference points were measured 30 mm apart, and were marked in ink on the dried casts. The marked casts were placed in a Goodkin and projected at 3.115 F top dial and 1 F bottom dial. The enlarged surface margins and reference points were then traced onto flat plastic sheets. Both reference points, as well as the upper right and lower left direction were identified by the computer. Then, the outer margin of each surface was traced and surface area accurately calculated to within a thousandth of a millimeter. This provided an accurate estimate of the surface to which the results of the new simple triangulation technique could be compared.

Each of the 33 test sample surfaces were then remeasured using the triangulation technique. Finally, the areas of each surface determined by computer and triangulation were compared to estimate the average difference in area. Table 2 shows the test sample results for differences produced by technique. The results show a mean difference of 345 mm squared between the surface areas, representing a mean loss of information. Approximately 40-45% additional surface area is unrepresented by the triangulation method, thus data derived by these separate techniques are not comparable unless the triangulation error is accounted for in the analysis.

A visual description of the left and right auricular surface was noted as well defined edges like a platform, or not well defined, and a smooth surface, or a rough surface. Abnormalities were noted and comments recorded (Appendix 2I,J).

The sacrum was measured with a sliding caliper for maximum height, maximum breadth, sacral index calculated, number of segments, curvature of sacrum and where curvature begins (from Stewart 1952:166). Additionally, maximum sacral angle depth was measured perpendicularly along a

TABLE 2

AREA METHOD TEST

N =33	Computer Area	Triangulation Area
Mean	791.861	446.687
Variance	47250.594	15817.137
Range	890.300	485.500
Standard Error	37.840	21.893
Standard Deviation	217.372	125.766

Mean Difference 345.174

straight line extending from the sacral promontory to the fifth sacral segment. Computer notation for sacral measurements begins with the letter S. Comments and all conditions were noted (Appendix 2K).

The last set of measurements in this study was performed on semi - or fully articulated pelvic girdles to aid in determining the limitations allowed by bony restriction or flexibility. These measurements are used to establish baseline measurements for the articulated pelvic girdle. Next, each articulation is expanded to its bony limits and remeasured in order to determine the functional limits set by the bone as suggested by Işcan (1985). Although the pelvic girdle would never be expanded to its bony limit in life, Bock and Wahlert (1965) point out that much can be learned from studying the functional limits of an anatomical feature in this way. Computer notation for the articulated measurements begins with the letters AM.

The anteroposterior diameter of the pelvic outlet and sacral angle expansion were both measured semi-articulated. Holding the sacrum and the left ilium articulated in one hand, measurements were made with a sliding caliper by the other hand as shown in Figure 8.

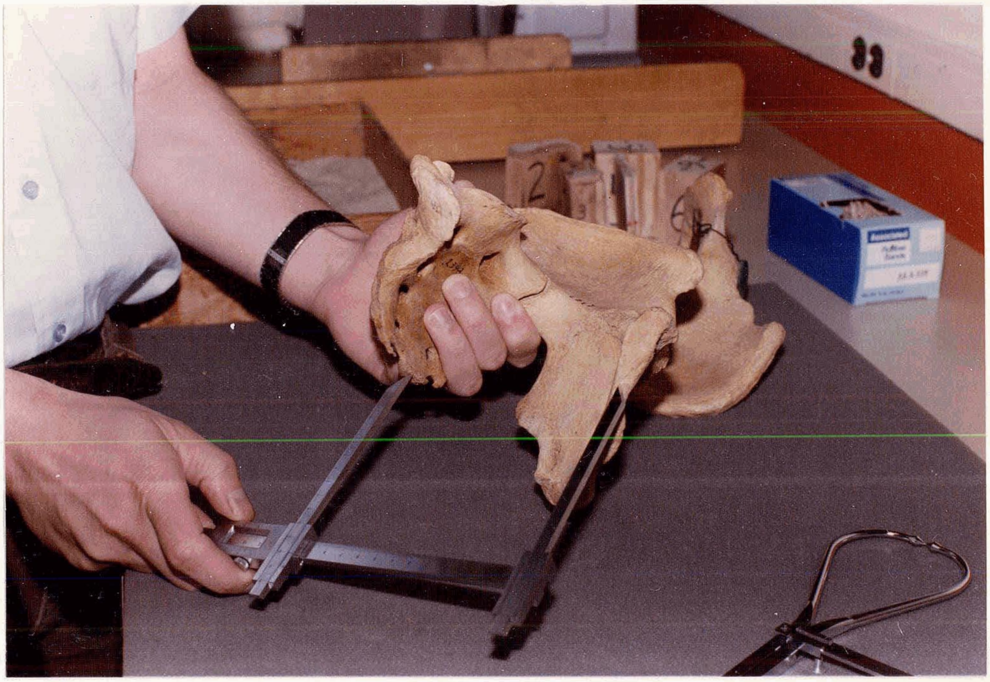


FIGURE 8 Semi-articulated Pelvic Girdle

The anteroposterior diameter of the outlet is measured from the end of the fifth sacral segment to the lower border of the symphysis pubis in millimeters. The expanded anteroposterior diameter is obtained by gradually rotating the articulated sacrum against the auricular surface of the ilium, as far as the bone will permit: then, the outlet is remeasured. This provides an anteroposterior diameter baseline measurement and an expanded sacral articulation measurement. The difference between the baseline measurement and the rotated measurement reflect the maximum sacral rotation allowed by the bony architecture.

For sacral angle expansion (from the fifth sacral segment to the pubic crest), the sacrum and ilium are held and measured anatomically and maximally rotated in the same manner as the anteroposterior diameter of the outlet. The difference here reflects the maximum increase in expansion of the sacral angle.

All fully articulated pelves were articulated with rubber bands and a small 0.5mm rubber spacer between the pubic bones as devised by Howells and Hotelling (1936) and demonstrated in Figure 9.

The biiliac breadth (maximum distance between iliac

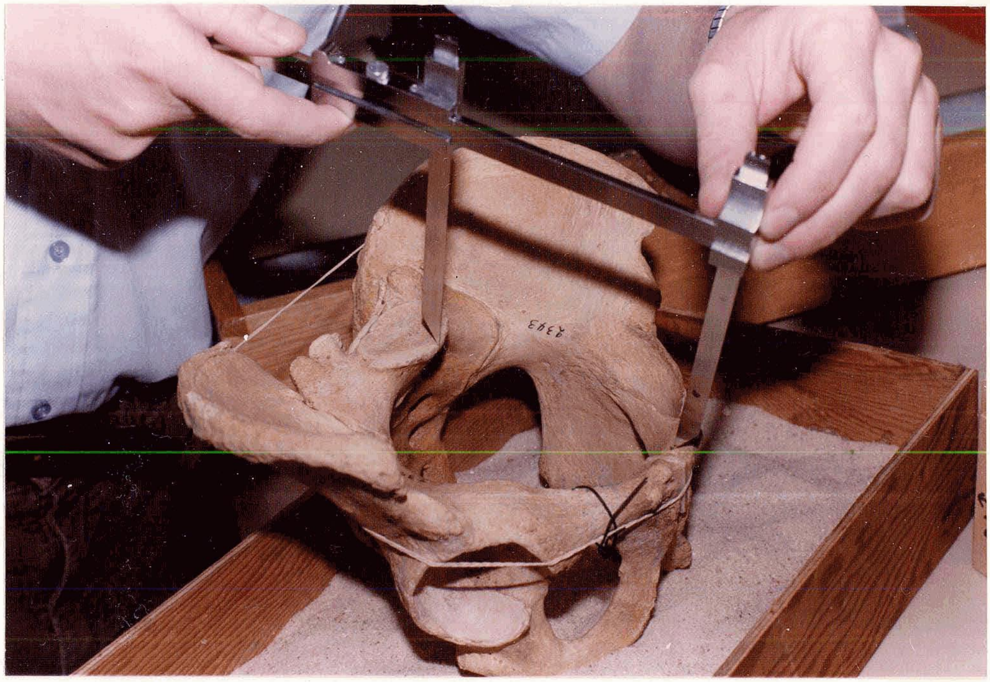


FIGURE 9 Articulated Pelvic Girdle

crests) of each articulated pelvic girdle was measured on an osteometric board. All other articulated pelvic girdle measurements: 1) distance between ischial spines, 2) anteroposterior diameter/height of the inlet (sacral promontory to pubic crest), 3) transverse diameter of the inlet (distance between arcuate lines), and 4) the distance between ischial tuberosities, were measured by sliding caliper. A sand box was used to support the articulated pelvic girdle when both hands were needed for measurement (Figure 9).

Distance between ischial spines, anteroposterior diameter/height of the inlet, and the transverse diameter of the inlet were all remeasured after the pelvic girdle was maximally expanded as shown in Figures 10, 11a,b.

In order to provide expansion replicability seven wooden spacers were constructed. Each spacer is one centimeter larger than the last beginning with a one to a seven centimeter wide spacer.

The pelvic girdle was then opened at the pubis as far as possible, maintaining the sacroiliac articulations with both hands. The symphysis was swung apart until bony restriction by the sacroiliac region stopped further

FIGURE 10 Spacer Insertation

FIGURE 11a Transverse Diameter of the Inlet,
Expanded Measure.

FIGURE 11b Expanded measurement of the Distance between Ischial Spines.

expansion. The largest spacer possible (1-7cm) was then fitted into the symphyseal opening and the expanded girdle was carefully nestled into the sandbox for measuring the expanded girdle (Figures 10, 11a,b). Great care is used to maintain a normal angle of articulation at the sacroiliac joint when positioning the pelvic girdle into the sand.

After all measurements of the sample population were complete, the articulated measurements of sixty pelvic girdles randomly selected from the sample group were remeasured to test for observer error.

The maximum width of the pubic spacer and comments denoting the portion of the sacro-iliac articulation that limited rotation and/or expansion were noted. Notation was also made of all conditions present as shown in Appendix 2L.

ANALYSIS

The objective of this study is to investigate the relationship among pelvic variables including markers of parturition, biomechanics of the pelvic girdle, limits of pelvic movement and sexual and parity variables. Initially the sample, pelvic feature form and type, baseline measurements, and expansion variables were described by descriptive statistics from the Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975).

Frequency tables were constructed for dorsal pubic scarring (after Holt 1978; Suchey et al. 1979), preauricular groove form (after Houghton 1974, 1975), and combined parturition traits (after Kelley 1979).

The relationship between pairs of variables including markers of parturition such as dorsal pubic scarring, preauricular groove scarring, and interosseous groove scarring to variables such as parity, race, sex and age were initially examined by contingency chi square analysis, using the CROSSTABS program from SPSS (Nie et al. 1975).

In order to analyze the significance of pitting when it occurred in more than one are of an individual pelvis, an index of total scarring was constructed, (hereafter referred to as SCARDEX). Scardex was constructed so that combination scarring of the left (scardexl) or right (scardexr) side could be analyzed separately if desired. Appendix 4A shows how scardex was constructed.

For further analysis descriptive statistics such as the mean, standard deviation, and variance of the dependent variable for the entire population and for each subgroup of the population, were generated by the SPSS program BREAKDOWN (Nie et al. 1975). BREAKDOWN described the central tendencies of variables by breaking down complex classifications and then measured the relationship between independent variables. For instance, the mean sacral rotation is compared with the means of subgroups such as White females, in the 18-35 years age group, and definitely no children. Chi square and contingency coefficient statistics were produced by the use of the CROSSBREAK facility, a subroutine of the BREAKDOWN program. The subprogram BREAKDOWN also provides a one-way analysis of variance and a test of linearity.

For analysis of variance and covariance the program ANOVA (Nie et al. 1975) was used. Because there may be simultaneous effects of sex and movement (expansion factors) ANOVA analysis was used. Using ANOVA, the amount of explanation per variable is shown and a significance factor produced (Nie et al. 1975).

In an attempt to model the relationship between variables by way of a suitable equation, a multiple regression, was performed using SPSS (Kim and Kohout 1975).

Ten or fifteen years ago it was widely assumed that parametric statistics were inappropriate for dichotomous and ordinal data (Cohen 1968; Bohrnstedt and Carter 1971; Knoke 1975). Since that time, it has been shown that, when a variable "is measured at least at the ordinal level, parametric statistics not only can be, but should be, applied" (Bohrnstedt and Carter 1971:132). The objective of this step-wise linear regression analysis is to ascertain the relative contribution of individual variables (some of which are dichotomous variables) to the interval-ratio dependent variable, SCARDEX. Knoke (1975) compared log-linear and regression models for systems of dichotomous variables. He found that log-linear models were advantageous on logical grounds, however emperical examples showed that substantive differences were small. Knoke determined that results from log-linear and regression models were "likely to be identical" (p. 432) if the dependent dichotomy's range is between 0.25 to 0.75. Also, Borhrnstedt and Carter (1971) tested the regression model's underlying assumptions by systematically violating them and determined that the regression model is robust. Because all dichotomous variables in this study fall in the range from 0.25 to 0.75, and because the regression model is so robust, a regression analysis is appropriate for this study.

Regression analysis assumes that the underlying relationships among the variables are linear and additive.

> "In simple regression analysis, values of the dependent variable are predicted from a linear function of the form Y' = A+BX. Where Y' is the estimated value of the dependent variable X are multiplied, and A is a constant which is added to each case. The difference between the actual and the estimated value of Y for each case is called the residual, i.e., the error in prediction, and may be represented by the expression Residuals = Y-Y'. The regression strategy involves the selection of A and B in such a way that the sum of the squared residuals is smaller than any possible alternative values. Expressed in another way, (Y-Y') = minimum" (Kim and Kohout 1975:323).

A step-wise linear regression was chosen because the confounding factors (one variable's influence upon another) can be statistically controlled in order to evaluate the contribution of a specific variable. In the step-wise regression formula the next best predictor is sequentially selected at each step. The objective is to minimize R, the residual variation. In the step-wise procedure only the optimal set of variables is chosen, because not every possible subset is considered. The sequence in which variables are selected is not necessarily identical to their relative importance as indicators (Kim and Kohout 1975). A good predictor variable may be removed late, because it correlated highly with a variable removed early in the analysis. Another measurement which by itself is not a good predictor, may reside high on the list because it greatly enhances the predicting power of other measurements due to its relationship with them.

V

RESULTS

FREQUENCY ANALYSIS OF DORSAL PUBIC SCARRING

Frequency tables were constructed (after Holt 1978:92), in order to see the effects of sex and parity on dorsal pubic scarring. Frequency tables showing the incidence of dorsal pubic scarring are given in Tables 3a,b,c. Table 3a presents the breakdown of dorsal pubic scarring frequencies of females with known parity by age and amount of scarring. Of the women who had never given birth, 51.3% showed dorsal pubic changes. Of the 51.3% scarred pubes, 42% showed trace to small pits and 57.9% showed medium to large pits. Of the women who had given birth, 43.3% showed no evidence of dorsal pubic scarring. A slight decrease in scarring appears to occur over 60 years of age. Table 3b examined the frequencies of women with definite and probable parity assignment by age and amount of scarring. The sample population was broken down into separate categories of definitely no children, definitely had children, probably no children and probably had children. The women who had

TABLE 3a

BREAKDOWN OF DORSAL PUBIC SCARRING FREQUENCIES OF FEMALES WITH KNOWN PARITY BY AGE AND AMOUNT OF SCARRING

		NO PARTURITION			YES PARTURITION		
AGE	NO.	ABSENT	TRACE SMALL	MEDIUM LARGE	ABSENT	TRACE SMALL	MEDIUM LARGE
18-29	22	7	5	0	7	2	1
30-39	35	7	6	5	8	5	4
40-49	30	7	1	4	6	5	7
50-59	22	4	0	7	4	2	5
60-69	17	5	3	3	1	0	5
70-93	15	6	1	3	3	2	0
TOTAL	141	36	16	22	29	16	22
		(48.7%)	(21.6%)	(29.7%)	(43.3%)	(23.9%)	(32.8%)

TABLE 3b
BREAKDOWN OF DORSAL PUBIC SCARRING FREQUENCIES OF FEMALES WITH DEFINITE AND PROBABLE PARITY ASSIGNMENT BY AGE AND AMOUNT OF SCARRING

		DEFINITELY NO			DEFINITELY YES		
AGE	NO.	ABSENT	TRACE SMALL	MEDIUM LARGE	ABSENT	TRACE SMALL	MEDIUM LARGE
18-29	22	7	5	0	7	2	1
30-39	35	7	6	5	8	5	4
40-49	30	7	1	4	6	5	7
50-59	22	4	0	7	4	2	5
60-69	17	5	3	3	1	0	5
70-93	15	6	1	3	3	2	0
TOTAL	141	36	16	22	29	16	22
		(48.7%)	(21.6%)	(29.7%)	(43.3%)	(23.9%)	(32.8%)

		PROBABLY NO			PROBABLY YES		
AGE	NO.	ABSENT	TRACE SMALL	MEDIUM LARGE	ABSENT	TRACE SMALL	MEDIUM LARGE
18-29	7	2	1	0	3	0	1
30-39	7	1	1	1	2	1	1
40-49	13	4	0	2	3	2	2
50-59	10	2	0	3	2	1	2
60-69	12	4	1	3	1	0	3
70-93	11	3	1	3	2	2	0
TOTAL	60	16	4	12	13	6	9
		(50.0%)	(12.5%)	(37.5%)	(46.4%)	(21.4%)	(32.2%)

TABLE 3c

BREAKDOWN OF DORSAL PUBIC SCARRING FREQUENCIES OF MALES BY AGE AND AMOUNT OF SCARRING

AGE		ABSENT	TRACE/SMALL	MEDIUM/LARGE
18-29		4	-	-
30-39		17	-	-
40-49		22	-	-
50-59		19	-	-
60-69		18	-	-
70-93		3	2	-
TOTAL	N=85	83	2	0
		(97.6%)	(2.4%)	(0.0%)

definitely never had children showed dorsal pubic scarring 52.4% of the time (28.6% trace to small, 23.8% medium to large), while those who had definitely had children were not significantly different with 59% dorsal pubic scarring (25.6% trace to small, 33.3% medium to large). The probable categories were as would be expected, similar to the definite with dorsal pubic scarring absent 50.0% (probably no) and 46.4% (probably yes) of the total. Frequencies of pubic scarring did not seem to significantly decrease with age.

Males showed an extremely different pattern with 97.6% showing no dorsal pubic changes (Table 3c). Two individuals (2.4%) aged 80 and 83 years old did have a trace and a definate pit, respectively (Figure 12). Age may account for the two men with dorsal pubic scarring.

FREQUENCY ANALYSIS OF PREAURICULAR GROOVE FORM

Frequency tables were constructed (according to Houghton 1974:382) in order to see the effects of preauricular groove forms. Form frequency tables are presented in Tables 4a,b,c,d. Houghton (1974) defines the GP groove as, a groove composed of a series of pits

FIGURE 12 An 83 year old White male with a definite pit on the dorsal pubis

TABLE 4a

BREAKDOWN OF MALE AND FEMALE PREAURICULAR GROOVE FORM FREQUENCIES

	NONE	GL	GP	BOTH
MALE N=85	19 (22.3%)	48 (56.5%)	1 (1.2%)	17 (20.0%)
FEMALE N=141	8 (5.7%)	7 (4.9%)	106 (75.2%)	20 (14.2%)
TOTAL PELVES N=226	27 (11.9%)	55 (24.3%)	107 (47.4%)	37 (16.4%)

TABLE 4b

BREAKDOWN OF PREAURICULAR GROOVE FORM FREQUENCIES OF FEMALES WITH KNOWN PARITY

FEMALE	NONE	GL	GP	BOTH
HAD CHILDREN	4	1	51	12
N=68	(5.9%)	(2.5%)	(75.0%)	(17.6%)
NO CHILDREN	4	6	55	8
N=73	(5.5%)	(8.2%)	(75.3%)	(11.0%)
TOTAL PELVES	8	7	106	20
N=141	(5.7%)	(4.9%)	(75.2%)	(14.2%)

TABLE 4c

BREAKDOWN OF PREAURICULAR GROOVE FORM FREQUENCIES OF FEMALES WITH DEINITE AND PROBABLE PARITY ASSIGNMENT

FEMALE SPECIFIC PARITY	NONE	GL	GP	BOTH
DEFINITELY HAD CHILDREN N=44	1 (2.3%)	1 (2.3%)	33 (75.0%)	9 (20.4%)
DEFINITELY NO CHILDREN N=45	3 (6.7%)	4 (8.9%)	33 (73.3%)	5 (11.1%)
PROBABLY HAD CHILDREN N=24	3 (12.5%)	0 (0)	18 (75.0%)	3 (12.5%)
PROBABLY NO CHILDREN N=28	1 (3.6%)	2 (7.1%)	22 (78.6%)	3 (10.7%)
TOTAL PELVES N=141	8 (5.7%)	7 (4.9%)	106 (75.2%)	20 (14.2%)

TABLE 4d

BREAKDOWN OF BLACK AND WHITE, MALE AND FEMALE, PREAURICULAR GROOVE FORM FREQUENCIES

RACE FEMALE	NONE	GL	GP	BOTH
BLACK N=74	4 (5.4%)	2 (2.7%)	59 (79.7%)	9 (12.2%)
WHITE N=67	4 (6.0%)	5 (7.5%)	47 (70.1%)	11 (16.4%)
TOTAL PELVES N=141	8 (5.7%)	7 (4.9%)	106 (75.2%)	20 (14.2%)

RACE MALE	NONE	GL	GP	BOTH
BLACK N=43	11 (25.6%)	20 (46.5%)	1 (2.3%)	11 (25.6%)
WHITE N=42	8 (19.0%)	28 (67.0%)	0 (0)	6 (14.3%)
TOTAL PELVES N=85	19 (22.3%)	48 (56.6%)	1 (1.2%)	17 (20.0%)

coalescenced together with an uneven floor and wavy margins (characteristically female). The GL groove is commonly a short, narrow, straight-edged and shallow groove with a flat even floor (characteristically male). Table 4a presents a breakdown of male and female preauricular groove form frequencies. Most of the 226 individuals examined had both sides present and sometimes variation was found between sides. If one side was categorized as form "GP" and the other side "GL" the pelvic girdle was classified as both. Of the 85 males examined 22.3% had no grooves, 56.5% had GL grooves, 1.2% had GP grooves and 20.0% shared GL and GP form. Frequency results from the 141 females sampled showed 5.7% had no grooves, 4.9% had GL grooves, 75.2% had GP grooves and 14.2% shared GL and GP form.

Table 4b presents the frequencies of females with known parity. The percentage of females with GP form were remarkably close (75.0%) with children and (75,3%) without children. The frequencies for females with children were 5.9% none, 1.5% GL, and 17.6% both. For women without children the frequencies were 5.5% none, 8.2% GL, and 11% both.

In order to better understand the effects of parity, the breakdown of form frequencies of females with definite and probable parity is shown in Table 4c. All four categories of parity showed very similar frequencies for the GP form: definitely yes (75%), definitely no (73.3%), probably yes (75%), probably no (78.6%). All four female categories shared forms GP/GL in a range from 10,7% to 20.4%. Women in all categories had low frequencies of no grooves at all and the GL form.

FREQUENCY ANALYSIS OF SCARRING COMBINATIONS

Frequency tables were constructed (after Kelley 1979:544) in order to see the effects of pitting in different combinations on the pelvic girdle. Frequency table analysis of pitting in combination at the dorsal pubis, preauricular groove and the interosseous groove is listed in Tables 5a,b,c. Table 5a presents all possible combinations of pitting and scarring when the dorsal pubis, preauricular groove and the interosseous groove are utilized on females with known parity. Ninty-three percent of all females in this study exhibited some evidence of pelvic scarring, and only seven percent has none. Kelley (1979) suggests that females that are represented "above

TABLE 5a

FREQUENCIES OF ALL COMBINATION OF SCAR PRESENCE IN ALL THREE PELVIC AREAS EXAMINED ON FEMALES WITH KNOWN PARITY.

	Parturition		
	No	Yes	Total
3 absent	4	5	9
2 absent, 1 trace	1	2	3
2 absent, 1 present	16	9	25
2 trace, 1 absent	1	1	2
1 absent, 1 trace, 1 present	14	14	28
3 trace	0	0	0
2 trace, 1 present	2	0	2
2 present, 1 absent	14	13	27
2 present, 1 trace	10	11	21
3 present	7	10	17
Total	69	65	134

TABLE 5b

FREQUENCIES OF ALL COMBINATION OF SCAR PRESENCE IN ALL THREE PELVIC AREAS EXAMINED ONLY ON FEMALES WITH DEFINITE PARITY ASSESSMENT

	Parturition		
	No	Yes	Total
3 absent	4	3	7
2 absent, 1 trace	0	2	2
2 absent, 1 present	11	5	16
2 trace, 1 absent	0	0	0
1 absent, 1 trace, 1 present	8	10	18
3 trace	0	0	0
2 trace, 1 present	1	0	1
2 present, 1 absent	9	8	17
2 present, 1 trace	6	5	11
3 present	3	5	8
Total	42	38	80

TABLE 5c

FREQUENCIES OF ALL COMBINATIONS OF SCAR PRESENCE IN ALL THREE PELVIC AREAS EXAMINED ON MALES

	Total
3 absent	53
2 absent, 1 trace	11
2 absent, 1 present	14
2 trace, 1 absent	0
1 absent, 1 trace, 1 present	1
3 trace	0
2 trace, 1 present	0
2 present, 1 absent	2
2 present, 1 trace	0
3 present	0
Total	81

the upper line" indicate the nulliparous female. Although, 31.9% of the nulliparous females fall above the upper line (set by Kelley 1979), 26.2% of the multiparous females also fall above the upper line. 52.3% of the multiparous females have clustered below the lower line generally thought to indicate a multiparous female. However 44.9% of the nulliparous females also fall below this line. In Table 5b ony definite parity assessment is considered. Results are similar: 35.7% nulliparous females above the line, 26.3% multiparous above the line, 42.9% nulliparous below the line, and 47.4% multiparous females below the line.

Male pelves were examined for the same three trait combinations. The results from Table 5c show that 35% of all males showed some evidence of pelvic scarring whereas, 65% did not. Only 2.5% or two individuals fall below the line, and 96.3% fall above the line.

AURICULAR ARTICULAR DESCRIPTIVE STATISTICS

The auricular articular surface area was calculated by triangulation. The mean surface area in mm squared for a male left side is 1006.56, right side is 1027.83 (Table

TABLE 5d

AURICULAR ARTICULAR SURFACE AREA

T-TEST STATISTIC

N=226		1	2	3	4	5	6
		A B	A B	A B	A B	A B	A B
		45-93	117-109	146-40	85-141	28-46	42-40
CAUDAL	X	1.05	1.38	23.50	2.30	50.32	28.70
LIMB LT.	Y	0.832	0.094	0.001	0.001	0.001	0.001
			*	***	***	***	***
CRANIAL	X	1.04	1.38	83.49	2.37	30.59	51.91
LIMB LT.	Y	0.855	0.092	0.001	0.001	0.001	0.001
			*	***	***	***	***
CAUDAL	X	34.27	1.84	30.90	1.57	52.08	1.04
LIMB RT.	Y	0.001	0.001	0.001	0.018	0.001	0.896
		***	***	***	**	***	
CRANIAL	X	67.07	1.81	48.07	1.59	76.67	1.05
LIMB RT.	Y	0.001	0.002	0.001	0.016	0.001	0.884
		***	***	***	**	***	
LEFT	X	1.05	1.38	65.38	2.36	88.02	100.90
AREA	Y	0.830	0.091	0.001	0.001	0.001	0.001
			*	***	***	***	***
RIGHT	X	101.95	1.83	60.82	1.58	103.71	1.04
AREA	Y	0.001	0.001	0.001	0.016	0.001	0.897
		***	***	***	**	***	

X = F VALUE

Y = 2 TAIL PROBABILITY WITHIN GROUPS

*	P<.10
**	P<.05
***	P<.01

KEY

A AND B = BETWEEN GROUPS

1 = AGE

A = 18-35
B = 36-50

2 = RACE

A = BLACK
B = WHITE

3 = PREAURICULAR PITTING

A = NO
B = YES

4 = SEX

A = MALE
B = FEMALE

5 = PUBIC PITTING

A = NO
B = YES

6 = PARITY

A = NO
B = YES

5d). Mean surface area in mm squared for a female left is 730.52, the right is 789.85. For a complete breakdown and description see Appendix 5A,B,C. The caudal limb is significantly larger than the cranial ($p<.0001$) as shown in (Appendix 5A).

The right auricular surface is generally somewhat larger than the left though not significantly. Table 8a shows the F value for within and between group variation. Table 2 shows the test sample results for differences produced by technique. The results show a mean difference of 345.175 between the surface area, representing a mean loss of information. Approximately 40-45% additional surface area is unrepresented by the triangulation method.

CONTINGENCY TABLE ANALYSIS

In order to better understand the relationships between pairs of variables, Contingency table analyses are presented in Tables 6-10.

Contingency table analysis of dorsal pubic variables are presented in Table 6. Dorsal pubic scarring is not significantly associated with parity, race or age. Sex and the maximum amount of allowed expansion at the pubis are

TABLE 6

CONTINGENCY TABLE RESULTS (X2)
PARTURITION VARIABLES

		1	2	3	4	5	6	7
EXPANSION	a	24.481	25.494	24.559	35.473	41.953	52.827	
	b	.0001	.0001	.0001	.0001	.0001	.0001	
	c	2	4	4	8	8	14	
PARITY	a	0.454	0.398	1.677	0.475	1.644	5.119	0.330
	b	.5001	.8192	.4322	.9242	.8008	.5286	.8476
	c	1	2	2	3	4	6	2
RACE	a	0.052	0.053	3.734	1.274	1.694	7.687	2.154
	b	.8183	.9735	.1546	.8658	.7917	.3609	.3405
	c	1	2	2	4	4	7	2
SEX	a	54.947	73.709	62.818	103.362	98.058	110.480	77.798
	b	.0001	.0001	.0001	.0001	.0001	.0001	.0001
	c	1	2	2	4	4	7	2
AGE	a	2.282	8.380	10.425	13.922	13.792	20.744	15.551
	b	.5158	.2116	.1076	.3057	.3142	.4746	.0164
	c	3	6	6	12	12	21	6
DORSAL PUB	a							24.481
	b							.0001
	c							2

KEY

1. DORSAL PUBIC SCARRING
2. PREAURICULAR GROOVE PITS LEFT
3. PREAURICULAR GROOVE PITS RIGHT
4. SCAR INDEX LEFT
5. SCAR INDEX RIGHT
6. SCAR INDEX
7. PUBIC EXPANSION

a = Chi Square
b = Significance
c = d.f.

significantly associated with dorsal pubic scarring significant at (p<.0001).

Contingency table analysis of preauricular groove variables are presented in Table 6 and 7a,b. Table 6 shows that left and right preauricular groove pits are not significantly associated with parity, race or age, while sex and the amount of dorsal pubic expansion are highly significantly associated (p<.0001). Dorsal pubic expansion (ampubx) and age have been categorized into ordinal data. Four classes of age and four classes of maximum expansion at the dorsal pubis. Expansion and sex continue to be highly significantly associated (p<.0001) when all characteristics of the preauricular groove are examined on Table 7a,b. Because preauricular scarring was used in calculating the scar index "scardex", pit and scar variables such as the scarring and pitting variables 7,8,12 and 13 are significantly associated with scardex left and right (p<.0001). Scarring on the dorsal pubis is highly significantly associated with all the preauricular groove variables except when the groove is broad and shallow, and the type of groove (or form) on the right side. Age is only significantly associated with the right side type of

TABLE 7a
CONTINGENCY TABLE RESULTS (X2)
PREAURICULAR GROOVE VARIABLES

		1	2	3	4	5	6	7
EXPANSION	a	26.620	28.534	41.983	50.058	25.592	16.568	5.402
	b	.0030	.0015	.0001	.0001	.0001	.0003	.0671
	c	10	10	4	4	2	2	2
PARITY	a	6.847	4.616	0.992	1.765	1.804	1.463	0.454
	b	.2322	.4644	.6087	.4137	.1792	.2263	.5001
	c	5	5	2	2	1	1	1
RACE	a	10.397	13.427	0.062	6.575	0.545	0.373	0.048
	b	.0647	.0197	.9690	.0373	.4603	.5413	.8249
	c	5	5	2	2	1	1	1
SEX	a	59.706	52.534	97.017	112.040	4.141	66.476	33.299
	b	.0001	.0001	.0001	.0001	.0418	.0001	.0001
	c	5	5	2	2	1	1	1
AGE	a	16.827	21.557	6.264	8.403	2.175	1.568	8.552
	b	.3293	.1199	.3942	.2100	.5368	.6666	.0359
	c	15	15	6	6	3	3	3
DORSAL PUB	a	30.172	30.916	20.311	40.378	0.067	5.420	7.372
	b	.0001	.0001	.0001	.0001	.7950	.0199	.0066
	c	5	5	2	2	1	1	1
SCARDEXL	a			63.592	63.251	7.202	38.648	81.181
	b			.0001	.0001	.1256	.0001	.0001
	c			6	6	4	4	4
SCARDEXR	a			50.387	92.697	4.117	27.174	46.991
	b			.0001	.0001	.3903	.0001	.0001
	c			8	8	4	4	4
SCARDEX	a			71.057	89.052	10.863	43.092	77.410
	b			.0001	.0001	.1447	.0001	.0001
	c			12	12	7	7	7

KEY

1. SIZE OF GROOVE LEFT
2. SIZE OF GROOVE RIGHT
3. TYPE OF GROOVE (GL, GP) LEFT
4. TYPE OF GROOVE (GL, GP) RIGHT
5. BROAD SHALLOW GROOVE LEFT
6. NARROW SHALLOW GROOVE LEFT
7. DEVELOPED PITTED LEFT

a = Chi Square
b = Significance
c = d.f.

TABLE 7b
CONTINGENCY TABLE RESULTS (X2)
PREAURICULAR GROOVE VARIABLES

		8	9	10	11	12	13
EXPANSION	a	14.855	8.135	10.818	40.215	9.114	14.605
	b	.0006	.0171	.0045	.0001	.0105	.0007
	c	2	2	2	2	2	2
PARITY	a	0.014	0.0	2.885	0.0	1.220	0.0
	b	.9034	1.0000	.0894	1.0000	.2693	1.0000
	c	1	1	1	1	1	1
RACE	a	0.0	0.514	1.381	5.940	0.548	0.0
	b	1.0000	.4730	.2399	.0148	.4589	1.0000
	c	1	1	1	1	1	1
SEX	a	23.747	8.660	9.193	91.756	22.744	32.833
	b	.0001	.0033	.0024	.0001	.0001	.0001
	c	1	1	1	1	1	1
AGE	a	1.853	5.694	3.047	5.808	8.764	0.289
	b	.6033	.1275	.3844	.1213	.0326	.9620
	c	3	3	3	3	3	3
DORSAL PUB	a	14.926	9.563	0.955	23.768	9.466	22.381
	b	.0001	.0020	.3283	.0001	.0021	.0001
	c	1	1	1	1	1	1
SCARDEXL	a	62.115	13.358	2.396	39.504	34.095	58.454
	b	.0001	.0097	.6633	.0001	.0001	.0001
	c	4	4	4	4	4	4
SCARDEXR	a	27.506	15.396	7.549	76.279	87.223	77.353
	b	.0001	.0039	.1096	.0001	.0001	.0001
	c	4	4	4	4	4	4
SCARDEX	a	54.792	16.378	5.844	64.528	75.506	80.250
	b	.0001	.0219	.5580	.0001	.0001	.0001
	c	7	7	7	7	7	7

KEY

8. JOINED PITTED GROOVE LEFT
9. EXTENDED LEFT
10. BROAD SHALLOW GROOVE RIGHT
11. NARROW SHALLOW GROOVE RIGHT
12. DEVELOPED, PITTED GROOVE RIGHT
13. JOINED, PITTED GROOVE RIGHT

a = Chi Square
b = Significance
c = d.f.

groove ($p<.0001$) and with the pitted left side ($p<.05$). The type of groove (GL,GP) on the right side is highly significantly associated with pubic expansion ($p<.0001$), age, ($p<.0001$), scardex ($p<.0001$) left and right and parity ($p<.0001$). Sex is also associated at the $p<.03$ level with preauricular groove type/form.

Contingency table analysis of interosseous groove variables is presented in Table 8. Because scars in the interosseous groove were used in SCARDEX construction, scardex left and right are significantly associated with the interosseous groove variables. Parity is not associated with the pitting variables but are related to a shallow groove left ($p<.002$) and shallow groove right ($p<.012$). Race is only associated with pitting in the left auricular groove ($p<.09$) and to no other variables. Sex is significantly associated with pitting in the left groove ($p <.01$) and the right groove ($p<.0012$). Age is significantly associated with a shallow groove left ($p<.079$) and right ($p <.022$), and with pits on the right side ($p<.052$).

SCAR INDEX

Scardex was constructed in order to examine the effects

TABLE 8
CONTINGENCY TABLE RESULTS (X2)
INTEROSSEOUS GROOVE VARIABLES

		1	2	3	4	5	6	7
EXPANSION	a	7.475	1.300	0.240	8.170	3.773	3.013	0.404
	b	.1128	.5220	.8869	.0168	.4375	.2217	.8171
	c	4	2	2	2	4	2	2
PARITY	a	0.156	0.146	0.954	0.472	0.401	0.161	2.106
	b	.9246	.7016	.3286	.4917	.8183	.6875	.1466
	c	2	1	1	1	2	1	1
RACE	a	1.554	2.793	0.304	1.599	0.482	1.856	1.061
	b	.4598	.0946	.5808	.2059	.7855	.1731	.3029
	c	2	1	1	1	2	1	1
SEX	a	24.187	21.192	0.760	4.118	25.855	31.085	1.650
	b	.0001	.0001	.3833	.0424	.0001	.0001	.1989
	c	2	2	1	1	2	2	1
AGE	a	4.740	4.989	3.111	3.004	1.203	7.700	1.724
	b	.5774	.1726	.3748	.3909	.9767	.0526	.6316
	c	6	3	3	3	6	3	3
DORSAL PUB	a	11.983	4.026	0.997	3.246	8.712	3.674	2.668
	b	.0025	.0448	.3178	.0716	.0128	.0553	.1023
	c	2	1	1	1	2	1	1
SCARDEXL	a	30.805	66.107	5.848	9.067	18.718	27.269	8.212
	b	.0002	.0001	.2108	.0594	.0164	.0001	.0841
	c	8	4	4	4	8	4	4
SCARDEXR	a	29.924	22.846	10.044	9.959	26.421	69.512	6.557
	b	.0002	.0001	.0397	.0411	.0009	.0001	.1612
	c	8	4	4	4	8	4	4
SCARDEX	a	37.650	63.225	14.533	16.610	31.887	66.472	16.974
	b	.0006	.0001	.0425	.0201	.0042	.0001	.0176
	c	14	7	7	7	14	7	7

KEY

1. SHALLOW LEFT GROOVE
2. DEVELOPED, PITTED GROOVE LEFT
3. IRREGULAR, TRACE LEFT
4. PROJECTING LEFT
5. SHALLOW RIGHT GROOVE
6. DEVELOPED, PITTED GROOVE RIGHT
7. IRREGULAR, TRACE RIGHT

a = Chi Square
b = Significance
c = d.f.

or relationships of the total combination of scarring in these three areas of the pelvis. Contingency table results show that scardex at the dorsal pubis is significantly associated with sex ($p<.0001$) and pubic expansion ($p<.0001$) (Table 6). Scardex at the preauricular groove is still significantly associated with all the preauricular variables that are also associated with sex and expansion as shown in Table 7a and 7b. The relationship between the interosseous groove variables shows that scardex is significantly associated with all the variables (Table 8).

ARTICULAR AURICULAR SURFACE AND AREA ANALYSIS

Contingency table analysis of the auricular articular surface is presented in Table 9. Whether or not there was a platform surface was significantly associated with pubic expansion ($p<.0001$), sex ($p<.0001$), dorsal pubic pitting ($p<.0008$), and scardex ($p<.0001$) left and right. Sex ($p<.012$) and pubic expansion ($p<.0023$) were also significantly associated with how smooth or rough the surface. There is a trend for anomalies to be associated with age ($p<.099$) and pubic expansion ($p<.052$).

A contingency table summary of pelvic scarring is

TABLE 9
CONTINGENCY TABLE RESULTS (X2)
ARTICULAR AURICULAR SURFACE VARIABLES

		1	2	3	4	5	6
EXPANSION	a	31.872	16.568	33.242	16.600	4.101	5.882
	b	.0001	.0003	.0001	.0023	.1287	.0528
	c	4	2	4	4	2	2
PARITY	a	1.011	0.392	1.354	1.363	0.004	0.009
	b	.3146	.5312	.5080	.5060	.9462	.9236
	c	1	1	2	2	1	1
RACE	a	0.014	0.253	1.696	1.816	0.325	0.116
	b	.9058	.6144	.4281	.4033	.5682	.7323
	c	1	1	2	2	1	1
SEX	a	38.685	8.908	56.342	8.710	0.211	0.599
	b	.0001	.0028	.0001	.0128	.6457	.4386
	c	1	1	2	2	1	1
AGE	a	8.166	4.701	8.307	5.402	14.704	6.252
	b	.0427	.1950	.2164	.4933	.0021	.0999
	c	3	3	6	6	3	3
DORSAL PUB	a	16.776	1.213	16.687	3.806	3.473	0.0
	b	.0008	.7498	.0002	.1491	.0623	1.0000
	c	3	3	2	2	1	1
SCARDEXL	a	20.083	7.251	34.438	21.018	6.772	0.878
	b	.0005	.1232	.0001	.0071	.1484	.9277
	c	4	4	8	8	4	4
SCARDEXR	a	31.380	2.981	39.063	13.472	6.191	1.587
	b	.0001	.5610	.0001	.0966	.1853	.8110
	c	4	4	8	8	4	4
SCARDEX	a	27.955	8.742	46.520	27.771	5.754	3.874
	b	.0002	.2717	.0001	.0153	.5687	.7941
	c	7	7	14	14	7	7

KEY

1. PLATFORM SURFACE LEFT
2. SMOOTH/ROUGH LEFT
3. PLATFORM SURFACE RIGHT
4. SMOOTH/ROUGH RIGHT
5. PATHOLOGIES LEFT
6. PATHOLOGIES RIGHT

a = Chi Square
b = Significance
c = d.f.

presented in Table 10. Dorsal pubic pitting, preauricular groove pitting and interosseous groove pitting are all significantly associated with sex and dorsal pubic expansion. Dorsal pubic pitting is significantly associated with pitting in the preauricular and interosseous grooves.

EXPANSION ANALYSIS

Movement or expansion variables were examined by ANOVA in order to test discrete and continuous variables at the same time. With the six expansion variables, scardex and parity were tested by ANOVA (Tables 11a,b). In all six expansion variables parity contributes very little to the amount explained. No scardex by total parity statistics were found to be significant. When parity was broken down to only definte parity assignment, only pubis expansion was significant (p<.059) (Tables 12a,b). When scardex and sex were tested with the expansion variables, sex significantly contributed to the explanations (Tables 13a,b). Pubis expansion (p<.0001), inlet expansion (p<.031), and transverse expansion (p<.0001) were significant. Outlet expansion was also significant at (p<.003). Sacral

TABLE 10

CONTINGENCY TABLE RESULTS (X2)
SUMMARY
PARTURITION VARIABLES

		1	2	3	4	5	6
EXPANSION	a	24.481	25.494	24.559	1.300	3.013	52.827
	b	.0001	.0001	.0001	.5220	.2217	.0001
	c	2	4	4	2	2	14
PARITY	a	0.454	0.398	1.677	0.146	0.161	5.119
	b	.5001	.8192	.4322	.7016	.6875	.5286
	c	1	2	2	1	1	6
RACE	a	0.052	0.053	3.734	2.793	1.856	7.687
	b	.8183	.9735	.1546	.0946	.1731	.3609
	c	1	2	2	1	1	7
SEX	a	54.947	73.709	62.818	21.192	31.085	110.480
	b	.0001	.0001	.0001	.0001	.0001	.0001
	c	1	2	2	2	2	7
AGE	a	2.282	8.380	10.425	4.989	7.700	20.744
	b	.5158	.2116	.1076	.1726	.0526	.4746
	c	3	6	6	3	3	21
SCARDEX	a	52.827	77.410	75.506	63.225	66.472	
	b	.0001	.0001	.0001	.0001	.0001	
	c	14	7	7	7	7	

KEY

1. DORSAL PUBIC SCARRING
2. PREAURICULAR GROOVE PITS LEFT
3. PREAURICULAR GROOVE PITS RIGHT
4. INTEROSSEOUS GROOVE PITS LEFT
5. INTEROSSEOUS GROOVE PITS RIGHT
6. SCAR INDEX

a = Chi Square
b = Significance
c = d.f.

TABLE 11a

ANOVA

FEMALE EXPANSION VARIABLES BY SCARDEX AND PARITY

N=141	MAIN EFFECTS	SCARDEX	PARITY	EXPLAINED
PUBIS EXPANSION				
1	16.689	16.513	0.018	16.689
2	1.092	1.260	0.008	1.092
3	0.373	0.281	0.928	0.373
ISCHIAL SPINE EXPANSION				
1	40434.613	35442.090	4569.215	40434.625
2	0.858	0.877	0.679	0.858
3	0.542	0.514	0.412	0.542
INLET EXPANSION				
1	296.476	294.313	0.020	296.477
2	0.640	0.741	0.000	0.640
3	0.722	0.617	0.986	0.722
TRANSVERSE EXPANSION				
1	392.370	390.385	12.346	392.371
2	0.930	1.079	0.205	0.930
3	0.486	0.379	0.652	0.486
OUTLET EXPANSION				
1	750.237	690.156	85.742	750.238
2	1.213	1.301	0.970	1.213
3	0.301	0.261	0.327	0.301
SACRAL ROTATION				
1	72.980	69.477	3.404	72.980
2	0.214	0.238	0.070	0.215
3	.982	0.963	0.792	0.982

KEY

1	SUM OF SQUARES
2	F
3	SIGNIFICANCE

TABLE 11b

ANOVA

FEMALE EXPANSION VARIABLES BY SCARDEX AND PARITY CONTINUED

N=141

	RESIDUAL	TOTAL
PUBIS EXPANSION		
1	259.924	276.613
ISCHIAL SPINE EXPANSION		
1	834767.438	875202.063
INLET EXPANSION		
1	8203.133	8499.609
TRANSVERSE EXPANSION		
1	7476.617	7868.988
OUTLET EXPANSION		
1	10960.734	11710.973
SACRAL ROTATION		
1	6026.992	6099.973

KEY
1 SUM OF SQUARES

TABLE 12a

ANOVA

FEMALE EXPANSION VARIABLES BY SCARDEX AND ONLY DEFINITE PARITY ASSIGNMENT

N=82	MAIN EFFECTS	SCARDEX	PARITY	EXPLAINED
PUBIS EXPANSION				
1	18.118	17.544	1.812	18.118
2	2.058	2.325	1.440	2.058
3	**0.059	**0.042	0.234	**0.059
ISCHIAL SPINE EXPANSION				
1	523.800	522.983	4.057	523.801
2	0.293	0.342	0.016	0.293
3	0.954	0.912	0.900	0.954
INLET EXPANSION				
1	76.683	73.700	9.134	76.683
2	0.596	0.669	0.497	0.596
3	0.757	0.675	0.483	0.757
TRANSVERSE EXPANSION				
1	496.030	399.650	181.132	496.030
2	1.739	1.635	4.446	1.739
3	0.113	0.150	**0.038	0.113
OUTLET EXPANSION				
1	1267.479	1124.867	156.411	1267.480
2	1.754	1.816	1.515	1.754
3	0.110	0.107	0.222	0.110
SACRAL ROTATION				
1	130.315	126.254	11.198	130.316
2	0.716	0.810	0.431	0.716
3	0.658	0.566	0.514	0.658

KEY

* P<.10	1	SUM OF SQUARES
** P<.05	2	F
***P<.01	3	SIGNIFICANCE

TABLE 12b

ANOVA

FEMALE EXPANSION VARIABLES BY SCARDEX AND ONLY DEFINITE PARITY ASSIGNMENT CONTINUED

N=82

	RESIDUAL	TOTAL
PUBIS EXPANSION		
1	89.299	107.417
ISCHIAL SPINE EXPANSION		
1	18871.711	19395.512
INLET EXPANSION		
1	1359.043	1435.727
TRANSVERSE EXPANSION		
1	3015.016	3511.046
OUTLET EXPANSION		
1	7637.703	8905.184
SACRAL ROTATION		
1	1923.376	2053.692

KEY
1 SUM OF SQUARES

TABLE 13a

ANOVA

MALE AND FEMALE EXPANSION VARIABLES BY SCARDEX AND SEX

N=226	MAIN EFFECTS	SCARDEX	PARITY	EXPLAINED
PUBIS EXPANSION				
1	344.830	18.324	182.163	344.830
2	25.789	1.599	95.365	25.789
3	***0.000	0.149	0.000	0.000
ISCHIAL SPINE EXPANSION				
1	32590.254	31792.699	2415.545	32590.313
2	1.179	1.342	0.612	1.179
3	0.316	0.240	0.435	0.316
INLET EXPANSION				
1	1000.594	85.281	414.268	1000.594
2	2.253	0.224	6.528	2.253
3	**0.031	0.969	0.011	0.031
TRANSVERSE EXPANSION				
1	6978.070	383.642	2748.803	6978.070
2	8.127	0.521	22.410	8.127
3	***0.000	0.792	0.000	0.000
OUTLET EXPANSION				
1	1490.965	545.377	1025.427	1490.969
2	3.165	1.351	15.237	3.165
3	***0.003	0.236	0.000	0.003
SACRAL ROTATION				
1	364.705	220.946	13.223	364.707
2	0.502	0.355	0.127	0.502
3	0.832	0.907	0.721	0.832

KEY

* P<.10	1	SUM OF SQUARES
** P<.05	2	F
***P<.01	3	SIGNIFICANCE

TABLE 13b

ANOVA

MALE AND FEMALE EXPANSION VARIABLES BY SCARDEX AND SEX CONTINUED

N=226

	RESIDUAL	TOTAL
PUBIS EXPANSION		
1	404.954	749.784
ISCHIAL SPINE EXPANSION		
1	856671.125	889261.438
INLET EXPANSION		
1	13770.477	14771.070
TRANSVERSE EXPANSION		
1	26617.719	33595.789
OUTLET EXPANSION		
1	14603.762	16094.730
SACRAL ROTATION		
1	22522.125	22886.832

KEY
1 SUM OF SQUARES

rotation was most explained by scardex rather than sex.

For a breakdown of male expansion variable means by age and race see Table 14A. Females are represented in Table 14B. Table 14C shows male and female expansion variables averaged by scardex. It is easy to see that females have a much more flexible pelvic girdle than do males (Table 14C).

LOGISTIC REGRESSION

The results of a logistic regression analysis of the dichotomous dependent variable (parity) by the predictor independent variable (scardex) is presented in Table 15. Table 15 shows that the logistic regression fit is not good. Analysis of dispersion shows that the amount of variation due to residuals is quite large (86.468), compared to the very small amount (2.758) due to the model. The measures of association or measure of predictability points out that the reduction in error is quite small. When predicting parity without the scars information, the amount is small (0.030915) or 3.1%. When scarring is added to the model as a predictor the amount is still small (0.039578) and only adds (0.008663) or 0.8% to the

TABLE 14a

BREAKDOWN OF EXPANSION VARIABLE MEANS
MALES

N=85	A	B	C	D	E	AMPUBX
MEAN	9.2135	2.7671	7.7024	5.1188	6.0071	2.5647
19-35	11.7500	-4.4300	9.2600	5.3000	5.7900	2.8000
Black	11.5000	-3.0333	8.5111	5.8889	6.4333	2.6667
White	14.0000	-17.0000	16.0000	0.0	0.0	4.0000
36-50	8.9461	3.7658	7.5105	6.4321	5.4842	2.7632
Black	10.9731	4.1077	6.4038	5.8462	5.1192	2.7308
White	4.5542	3.0250	9.9083	7.4167	6.2750	2.8333
51-65	9.3000	3.6750	7.8286	4.2536	8.0464	2.3929
Black	8.2286	3.7429	6.0000	2.4286	1.9286	2.1429
White	9.6571	3.6524	8.4381	4.8619	10.0857	2.4762
65-HI	7.2556	3.7222	6.3889	2.4444	2.1111	2.0000
Black	12.5000	6.5000	13.0000	8.5000	8.0000	3.0000
White	6.6000	3.3750	5.5625	1.6875	1.3750	1.8750

KEY

A = Ischial Spine Expansion (mm)
B = Inlet Expansion (mm)
C = Transverse Expansion (mm)
D = Outlet Expansion (mm)
E = Sacral Expansion (mm)
F = Ampubx Pubic Expansion (cm)

TABLE 14b

BREAKDOWN OF EXPANSION VARIABLE MEANS FEMALES

N=141	A	B	C	D	E	AMPUBX
MEAN	13.2365	6.9702	18.9404	9.4298	7.7433	5.0809
19-35	19.6329	9.2600	21.7971	10.9457	9.8171	5.7353
Black	22.0500	9.9318	20.6045	11.4000	10.5727	5.6190
White	15.5423	5.4308	23.8154	10.1769	8.5385	5.9231
36-50	20.6491	6.1364	19.3291	9.6945	6.7891	5.1154
Black	21.0576	7.7212	20.2485	12.3515	8.6667	5.2188
White	20.0364	3.7591	17.9500	5.7091	3.9727	4.9500
51-65	19.1935	7.0129	16.5484	8.9226	7.9903	4.6452
Black	19.9467	6.7400	16.4800	8.4600	7.4267	5.0000
White	18.4875	7.2688	16.6125	9.3562	8.5186	4.3125
65-HI	-27.5750	6.9400	16.5800	6.8350	6.3550	4.5263
Black	-207.9250	7.8250	24.2250	9.0250	8.5250	6.0000
White	17.5125	6.7188	14.6688	6.2875	5.8125	4.1333

KEY

A = Ischial Spine Expansion (mm)
B = Inlet Expansion (mm)
C = Transverse Expansion (mm)
D = Outlet Expansion (mm)
E = Sacral Expansion (mm)
F = Ampubx Pubic Expansion (cm)

TABLE 14c

MALE AND FEMALE BY SCARDEX EXPANSION VARIABLES AVERAGED

N = 226
MA = 85
FE = 141

PUBIC EXPANSION (CM)

Scardex	MALE	FEMALE
0	2.62	5.45
1	2.25	5.10
2	2.67	5.07
3	5.00	5.46
4	0.0	4.76
5	0.0	4.50
6	0.0	3.00

TRANSVERSE EXPANSION (MM)

Scardex	MALE	FEMALE
0	7.02	17.89
1	8.88	18.72
2	8.33	18.98
3	20.00	21.12
4	0.0	18.14
5	0.0	17.42
6	0.0	10.00

ISCHIAL SPINE EXPANSION (MM)

Scardex	MALE	FEMALE
0	9.35	19.27
1	8.10	20.33
2	9.43	21.80
3	22.00	19.54
4	0.0	20.26
5	0.0	19.08
6	0.0	10.00

OUTLET EXPANSION (MM)

Scardex	MALE	FEMALE
0	5.70	15.49
1	3.37	7.30
2	4.75	9.06
3	8.50	8.19
4	0.0	10.60
5	0.0	7.79
6	0.0	5.00

INLET EXPANSION (MM)

Scardex	MALE	FEMALE
0	3.14	5.71
1	0.21	8.21
2	6.58	6.23
3	9.50	8.04
4	0.0	6.14
5	0.0	7.65
6	0.0	7.00

SACRAL EXPANSION (MM)

Scardex	MALE	FEMALE
0	4.97	7.79
1	9.58	6.59
2	4.00	7.54
3	6.50	7.53
4	0.0	9.34
5	0.0	7.19
6	0.0	3.70

TABLE 15

LOGISTIC REGRESSION

PARITY BY SCARDEX

DEPENDENT VARIABLE - PARITY

ANALYSIS OF DISPERSION

SOURCE OF VARIATION	DISPERSION ENTROPY	CONCENTRATION	DF
DUE TO MODEL	2.758	2.545	
DUE TO RESIDUAL	86.468	61.765	
TOTAL	89.226	64.310	128

MEASURES OF ASSOCIATION

ENTROPY = .030915

CONCENTRATION = .039578

reduction in error.

REGRESSION ANALYSIS

A step-wise regression analysis was performed using Scardex as the dependent variable, and background and expansion variables as independent variables (Table 16a). The correlations on which all the calculations are based are shown in Tables 16b and 16c.

Multiple R and R square are both ways of looking at the proportion of variation explained by the variables included in the regression equation. R square change shows the additional variance explained by that variable only. Beta (standardized regression coefficients) and B (unstandardized regression coefficients) are the weights for each independent variable in the regression equation. The relative size of the weight gives the relative importance of that particular variable. It is worth noting that the relative size of the Beta of an independent variable can be quite different from its regression coefficient with the dependent variable since the coefficient is confounded with the effects of other independent variables. For example, R square (Table 16a)

TABLE 16a

MULTIPLE REGRESSION

DEPENDENT VARIABLE SCARDEX

N=226

SUMMARY TABLE

INDEPENDENT VARIABLES	MULTIPLE R	R SQUARE	RSQ CHANGE	B	BETA
Sex	0.06751	0.00456	0.00456	-5.515389	-0.12693
Age	0.08918	0.00795	0.00339	-0.8718785D-01	-0.06299
B	0.09422	0.00888	0.00093	0.7531429D-01	0.02898
Ampubx	0.09706	0.00942	0.00054	-0.4428378D-01	-0.02962
Parity	0.10019	0.01004	0.00062	-0.2915712D-01	-0.06648
C	0.10139	0.01028	0.00024	-0.3023703D-01	-0.01757
E	0.10188	0.01038	0.00010	-0.2172684D-01	-0.01043
(Constant)				21.54950	

B = Inlet Expansion
Ampubx = Dorsal Pubic Expansion
C = Transverse Expansion
E = Sacral Rotation

TABLE 16b

MATRIX FOR REGRESSION ANALYSIS

N=226

SEXES COMBINED

CORRELATION COEFFICIENTS	SCARDEX	AMPUBX	SEX	PARITY	AGE
AMPUBX	-0.04012				
SEX	-0.06751	0.20120			
PARITY	0.05333	-0.20382	-0.92848		
AGE	-0.05266	-0.02398	-0.08021	0.05888	
A	0.00342	-0.01221	0.03106	-0.02527	-0.10946
B	0.01115	-0.09086	0.25135	-0.29089	0.00243
C	-0.02713	-0.02897	0.44513	-0.42953	-0.15033
D	-0.00756	0.16265	0.24612	-0.19697	-0.17458
E	-0.00486	-0.20143	0.08327	-0.05013	-0.06081

TABLE 16c

MATRIX FOR REGRESSION ANALYSIS

N=226

CORRELATION COEFFICIENTS	A	B	C	D	E
SCARDEX	0.00342	0.01115	-0.02713	-0.00756	-0.00486
AMPUBX	-0.01221	-0.09086	-0.02897	0.16265	-0.20143
SEX	0.03106	0.25135	0.44513	0.24612	0.08327
PARITY	-0.02527	-0.29089	-0.42953	-0.19697	-0.05013
AGE	-0.10946	0.00243	-0.15033	-0.17458	-0.06081
A		0.07935	0.04664	0.05156	0.03754
B			0.33043	0.22596	0.19229
C				0.20490	0.14623
D					0.40037

shows that age in conjunction with sex explains 8.9% of the variance in the amount of scarring. When the age variable was added to sex there was a change or an increase of 0.3% (R square change) in the amount explained. The Beta weight for age is only 0.0629 which indicates that alone, age is not a strong predictor. The proportion of variation explained by the entire set of variables included in the regression equation (R square) is 0.01038. The amount of additional change (R square change) falls off sharply after the addition of age. However, the placement of parity is unusual because, the amount of additional explanation (Beta) by the addition of the parity variable is more than the three variables preceding it. The corresponding correlation matrix for Table 16a given in Tables 16b and 16c shows a significant correlation between sex, parity and age. This is to be expected, because only females have children and the female sample was preferentially selected for females of the childbearing ages between 18 and 50 years. Scardex in the correlation matrix (Tables 16b and 16c) is inversely related to dorsal pubic scarring, sex, age, race, sacral rotation, transverse and outlet expansion. As the incidence of scarring goes up more females exhibit them, older ages have less, Whites have less, there is less sacral rotation, less transverse and outlet expansion. Sex, age, parity, dorsal pubic expansion and inlet expansion are shown to be the most importantly interrelated to Scardex.

Because of the high amount of weight (Beta) given to the sex, age and parity variables in Table 16a, a separate regression was run on Scardex of only the male population given in Table 17a. Thirth-five percent of the males in the sample had pelvic scarring without the possibility of parity acting as partial explanation. Table 17a shows that in males, scardex is most importantly determined by dorsal pubic scarring. Correlations on which the calculations are based are presented in Tables 17b and 17c. Age and transverse expansion did not meet the criteria to be entered into the equation. The proportion of variation explained by the entire set of variables included in the regression equation (R square) is 0.02387.

The importance of age was specifically examined due to its high placement in the regression analysis presented in Table 16a. A summary table of the regression analysis with age as the dependent variable is shown in Table 18a.

TABLE 17a

MULTIPLE REGRESSION

DEPENDENT VARIABLE SCARDEX

SUMMARY TABLE

MALES N=85

INDEPENDENT VARIABLES	MULTIPLE R	R SQUARE	RSQ CHANGE	B	BETA
AMPUBX	0.13591	0.01847	0.01847	-4.208826	-0.19242
E	0.14145	0.02001	0.00154	-0.1100425	-0.05541
D	0.14769	0.02181	0.00180	0.2326575	0.04658
B	0.15163	0.02299	0.00118	0.1611541	0.03770
A	0.15458	0.02389	0.00090	0.9366098	0.03851
(CONSTANT)				17.52033	

AMPUBX = Dorsal Pubic Expansion
E = Sacral Rotation
D = Outlet Expansion
B = Inlet Expansion
A = Ischial Spine Expansion

TABLE 17b

MATRIX FOR REGRESSION ANALYSIS

N=85

MALES

CORRELATION COEFFICIENTS	SCARDEX	AMPUBX	AGE
AMPUBX	-0.13591		
AGE	0.02148	-0.15263	
A	-0.06461	0.62087	-0.08682
B	-0.00283	0.27364	0.26829
C	-0.03207	0.27307	0.02045
D	-0.02469	0.37178	-0.20108
E	-0.02686	-0.08972	0.00105

TABLE 17c

MATRIX FOR REGRESSION ANALYSIS

N=85

MALES

CORRELATION COEFFICIENTS	A	B	C	D	E
SCARDEX	-0.06461	-0.00283	-0.03207	-0.02469	-0.02686
AMPUBX	0.62087	0.27364	0.27307	0.37178	-0.08972
AGE	-0.08682	0.26829	0.02045	-0.20108	0.00105
A		0.12298	0.22324	0.25131	-0.00004
B			0.03280	0.13258	-0.02190
C				0.10763	-0.01053
D					0.26010

TABLE 18a

MULTIPLE REGRESSION

DEPENDENT VARIABLE AGE

SUMMARY TABLE N=226

INDEPENDENT VARIABLES	MULTIPLE R	R SQUARE	RSQ CHANGE	B	BETA
D	0.17458	0.03048	0.03048	-0.3018154	-0.16841
C	0.21018	0.04418	0.01370	-0.1816295	-0.14608
A	0.23121	0.05346	0.00928	-0.2466832	-0.10179
B	0.24727	0.06114	0.00768	0.1789342	0.09532
SCARDEX	0.25410	0.06457	0.00342	-0.4208340	-0.05825
E	0.25435	0.06469	0.00013	0.2203251	0.01463
AMPUBX	0.25444	0.06474	0.00005	0.7793049	0.00721
(CONSTANT				52.34428	

D = Outlet Expansion
C = Transverse Expansion
A = Ischial Spine Expansion
B = Inlet Expansion
SCARDEX = Scar Index
E = Sacral Rotation
AMPUBX = Dorsal Pubic Expansion

Correlations on which the calculations are based are shown in Tables 18b and 18c. The amount of pelvic scarring is relatively unimportant to age being placed fifth in the equation (Table 18a). As age increased, pelvic flexibility generally decreased.

TABLE 18b

MATRIX FOR REGRESSION ANALYSIS

N=226

DEPENDENT VARIABLE AGE

CORRELATION COEFFICIENTS	SCARDEX	PARITY	SEX	AGE	AMPUBX
PARITY	-0.03264				
SEX	-0.06751	-0.58589			
AGE	-0.05266	0.29345	-0.08021		
AMPUBX	-0.04012	-0.13399	0.20120	-0.02398	
A	0.00342	-0.09733	0.03106	-0.10946	-0.01221
B	0.01115	-0.34716	0.25135	0.00243	-0.09086
C	-0.02713	-0.31884	0.44513	-0.15033	-0.02897
D	-0.00756	-0.19964	0.24612	-0.17458	0.16265
E	-0.00486	-0.06641	0.08327	-0.06081	-0.20143

TABLE 18c

MATRIX FOR REGRESSION ANALYSIS

N=226

DEPENDENT VARIABLE AGE

CORRELATION COEFFICIENTS	A	B	C	D	E
SCARDEX	0.00342	0.01115	-0.02713	-0.00756	-0.00486
PARITY	-0.09733	-0.34716	-0.31884	-0.19964	-0.06641
SEX	0.03106	0.25135	0.44513	0.24612	0.08327
AGE	-0.10946	0.00243	-0.15033	-0.17458	-0.06081
AMPUBX	-0.01221	-0.09086	-0.02897	0.16265	-0.20143
A		0.07935	0.04664	0.05156	0.03754
B			0.33043	0.22596	0.19229
C				0.20490	0.14623
D					0.40037

VI

DISCUSSION

It has been proposed that differential fertility can accurately be determined by analysis of scars of parturition (Angel 1969; Houghton 1975; Ullrich 1975).

Putschar (1931) and Boland (1933) have pointed out that parturition causes changes and trauma to the soft tissue of the pelvis such as cartilageous tears and calcium deposits in the ligaments. Angel (1969) proposed that parturition not only caused soft tissue changes but also suggested that those changes were reflected in the bony pelvis in the form of dorsal pubic pits. He reasoned that the presence of dorsal pubic pitting was a result of childbearing and that the bigger and more frequent the scarring, the more childbirth events. Only dorsal pubic pitting was considered to be diagnostic at first and males rarely have pits or scars in this area. Angel's sample gave the impression that males never exibited dorsal pubic pitting. Thus a causal factor unique to females would seem the best answer. Angel's explanation for dorsal pubic pitting seemed to be acceptable in the absence of parity data.

THE DORSAL PUBIS

The dorsal pubic region of the study population were examined for evidence of dorsal pubic scars, grooves, or pits. The scars have a very distinctive appearance not easily missed or confused (Figures 13a,b). Figure 13a is a view of a normal unmarked female pubis from a Black female 48 years old who definitely had had children. A typical dorsal pubic scar is shown in Figure 13b on a female of 42 years who had definitely never had children. A view of a rare trace to small pit on the dorsal pubis of an 83 year old male has also been shown in Figure 12.

Table 3a,b, and c show dorsal pubic scarring frequencies of this study. Holt (1978) was the first to systematically test the validity of dorsal pubic pitting as an indicator of parturition. The construction of these tables were after Holt (1978). Kelley (1979) rejected Holt's results because Holt did not use a sample population with definite parity information. However, Tables 3a,b, and c support Holt's contention that no distinction between

FIGURE 13a A view of the dorsal pubis of a Black female (48 years old) who definitely has had children with no abnormal dorsal pubic changes.

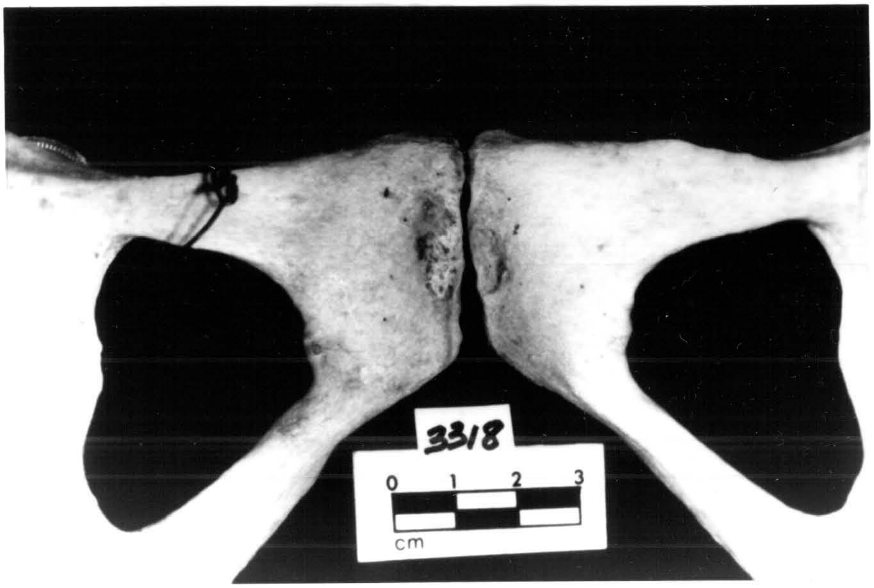


FIGURE 13b A typical dorsal pubic scar is shown in a Black female of 42 years who had definitely never had children.

nulliparous and multiparous females can be made on the basis of dorsal pubic pitting. Table 3b shows that when definite and probable parity categories are analyzed separately no significant difference exists in percentages of frequencies. It is true that many (47.6%) nulliparas showed no dorsal pubic pitting and this would seem to be a significant indicator. However, many (41.0%) multiparas also showed no scarring or pitting at the dorsal pubis. This only shows that dorsal pubic pitting is not a frequent trait. Of the definitely nulliparas females, 23.8% showed medium to large pits while multiparas showed a slightly higher percentage (33.3%) of medium to large pits. The "probable categories" frequencies were very similar to the "definite categories" frequencies, apparently reflecting an accurate assessment of parity in the absence of definite features by the researchers at the Hamann-Todd Collection. Males rarely exhibit pubic pitting as shown in Table 3c. The two males who did have pits (2.4% of the sample) were in their eighth decade and the scarring may be a result of their advanced ages. Contingency table analysis (Table 6) also shows that dorsal pubic scarring is not significantly associated with parity, race or age. Thus, the presence of dorsal pubic pitting does not indicate a history of childbirthing events.

THE PREAURICULAR SULCUS

Houghton (1974) determined two forms of the preauricular sulcus (Figure 22b). According to Houghton all males had the GL form and no dorsal pubic pits, whereas, the females were predominately GP with some GL. In addition to the GP form, females had a much higher incidence of pubic pitting. Therefore, Houghton attributed the GP form and dorsal pubic changes, to changes due to parturition.

Contingency table analysis showed that parity and preauricular groove pits were not significantly associated at p<.8192 for the left and p<.4322 for the right side (Table 6). Figure 14a shows two females of the same age with definite preauricular groove pitting. Figure 14b shows a very broad pitted preauricular groove. Note the deformation of the auricular surface margin. All three of these females have never had children.

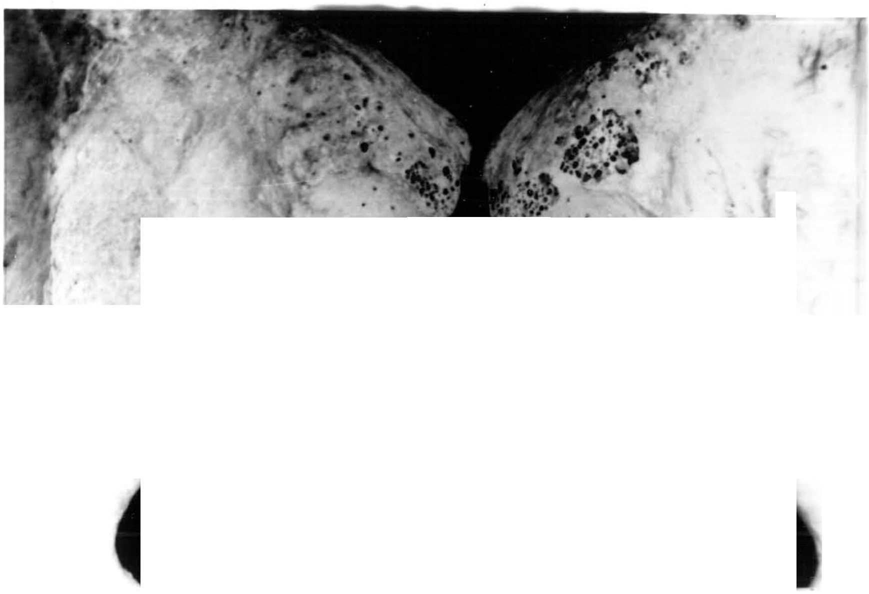
Tables 4a,b,c,d show the groove form frequencies of this study. The results do not replicate Houghton's

#1049 A 40 year old White female who shows typical preauricular groove pitting. This female has never had children.

#657 A 40 year old Black female who definitely has not had children and shows severe preauricular groove pitting.

FIGURE 14a Preauricular Sulcus Scarring

#1049



#657

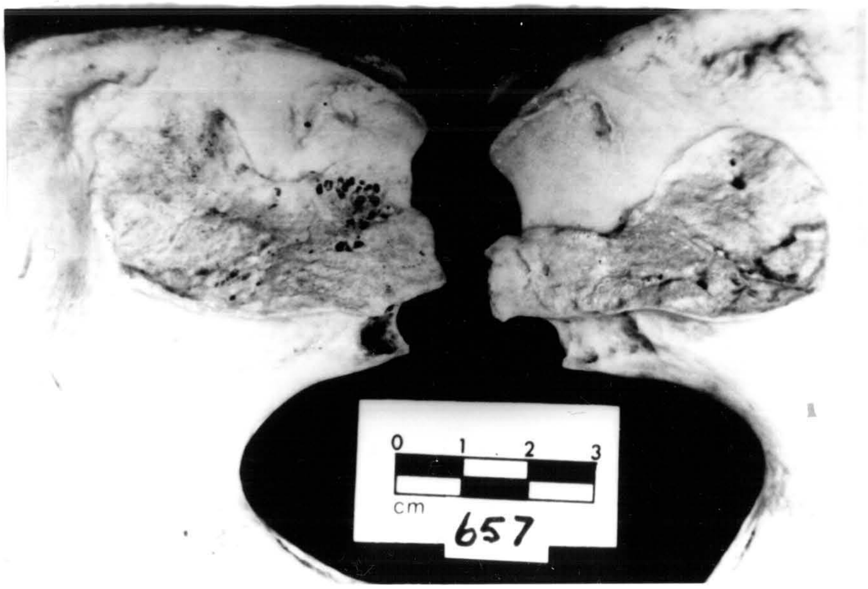


FIGURE 14a

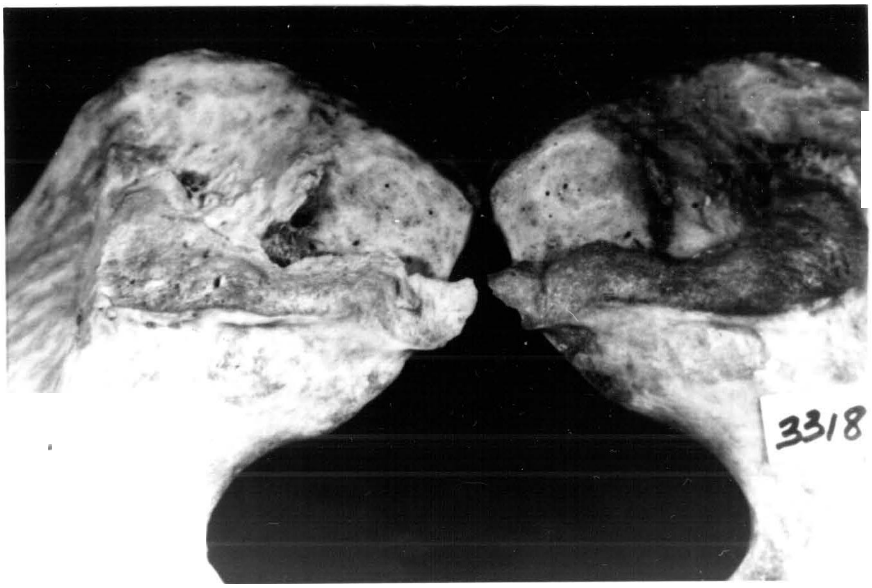


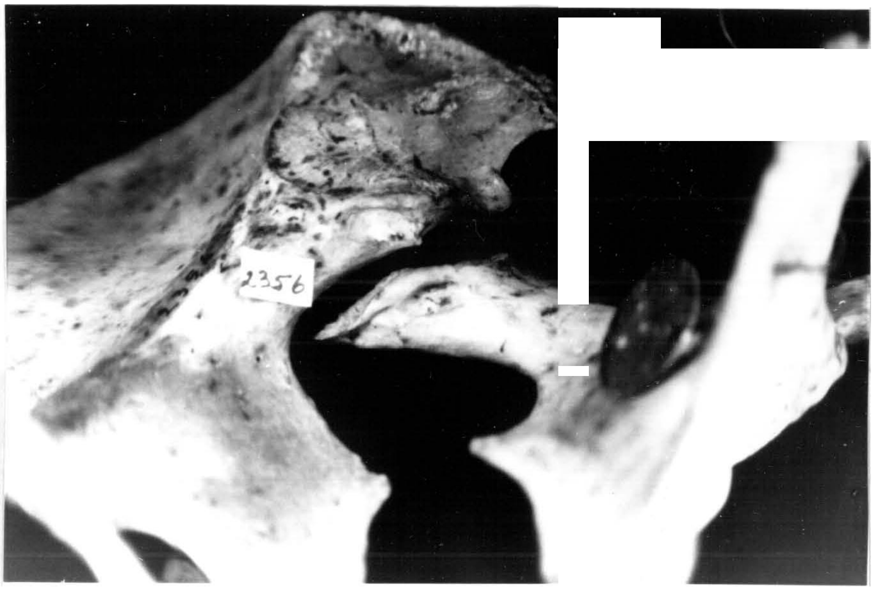
FIGURE 14b A Black female of 42 years of age who definitely has not had children and shows broad preauricular groove pits.

#2356 A 28 year old Black female who definitely has not had children and shows deep round preauricular groove pits.

#1302 A 47 year old White female who definitely has had several children and exhibits a pit in the left preauricular groove. This groove can be classified as (GL).

FIGURE 15 Preauricular Sulcus Scarring

#2356



#1302

FIGURE 15

FIGURE 16 An 83 year old White male exhibits a pitted preauricular groove. This pelvic girdle was more loosely fitted than for the average male.

results. However, two features of this research design differ from Houghton's 1) Houghton's sample did not have provenience for half the material studied and the other half were archaeological material from Maori and Moriori. Thus, no known parity information was available to him, and 2) no class is given by Houghton to categorize the pelvic girdle exhibiting both forms. Table 4a shows that males do have GP form characteristics represented and that 20% of the males are classified as "both". Houghton's results do not include any males with a GP form. This lack may reflect the need for the "both" category which may have provided Houghton with additional discrimination. Figure 15 shows a 28 year old Black female with very distinct preauricular pits. In the same figure is a White female, 47 years old who has definitely had several children and has a GL form groove. Even though the interosseous groove has pits, the preauricular groove is long, straight, flat even floor with no pits. Figure 16 demonstrates a very unusual preauricular sulcus (pitted) on an elderly male of 83 years.

In an attempt to test the importance of parity on preauricular form, Table 4c shows an almost too perfect clustering of GP form in approximately the 75th percentile. GL form in females were in very low frequencies.

In this study only two preauricular variables are associated with parity (Table 7a). Chi square analysis shows that the groove form of the left side is significantly associated with parity ($p<0.001$) and in Table 7b, a broad shallow right side shows a trend to be associated ($p<0.089$). Sex is shown to be significantly associated with all preauricular groove variables including forms (GP and GL) ($p<0.001$) and pitting ($p<0.001$) in Tables 7a,b. Females have a much higher incidence of pelvic scarring and generally exhibit the GP form.

It appears that the GL form is a sexual characteristic of the male not infrequently found in the female. The GP form is a sexual characteristic of the female infrequently found in the male. Parity has no significant effect on the form of the preauricular groove or pitting in the groove. It is possible that Houghton was seeing the effects of the sexual characteristics and did not have an adequate sample to conclude that pitting and form were not associated with parity.

THE INTEROSSEOUS GROOVE

Pitting in the interosseous groove can be difficult to ascertain. Of the three areas of the pelvic girdle that exhibit scarring, pitting in the interosseous groove is the least obvious. Interosseous groove scars are shown in Figures 17a,b and 18a,b. The scarring is not obvious in Figures 17a and b, but Figures 18a and b show very dramatic pitting. This is probably due to the topography of the surfaces which are generally more rugged than the other two surfaces. In Table 8a sex is significantly associated with pitting in the developed interosseous groove of the left ($p<0.001$) and right ($p<0.018$), whereas parity is not associated. Females show more pitting in the interosseous groove than do males.

Convinced that no one trait was able to predict parity, Kelley (1979) attempted to show that by analyzing the combination of scars of the dorsal pubis, preauricular groove and the interosseous groove better parity assessment could be attained. Tables 5a,b,c show that the overlap in range is too great for parity assessment to be made from this method. Kelley suggested that females that fall above the upper line (Table 5a) are nulliparae. While 31.9% of

FIGURE 17a Postauricular sulcus/interosseous groove scars with typical male preauricular groove are shown on this 47 year old White female that definitely has had children.

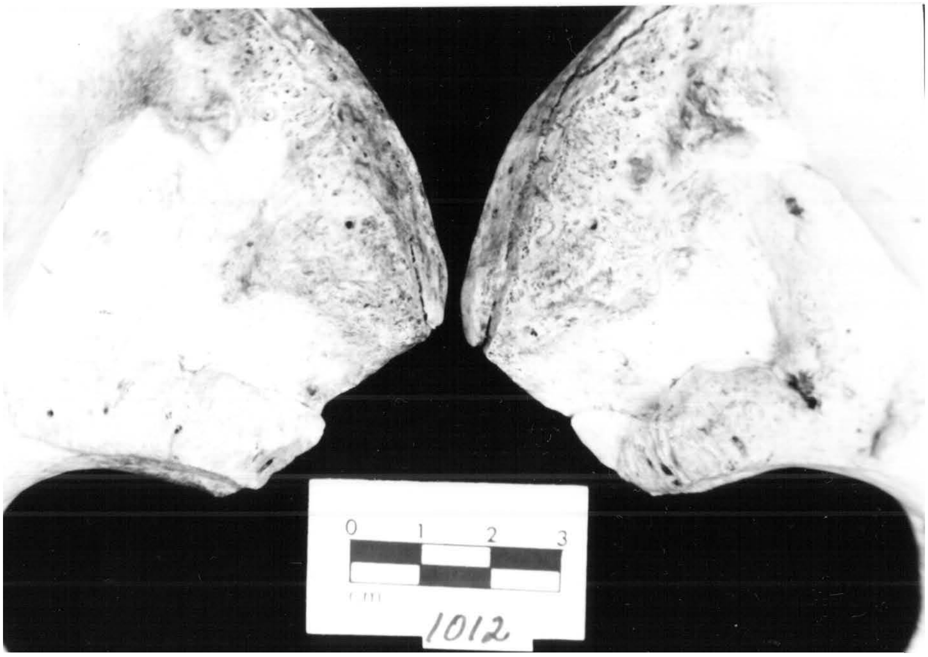


FIGURE 17b Postauricular sulcus/interosseous groove scars with typical male preauricular groove belongs to this 18 year old Black female who definitely has not had children.

#3318 This 42 year old Black female who definitely has not had children shows large interosseous groove scars.

#2942 Interosseous groove scars are also shown on this 39 year old Black female who definitely has never had children.

FIGURE 18a Interosseous Groove Scarring

#3318

#2942

FIGURE 18a

FIGURE 18b An 80 year old White male exhibits interosseous groove pitting.

the nulliparous females in this study fall above the cut off as Kelley expects, 26.2% of the multiparae also fall above this line. Conversely 52.3% of the multiparae females are below the line supposedly indicating parity. Forty-four percent of the nulliparous are below the line also. Kelley's combination method is not sufficiently discriminating for parity assessment. In an attempt to examine possible effects of more than one pit or a combination of pits, scar index was constructed named scardex. Scardex or the total amount of pitting was not associated with parity and was significantly associated with sex ($p<0.001$) and pubic expansion ($p<0.001$) (Table 6). Thus, neither dorsal pubic pitting, interosseous groove pitting nor preauricular groove pitting can be shown to be associated with parity. Yet all those variables are related to sex.

Logistic regression analysis presented in Table 15 also shows that pelvic scarring cannot predict parity. Parity is neither associated nor correlated with pelvic scarring. Thus, the supposition that pelvic scarring is caused by parturition is not supported by the data.

Although parity was not found to be associated with pelvic scarring, sex was significantly associated and correlated with pitting and scarring in the pelvic girdle. Male and female pelves are significantly different with respect to pelvic scarring. Females have significantly more scarring (93%) than do males (35%) (Tables 5a and 5c). Because both males and females can exhibit scarring the cause or causes must not be unique to one sex or the other. However, scarring is more commonly expressed in the female. Parity or actual childbirthing are unique to females and thus must be excluded as a possible causal factor.

→ Not! it may be a factor but not the only cause

If actual childbirth is not the causal factor then perhaps hormonal changes generally associated with childbirth may play a role in pelvic pitting. Hormone levels are similar in some males and females and could explain the disproportionate percentages of scars. Hormonal changes can cause resorption of bony tissue (Enlow 1963, 1976; Hancox 1972; Turlk 1977; Katz 1980). However, the effects are systemic bone removal due to the systemic delivery of hormones throughout the body. The data are not represented in this manner. Pelvic scarring are definite pits or crater-like depressions not general loss of bone mass. Additionally, the pelvic scars and pits are very specifically located in the girdle not all over the body. They are found at the three pelvic stabilizing attachment sites. Nutation in the sacroiliac area is stabilized by the sacrotuberous, sacrospinous, and the anterior sacroiliac ligament. The interosseous ligament limits any linear displacement of the sacroiliac joint, and the crisscrossing transverse ligament of the dorsal pubis prevents against a shearing motion caused by walking. Haversian systems are frequently found at attachment sites where fibers of attachment (Sharpy's fibers) attach to the bone (Enlow 1963, 1976; Hancox 1972; Turlk 1977; Katz 1980). Osteoclastic activity or bone removal occurs when bone is modeling or remodeling. It would appear that hormonal changes are not the cause of pelvic pitting, and that pelvic stabilization must be considered as a primary causal factor.

The human pelvis is designed so that the wedge of the sacrum can cause the bony pelvis to be tightly articulated and provide structural stability. To maintain the integrity of the pelvic girdle, the bony parts must be firmly articulated with no "play" or "shearing movement" (Kapandji 1974) except during parturition. In addition to the wedge shape of the sacrum the soft tissue play a vital role in maintaining the firm position of the girdle during bipedalism. Any relaxation of (for example) rectus abdominis, internal oblique, the anterior ligament, conjoint tendon, fascia transversalis, etc., plus all tissues of the pelvic floor, is not desirable for that reason.]

Scardex is significantly associated with sex and the expansion measurements of the pelvic girdle as shown in Tables 11a-13b, with Tables 14a,b,c giving the breakdown of means of expansion by sex, race, and age. The average dorsal pubic expansion for a young Black male was 2.66 cm. The average dorsal pubic expansion for a young Black female was 5.61 cm. The sacral expansion mean for a young Black male is 6.43 mm and 10.57 mm for a female in the same category. Thus, expansion limits set by the bone contrast sharply between male and female. The average female pelvis is almost twice as flexible as the average male pelvis demonstrating that the female pelvis is especially adapted for childbearing.

The expansion limits are set by the bony surfaces, including the iliac tuberosity, the posterior superior spine and then the accessary surface. In many males there was little to no allowable expansion due to the extremely tight fit between the sacrum and ilium. In some of the females the maximum measurement recorded was 7 cm +. There was virtually nothing constraining movement of these very loose pelves other than soft tissue in life.

In most cases there is not a tight bony fit among female pelves. It is true that the pelvis is never expanded in life in this experimental manner except in cases of great trauma. However, this experiment demonstrates that the soft tissue of the male expends less effort than a female in maintaining the integrity of the pelvic girdle.

Tables 13a,b and 14c show the significance of mobility and scardex. Scardex is associated with sex. The more flexible the pelvis the higher scardex. Female pelves are almost twice as flexible as male pelves. Thus, females show the most scars and pits in the pelvic girdle. This is not a result of childbearing, but is because the flexible pelvis adaptation for childbearing is most often found in women. Figures 19, 20, and 21 show severe and extreme changes best explained by the attempt of the soft tissue to control excess motion and maintain the integrity of the

FIGURE 19 Extensive preauricular groove pitting and a roughened postauricular sulcus are exhibited by this 44 year old White male.

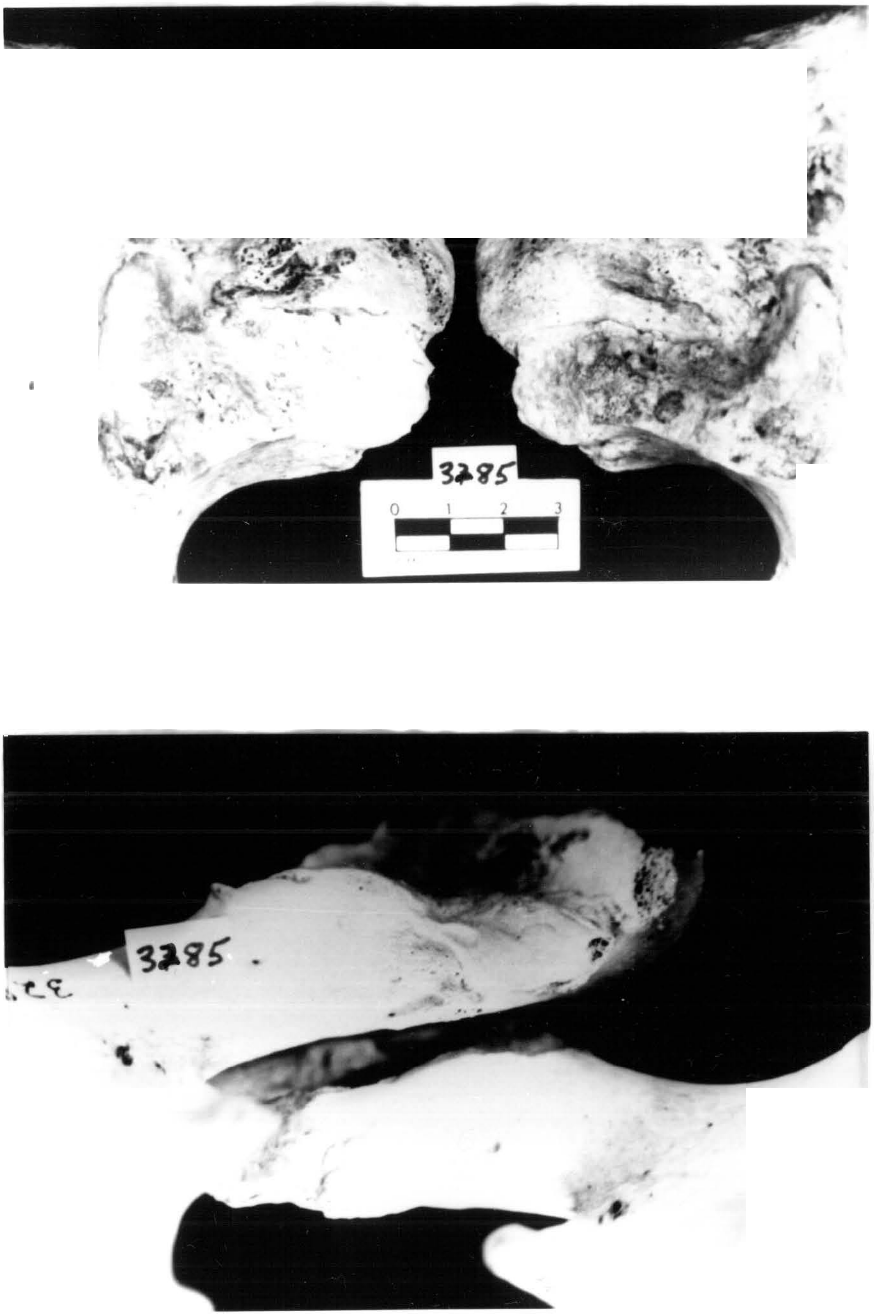


FIGURE 19

FIGURE 20 A 51 year old White female who probably has not had children shows severe changes of the articular auricular surface and the preauricular sulcus.

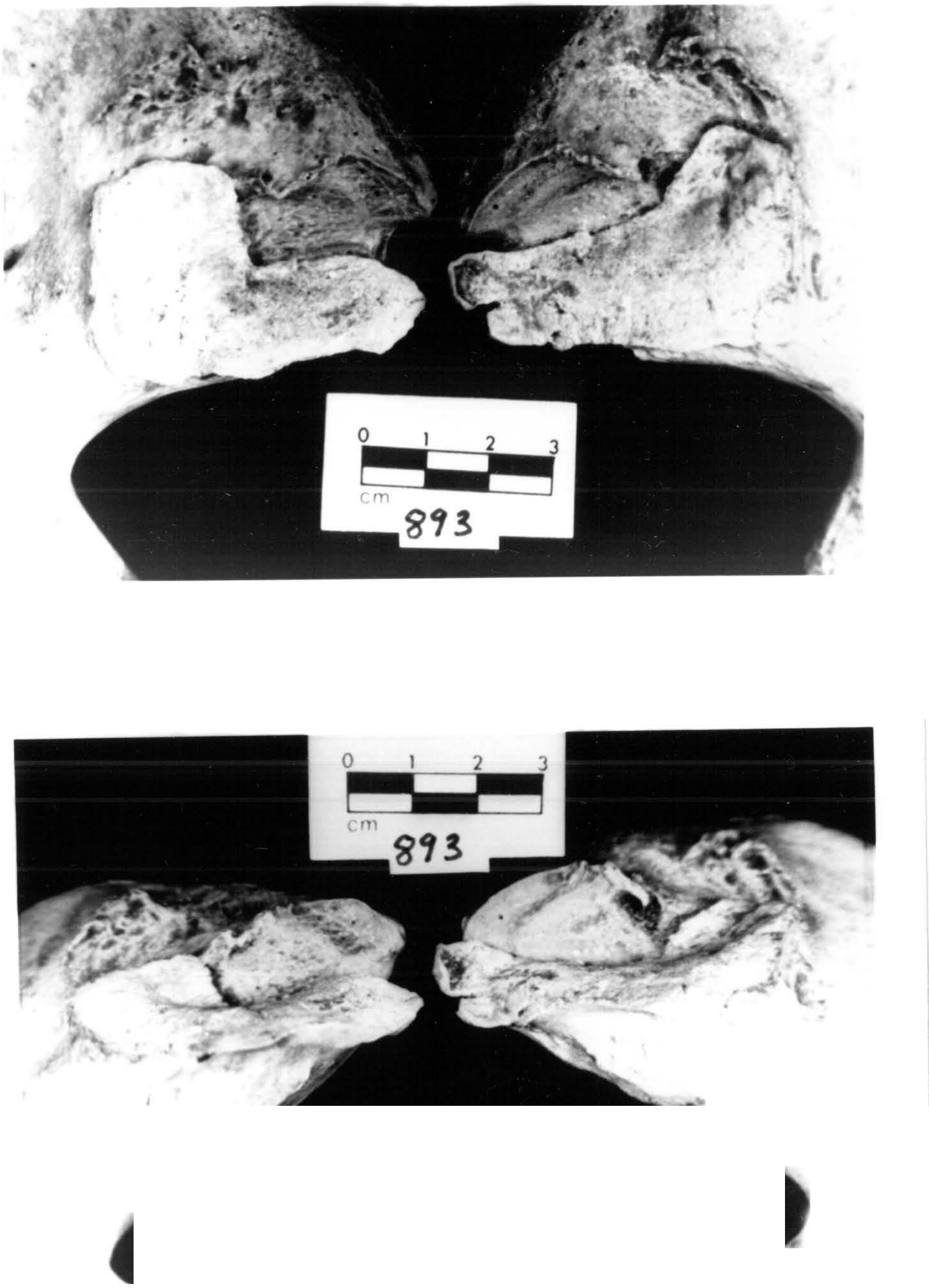


FIGURE 20

FIGURE 21 An example of extreme change in the preauricular sulcus, auricular shape and postauricular sulcus is shown on this 42 year old Black female pelvis.

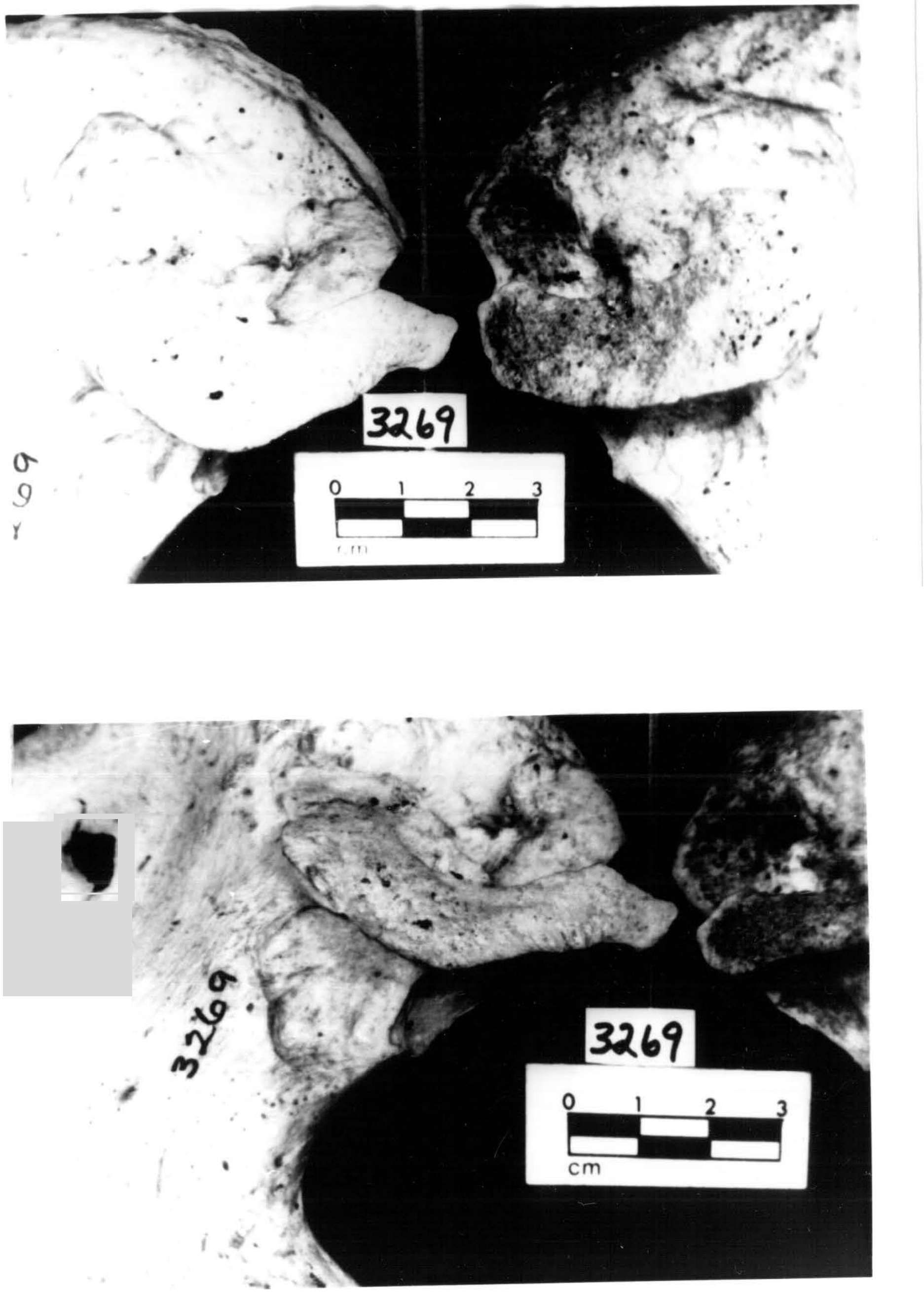


FIGURE 21

pelvic girdle. Figures 22a,b show typical male and female articular areas.

Weed (1972) suggested that postural changes due to ageing causes relaxation of the pelvic floor. Regression analysis (Table 17ab) shows age to be a weak predictor of pelvic scarring in males. When males are not separately analyzed, the variable "age" gains in ability to predict (Table 16a). This may be because the female pelvis must rely more on soft tissue support than the male. Sex is the most important variable in explanation because females have the most incidence of scarring. Scarring cannot be caused by parity because too many males also exibit scarring. By removing the females from the sample analyzed, a clear picture of "excess motion" emerges. Multiple regression analysis (Table 17a) shows that expansion variables are critically important to the incidence of pelvic scarring.

The bony pelvic girdle must be supported by an integrated system of soft tissue. If the bony girdle is tightly articulated then the support of the soft tissue may be redundant. If, however, the bony girdle is not constrained by bone, then, the soft tissue and the pelvic floor must be considered a functional link in the system of

#3062 This 50 year old White male exhibits typical male characteristics.

#2516 This 31 year old Black female who has never children exhibits typical female characteristics.

FIGURE 22a Typical male and female

#3082

#2516

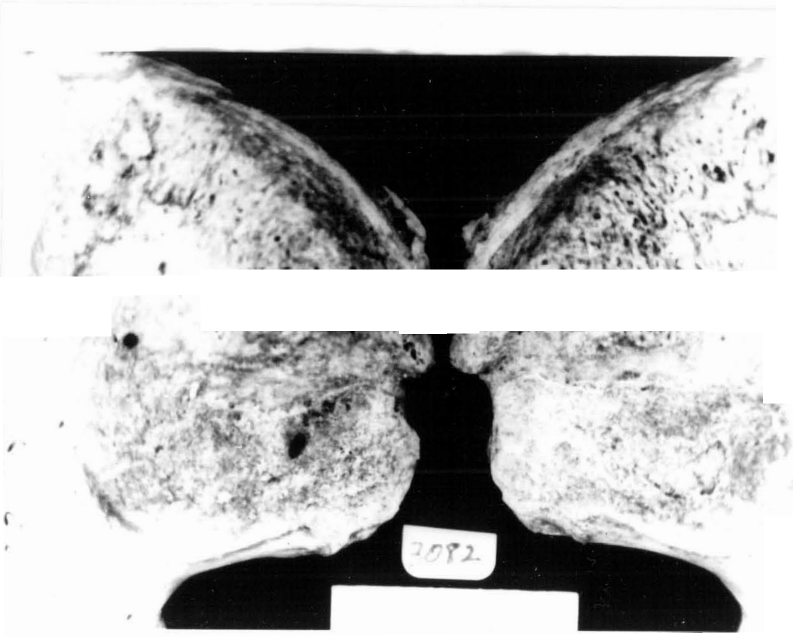
FIGURE 22a Typical male and female

#3062 A typical preauricular groove form for a 50 year old White male (GL).

#2516 A typical preauricular groove form shown by a 31 year old Black female who has never had children (GP). Note the scar on the preauricular groove.

FIGURE 22b Typical preauricular groove form.

#3082



#2516

FIGURE 22b Typical male and female preauricular groove form.

an integrated pelvic girdle. The soft tissue support system may be breeched by 1) lengthening and stretching of the pelvic floor or trauma to the ligamentous attachments such as cartilageous tears as a result of parturition, 2) habitual squatting which encourages lifting of the sacrum and expansion of the pelvic girdle as shown by increased diameter of the outlet when in Walcher's position, 3) heavy or frequent straining and/or lifting, 4) postural changes causing pelvic floor relaxation, 5) weakening and stretching of the pelvic floor and ligamentous attachments due to overweight, and 6) trauma from an unknown source.

When the bony and soft tissue support systems are breeched there will be too much motion permitted during bipedalism, and change occurs at the ligamentous attachment sites in response to habitual stress. Thus scarring and pitting at attachment sites in the pelvic girdle are a consequence of excessive movement beyond the architectural design of a flexible pelvic girdle.

VII

CONCLUSION

The hypothesis that differential fertility can be accurately determined by analysis of "scars of parturition" is rejected. The results of this study show that parity is not statistically significantly associated with "scars of parturition" at the dorsal pubis, preauricular groove or the interosseous groove. Nor is parity significantly associated with a combination of scars in one or all of the three areas examined.

1) The nulliparous female may have scarring in any or all three locations on the pelvic girdle.

2) The multiparous female may have absolutely no scarring on any of the three location on the pelvic girdle.

3) Older women well past childbearing years (+50 years) show no difference in pelvic scarring.

4) Males have shown "scars of parturition" in the pelvic girdle, most frequently the preauricular groove and interosseous groove as dorsal pubic pitting is rare.

It is not possible to determine whether or not a female has borne children by analysis of pelvic scarring or pitting. Thus the conclusion that pelvic changes in the form of pits or scars are a direct result of parturition cannot be supported. If it is not possible to determine whether or not a female has borne children by analysis of scarring then by extrapolation it is impossible to determine the number of offspring by the same analysis.

It may be that childbearing indirectly contributes to scars or pits on the pelvic girdle but it can be said that these are not "scars of parturition" and should not be used to make inferences regarding childbearing or fertility.

THEORETICAL MODEL: "SCARS OF EXCESS MOTION"

The most parsimonious explanation for scars or pits on the pelvic girdle is that scarring occurs at sites of stabilizing ligamentous attachments adjoining the joints of the pelvic girdle due to a response to excess motion allowed by flexible pelvic architecture. The articulation of the pelvic girdle is maintained by the bony fit of the wedge shaped sacrum into the pelvic girdle and the soft tissue such as, smooth and striated muscle of the pelvic floor and connective tissue.

Sex is statistically significantly associated with all pelvic changes that have been called "scars of parturition" at the dorsal pubis, preauricular groove and the interosseous groove. The bony pelvic girdle of the male is significantly more tightly articulated allowing less play or shearing movement than the female and is best adapted for bipedalism. It has been demonstrated that the female has significantly more rotation of the sacrum and expansion of the pelvic articulations due to the more loosely articulated bony pelvis which is the best adapted for parturition. The male pelves that are less tightly fit, tend to show more scarring than the tighter fitting male pelves. The tighter fitting female pelves tend to show less scarring than the more common loosely fitted female pelvis.

Arthritic changes such as bony lipping and articular exostosis restrict flexibility of the pelvic joints. Arthritic bone changes increase with aging (Steinbock 1976; Ortner and Putschar 1981) and because of this pelvic flexibility may decrease as age increases.

Relaxation, stretching or trauma of the soft tissue for any reason may provide too much flexibility for a bony pelvis that is not tightly articulated. In some cases the soft tissue is redundant in males to limit movement and in some cases the soft tissue in females is all that can limit movement due to the total lack of bony restriction. Factors contributing to relaxed, stretched or traumatized soft tissue are 1) lengthening and stretching of the pelvic floor or trauma to the ligamentous attachments such as cartilageous tears as a result of parturition, 2) weakening and stretching of the pelvic floor and ligamentous attachments due to overweight, 3) habitual squatting which encourages lifting of the sacrum and expansion of the pelvic girdle as shown by increased diameter of the outlet when in Walcher's position, 4) heavy or frequent straining as in lifting or carring loads which can lengthen and stretch the support system of the pelvic floor, 5) trauma from an unknown source.

It is the function of the ligaments of the pelvic joints to restrict movement and maintain the integrity of the pelvic girdle. Movement in excess of the optimal architectural limits of the pelvis cause the ligamentous attachment sites to change in response to habitual stress.

The dorsal pubis, preauricular groove, and interosseous groove are examples of such attachment sites. Therefore, scarring and pitting at attachment sites in the pelvic girdle are a consequence of excessive movement beyond the architectural design of a flexible pelvic girdle schematically demonstrated in Figures 23a and b.

This analysis presents new evidence indicating that pelvic instability is a major consequence of the structural compromise that exists in a pelvic girdle which is adapted for both bipedalism and childbearing. The most parsimonious explanation for pelvic scarring is the reaction of the tissues of the pelvis to instability and are more frequently found in the flexible pelves of women. Characteristic scars and pits found in the pelvic girdle have been inaccurately identified as "scars of parturition". This study has determined that these marks should be more accurately named "scars of excess motion".

Figure 23a,b

21a - A schematic representation of the theoretical model of "excess motion". The extremes of bony pelvic flexibility are shown. The data are on a continuum mainly ranging between the two extremes.

21b - A representation of the theoretical model of "excess motion" which shows possible degrees of influence. "A" is influenced by sex, (males have a more firmly articulated pelvis than females). "B" is influenced by factors that may weaken or stretch the soft tissue such as 1) parturition, 2) hapitual squatting, 3) lifting or straining, 4) postural changes due to aging, or 5) trauma. The influence of "e" error is untested, thus an empirical model remains unmeasured.

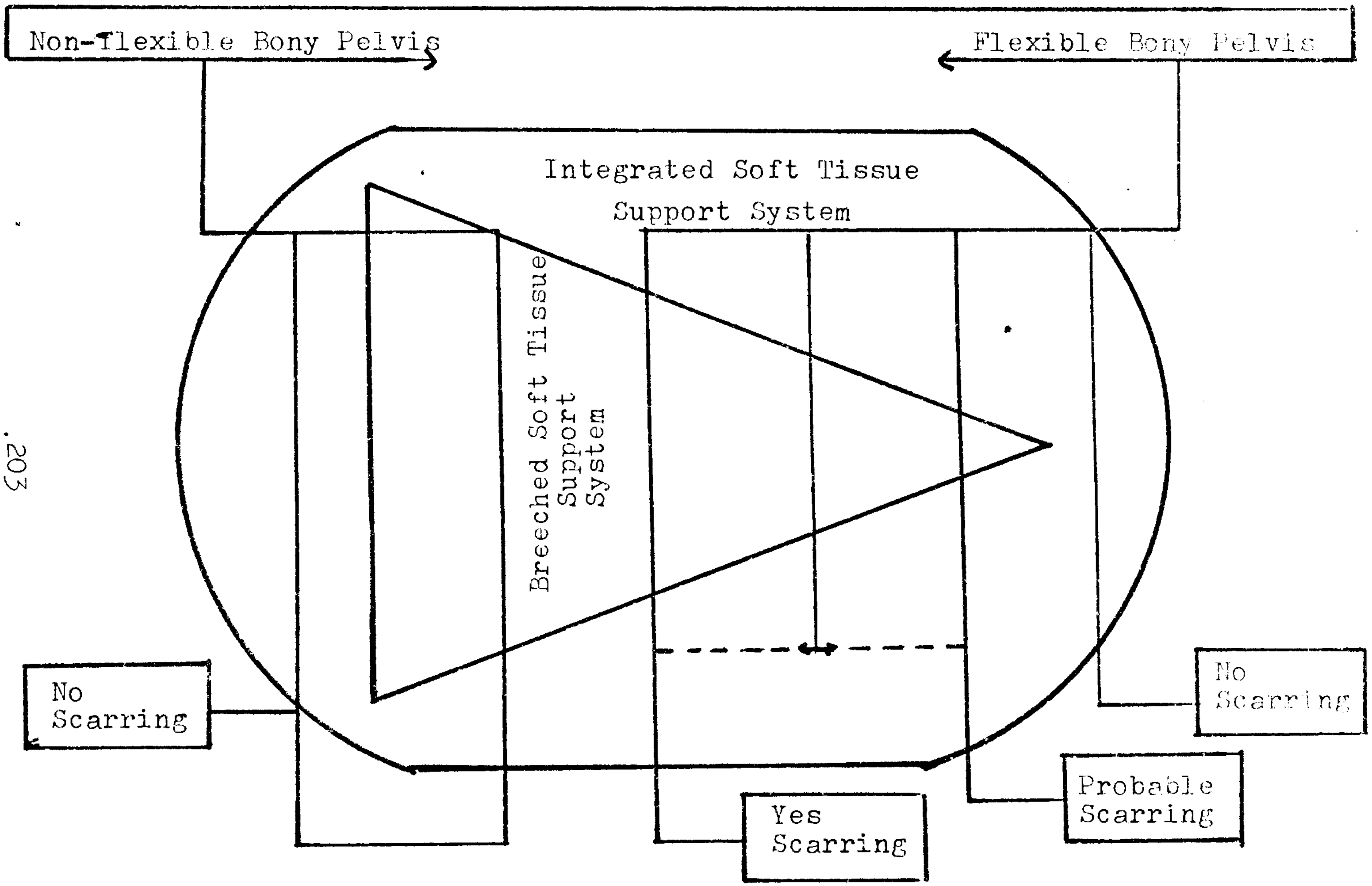


FIGURE 23a Theoretical model of "excess motion".

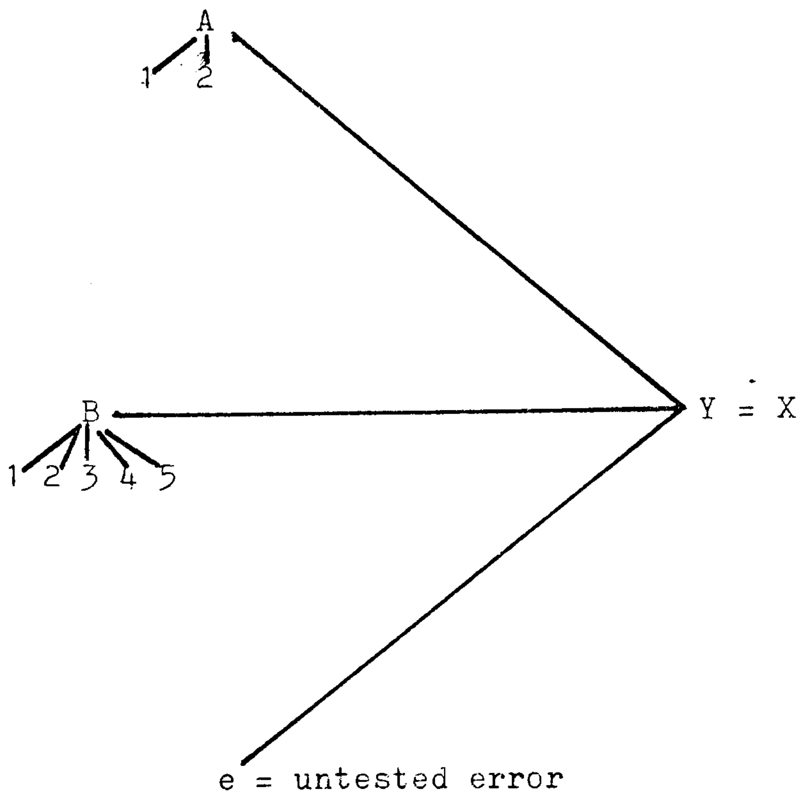


FIGURE 23b The influence of bony architecture (A) and soft tissue integrity (B) to flexibility (Y) determines scarring (X).

VIII

APPENDICES

APPENDIX 1A

Parity Assessment

Definitely None

"#1175, perineum intact, hymen present, outlet virginal, os round and firm, nipples virginal, no linea alba, has certainly not had children."

"#3111, no linea alba on abdomen or thighs, fourchette intact, hymen complete, os round. Has certainly had no children."

Definitely Some

"#0929, fourchette gone, car. myrt., vagina not senile. Os large soft and patulous, many lineal alba, os bloody. Old healed transverse tear. Fluid can be expressed from both nipples. Has certainly born children."

"#1302, fourchette ruptured, vagina patulous, os stellate. Linea alba on abdomen, nipple multiparous. Has certainly had children."

Probably None

"#0925, fourchette present, no linea alba, car. myrt. present, os transverse, not split. Probably has not borne children."

"#2939, several large fibroids of the uterus. Fourchette intact, os round, no striae. Probably has not had children."

Probably Some

"#0839, old linea alba abdomen, perineum torn, probably has borne children."

"#3269, linea alba abdomen, very faint on thighs. Uterus prolapsed. Os round and knotted. May have had children" (Records, Hamann-Todd Osteological Collection, Cleveland Museum of Natural History).

Appendix 2:A

Information

Project # ____________

Barbara C. Andersen
Department of Archaeology
Simon Fraser University
Burnaby, B.C. Canada
V5A 1S6

Summer 1984
Cleveland Museum of Natural History
Hamann-Todd Collection

Project # _________
Catalogue # _______
Cause of death __________
Age at Death ________
Black White Eskimo Other _______________
Comments:

Parity status:

has ever been pregnant, yes no
has ever given birth, yes no
# of births ___________
additional information:

Any known pathologies or illnesses.

Comments:

Appendix 2:B

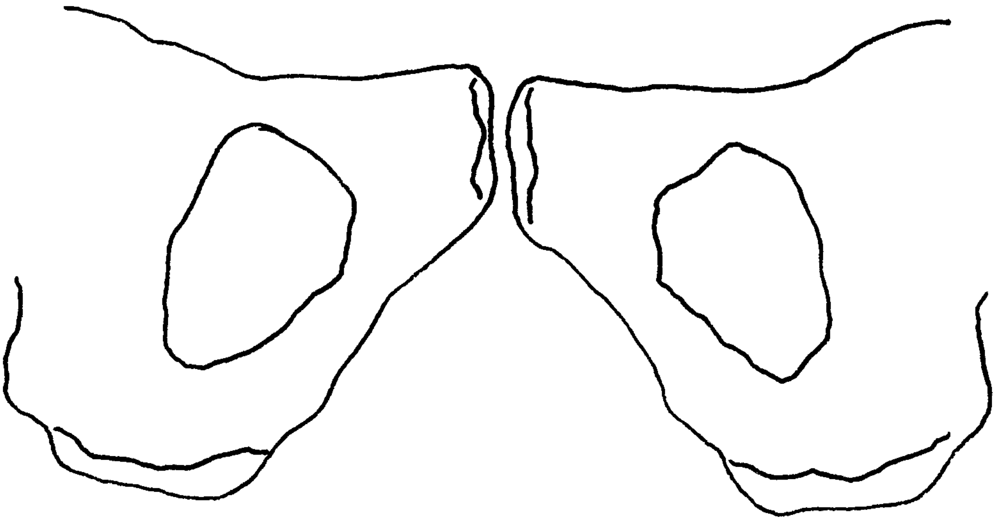
Dorsal Pubic Changes

1) Absent
2) Trace to small
3) Medium to large

Trace to small = very shallow, poorly demarcated depressions or as small well-defined pits not exceeding 2mm in diameter.

Medium to large = definite changes which range from more or less distinct depressions to unmistakable cavieties.

(Stewart 1970; Suchey et al. 1979)



Comments and/or Pathologies:

[illegible] ________
Age at death ________
# of children ________
Comment:

Appendix 2:C

Project # ________

PRE-AURICULAR GROOVE (diagram attached)

Preauricular Groove

	LEFT	RIGHT
size of groove -	1 2 3 4 5	1 2 3 4 5
description -	1 2 3 4 5	1 2 3 4 5
depth	________	depth ________
length	________	length ________

Pathology: Ankylosis?

GL GP

Size of groove = small - 1 2 3 4 5 - large.

Description :
1) broad-shallow = absent to poorly demarcated, broad and shallow
2) narrow-shallow = ~~short~~ straight-edged and shallow, flat even floor
3) developed = one or more deeper and well demarcated pits in the pre-auricular region.
4) scooped-wavy = elongated pits joined as though bone scooped out with wavy margins
5) extended = extension of groove superiorly on the anterior surface of the adjacent surface of the ilium

---

Houghton (1974)
Kelley (1979)

Comment and/or Pathology:

GP (fe) = Coalescence of series of pits
uneven floor Can be smooth pits

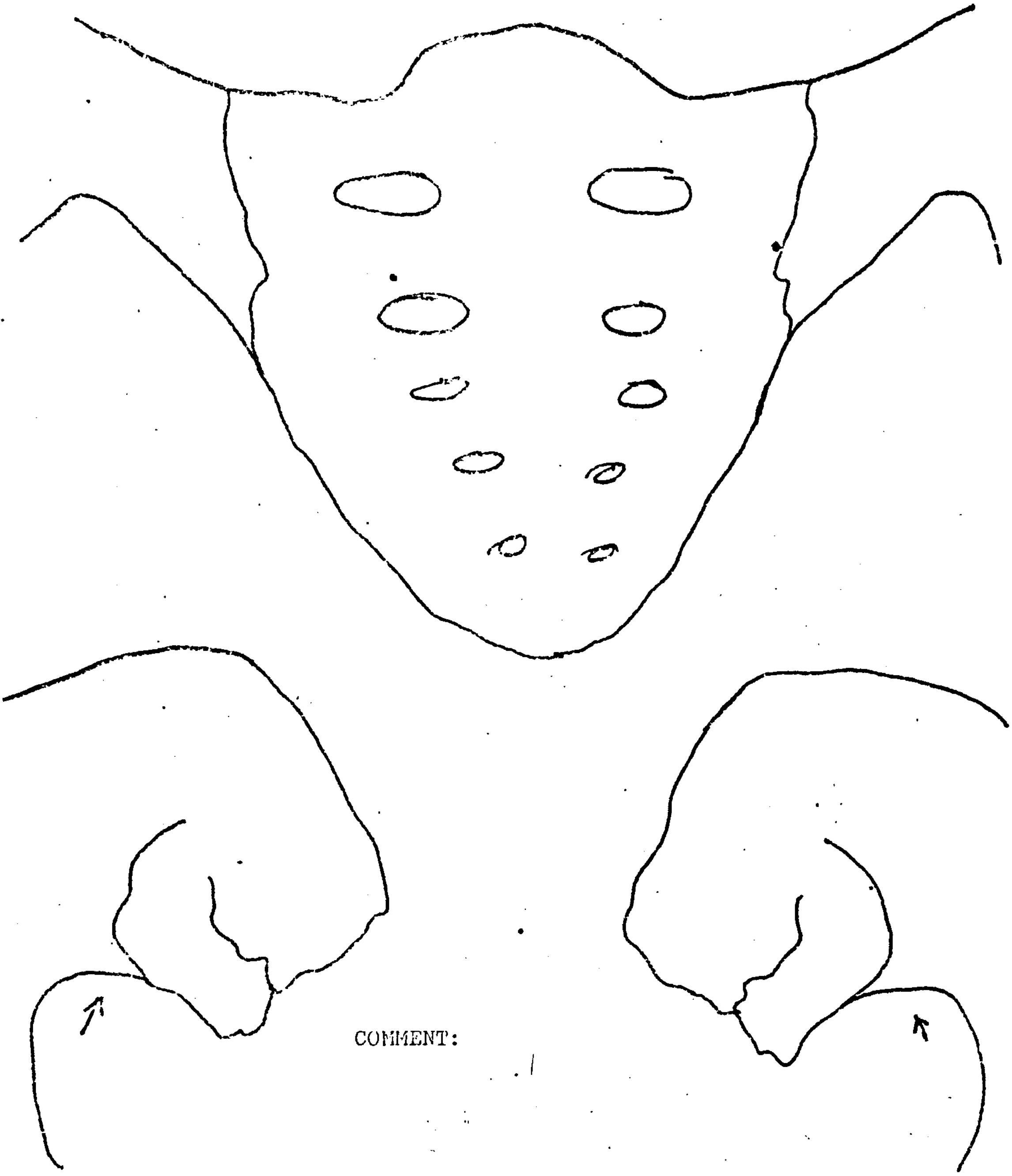
GL (ma) = flat even floor
sometimes like deep scratches

Catalogue # ____ Project # ____________

Appendix 2:D

PRE-AURICULAR GROOVE

Preauricular Groove



COMMENT:

Appendix 2:E
Interosseous Groove

Depth: floor of sulcus to highest margin of posterior auricular surface near the posterior inferior iliac spine.

left __________ right ___________

Width: widest point between superior margin of sulcus to inferior margin between posterior superior and inferior iliac spines.

left __________ right ___________

Length 0 1/3 1/2 2/3 all

Description: left 1 2 3 4 5 right 1 2 3 4 5

1) shallow and poorly demarcated.
2) shallow straight-edged even floor.
3) deeper and well defined platformed.
4) developed with one or more pits in sulcus.
5) irregular floor and or margins.
6) projecting.

Comments:

Iliac Tuberosity

Thickness: with spreading calipers the anteroposterior thickness at the highest point of iliac tuberosity to posterior of ilium.

left __________ right __________

Thickness accessory surface

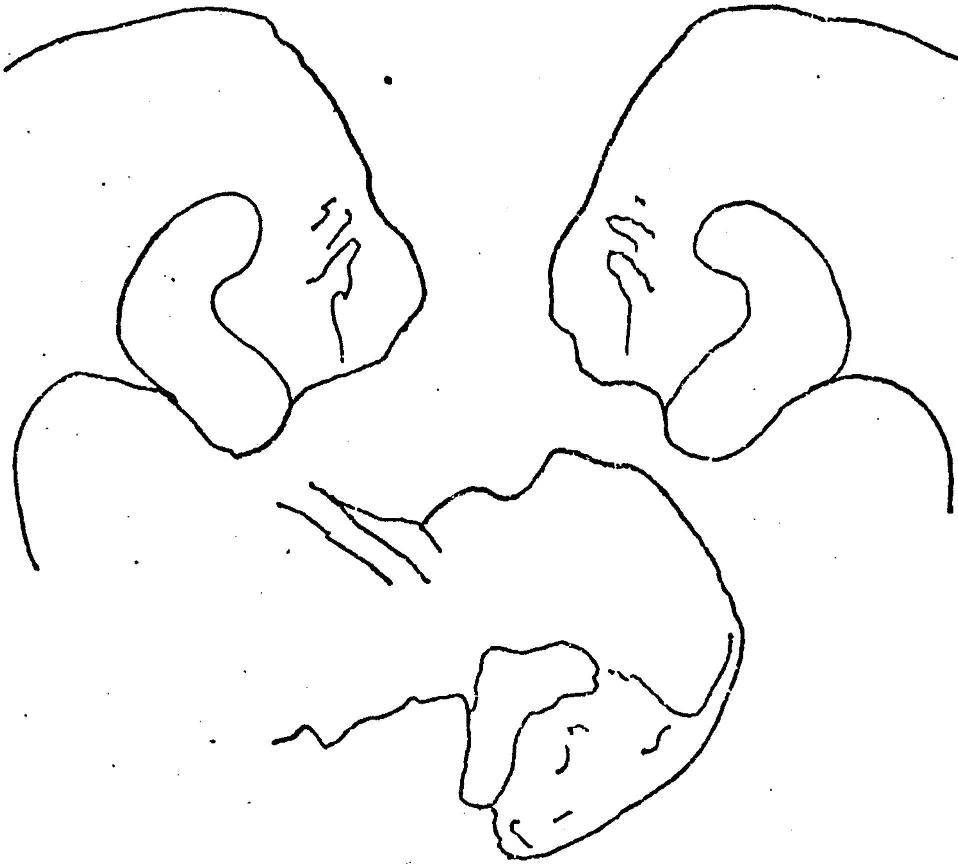
left ___________ right __________

Appendix 2:F

Catalogue # ________ Project # ________

Interosseous Groove

INTEROSSEOUS GROOVE
ILIAC TUBEROSITY
accessory surface



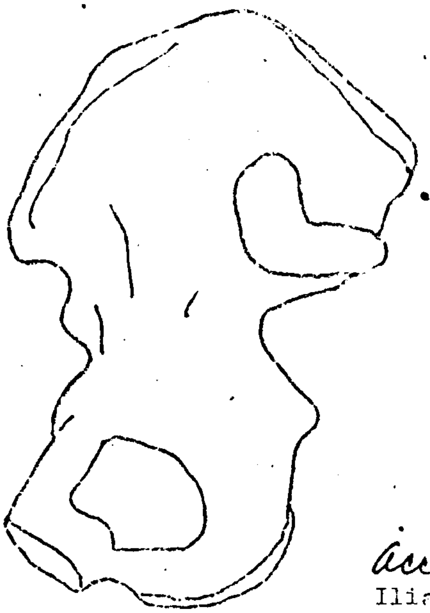
COMMENTS:

Appendix 2:G

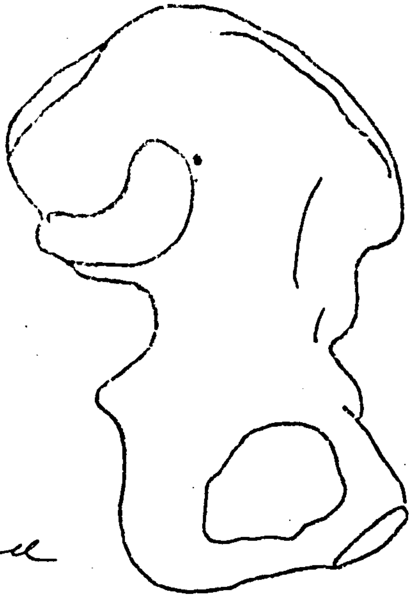
Catalogue # ________ **Interosseous Groove** Project # ____________

Interosseous Groove or Sulcus

RIGHT



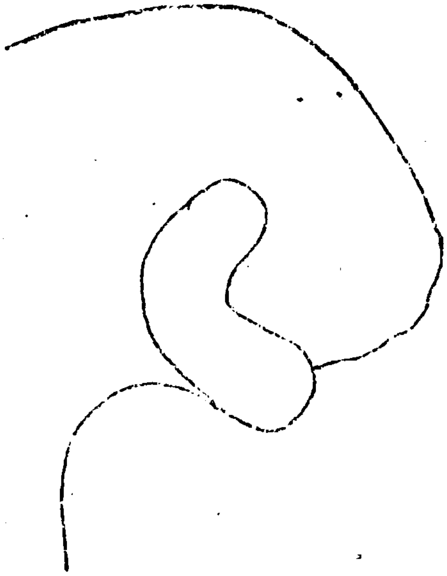
LEFT



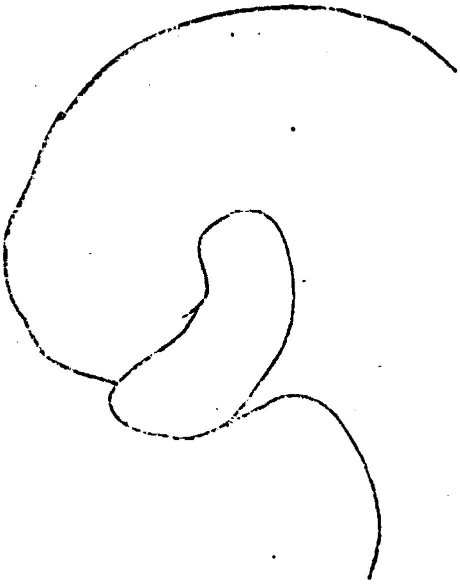
Accessory Surface

Iliac Tuberosity
and
Posterior Auricular Surface

RIGHT



LEFT



Appendix 2:H
cont.

Catalogue # ________ Project # ________

Iliac Tuberosity

	Left	Right
Tuberosity size	sm. 1 2 3 4 lg.	1 2 3 4
Tuberosity shape	1 2 3 4	1 2 3 4

(Iscan and Derrick 1984)

1) fossa without any bony prominance
2) depressed 'mound'/rounded
3) pointed mound ~~crest~~
4) rugged-convoluted tuberosity /crest

Comments: accessory surface
sm med lg

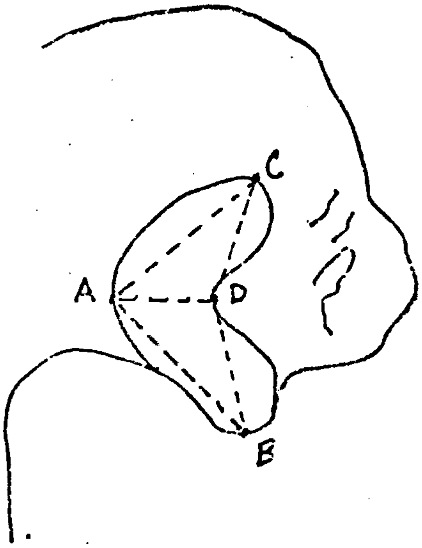
pointed
crested
mound

POSTERIOR AURICULAR SURFACE

	Left	right
A-B	______	______
A-C	______	______
B-D	______	______
C-D	______	______
A-D	______	______
Description	1 2 3 4	1 2 3 4

1) well defined edges like platform
2) not well demarcated edges
3) smooth surface
4) rough surface

Comments:



Appendix 2:I

Catalogue # ________ Project # ________

SACRUM

height Max. (a)	breadth Max. (b)	Sacral index $\frac{b \times 100}{a}$	# of segments ________	Curvature slight moderate pronounced	Curvature begins at seg. # ______

Comments:

Sacral angle depth ! ________
at segment # ________

Appendix 2:J
Articulated Measurements

left right

1) Distance between ischial spines
anatomical inverted
*expanded straight _______ _______
everted _______ _______

2) Distance between ischial tuberosities
anatomical _______ _______

3) Biiliac breadth (distance between iliac crests)
anatomical _______ _______

4) Anteroposterior diameter inlet
sacral promontory to pubic crest
anatomical _______ _______

5) Transverse diameter of inlet
distance between arcuate lines
anatomical _______ _______
*expanded _______ _______

6) Anteroposterior diameter of outlet and of
5th seg. to lower border of sym. pubis
anatomical _______ _______
rotated _______ _______

7) Transverse diameter of outlet (posterior part of one
ischiatic tuberosity to the same part on opposite side)
anatomical _______ _______

8) Sacral angle expansion (5th seg. to pubic crest)
anatomical _______ _______
rotated _______ _______

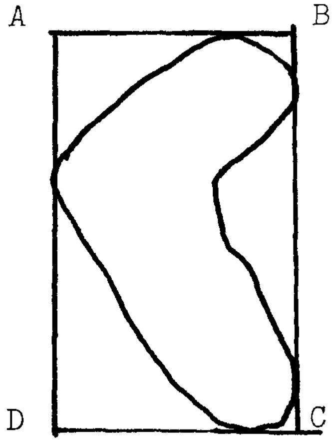
9) Max. width of pubic space
anatomical _______ _______
*expanded _______ _______

Comments:

APPENDIX 3A

Weisl's Measurement Technique

Each half sacrum was placed in a vice so that the dorsal, caudal and ventral markers of the auricular surface were arranged on the same plane. An instrument called a vertical vernier used for cartography and marked in inches, gauged the most prominent part of the auricular surface then marked out contour lines 1.27 mm apart. "This relief map was then photographed through a grid of centimetre squares resting in contact with the specimen (Weisl 1954:3). The outline of each map was then enclosed in a rectangle with (AD,BC) called length and (AB,DC) called width. Iliac measurements differed from the sacral on average by 1mm.



(Weisl 1954:1-3)

APPENDIX 3B

Articular Auricular Points

A = the most prominent part of the ventral border (Weisl, 1954) called by Derry (1923) the auricular point.

D = the deepest concavity of the dorsal border.

C = dorsal marker, the midpoint of the curve on the dorsal end of the cranial limb.

B = caudal marker, a similar point on the extremity of the caudal limb.

(after Weisl, 1954:2)

Appendix 4A

SCARDEX Construction

SCARDEX = Combined score of scarring in all three areas of the pelvic girdle.

SCARDEXL = Score of scar combination of left side. (S/L)

SCARDEXR = Score of scar combination of right side. (S/R)

	SCARDEX	S/L	S/R
Dorsal pubis			
absent	0	0	0
trace - small			
medium - large	2	1	1
Preauricular groove			
absent	0	0	0
left - pits present	1	1	0
right - pits present	1	0	1
Interosseous groove			
absent	0	0	0
left - pits present	1	1	0
right - pits present	1	0	1
Total	6	3	3

0 = min. score possible

6 = max. score possible

Appendix 5A

Auricular Articular Surface Means (mm)

	Left Caudal	Left Cranial	Left Area	Right Caudal	Right Cranial	Right Area
Male	535.5	471.0	1006.5	540.3	487.4	1027.8
Female	388.7	341.8	730.5	407.3	382.4	789.8
			t - Test (Means)			
N=226	443.9	390.4	834.3	457.3	421.9	879.3

2T - Probability from t-Test

Left Caudal/Cranial	= 0.001
Right Caudal/Cranial	= 0.001
Left Area - Right Area	= 0.665
Left Caudal/Right Caudal	= 0.795
Left Cranial/Right Cranial	= 0.550

Appendix 5B

Auricular Articular Surface Means (mm)

Right Area

Right Area	Male Black	Male White	Female Black	Female White
lo - 35	619.1	1175.1	584.1	599.1
36 - 50	1052.5	807.1	843.3	600.3
51 - 65	621.6	1177.8	1709.9	627.8
66 - hi	720.2	1766.7	694.5	701.1
N=226	43	42	74	67

Means

Males	1027.8	Females	789.8
Black	883.9	Black	933.8
White	1175.1	White	630.7
Entire Population		879.3	

Between Groups	Within Groups
F -1.865	-eta 0.0909
p<0.1734	-eta 0.0083

Appendix 5C

Auricular Articular Surface Means (mm)

Left Area

Right Area	Male Black	Male White	Female Black	Female White
lo - 35	1425.6	814.4	607.4	599.9
36 - 50	1028.2	1409.6	615.0	557.3
51 - 65	674.4	776.7	1219.5	618.4
66 - hi	676.6	819.0	761.2	1128.0
N=226	43	42	74	67

Means

Males	1006.5	Females	730.5
Black	1045.6	Black	743.2
White	966.5	White	716.4
	Entire Population	834.3	

Between Groups	Within Groups
F 3.005	-eta .01150
p<0.0844	-eta 0.0132

IX

LITERATURE CITED

Abramson, D., S. M. Roberts and P. D. Wilson 1934 "Relaxation of the pelvic joints in pregnancy". *Surgery, Gynecology and Obstetrics*, 58:595-613.

Acsádi, G., and J. Nemeskéri 1970 *History of Human Life Span and Mortality*. Akademiai Kiado, Budapest.

Anderson, James E. 1978 *Grant's Atlas of Anatomy*. 7th ed. The Williams and Wilkins Company, Baltimore.

Angel, J. L. 1969 "The bases of paleodemography." *American Journal Physical Anthropology*, 30:427-438.

Angel, J. L. 1976 "Colonial to modern skeletal change in the U.S.A." *American Journal of Physical Anthropology*, 45:723-736.

Arthur, Hugh R. 1974 "Pelvic architecture and pelvic assessment". *Practioner*, 213:829-831.

Ashworth, J. T., M. J. Allison, E. Gerszten and A. Pezzia 1976 "The pubic scars of gestation and parturition in a group of pre-Columbian and colonial Peruvian mummies." *American Journal of Physical Anthropology*, 45:85-89.

Basmajian, J. V. 1970 *Primary Anatomy*. Sixth Edition. The Williams and Wilkins Company, Baltimore.

Basmajian, J. V. 1974 *Muscles Alive: Their Functions Revealed by Electromyography*. The Williams and Wilkins Company, Baltimore.

Bezerin, D. 1950 "Pelvic insufficiency during pregnancy and after parturition." *Acta Obstetrica et Gynecologica Scandinavica*, Supplementum 30 (supplement 1):170-182.

Bock, Walter J. 1980 "The definition and recognition of biological adaptation." *American Zoology*, 20:217-227.

Bock, Walter J., and Gerd von Wahlert 1965 "Adaptation and the Form-Function Complex." *Evolution: International Journal of Organic Evolution*. 19:3:1965.

Bohrnstedt, George W. and T. Michael Carter 1971 "Robustness in Regression Analysis". *Sociological Methodology*. Herbert L. Costner, ed. Jossey-Bass Inc, Pub. pp:118-146.

Boland, Benedict F. 1933 "Separation of symphysis pubis." *New England Journal of Medicine*, 208:8:431-438.

Borell, U. and I. Fernstrom 1957 "The movements at the sacro-iliac joints and their importance to changes in the pelvic dimensions during parturition." *Acta Obstetrica et Gynecologica Scandinavia*, 36:42-57.

Borell, U. and I. Fernstrom 1967 "The mechanism of labour." *The Radiological Clinics of North America*, 5:73-85.

Brinker, R.A. 1985 "Pelvic index in Illinois Hopewell." *American Journal of Physical Anthropology*, 66:2:150 (Abstr).

Brooke, R. 1924 "The sacro-iliac joint." *Journal of Anatomy*, 58:299-305.

Broom, R. and J. T. Robinson 1950 "Notes on pelves of fossil ape-men." *American Journal of Physical Anthropology*, 8:4:489-494.

Brothwell, O. 1963 *Digging Up Bones*. British Museum, National History, London.

Caldwell, W. E.and H. C. Moloy 1933 "Anatomical variation in the female pelvis and their effect in labor with a suggested classification." American Journal of Obstetrics and Gynecology, 26:479-505.

Caldwell, W. E. and H. C. Moloy 1938 "Anatomical variations in the female pelvis: Their classification and obstetrical significance." Proceedings of the Royal Society of Medicine 32:1-30.

Caldwell, W. E., H. C. Moloy and D. A. D'Esopo 1934 "Further studies on the pelvic architecture." American Journal of Obstetrics and Gynecology, 28:482-497.

Campbell, Bernard G. 1979 Humankind Emerging. 2 Ed. Little Brown and Company, Boston.

Cleland, J. 1889 "On certain differences of form hitherto unoticed in the human pelvis, characterisics of sex, age and race." Memoirs and Memoranda in Anatomy, 1:95-103.

Cobb, W. Montague 1959 "Thomas Wingate Todd." Journal of the National Medical association. 51:3:233-246.

Cobb, W. M. 1933 "Human materials in American institutions available for anthropological study." American Journal of Physical Anthropology, 17 (Supplement):1-45.

Cohen, J. 1969 "Multiple regression as a general data-analytic system". Psychological Bulletin, 70:426-443.

Davivongs, V. 1963 "The pelvic girdle of the Australian aborigine; sex differences and sex determination." American Journal of Physical Anthropology, 21:4:443-455.

Derry, D. E. 1909 "Note on the innominate bone as a factor in the determination of sex: With special reference to the sulcus Preauricularis."

Journal of Anatomy and Physiology, 43:266-276.

Derry, D. E. 1911a "Note on accessory articular facets between the sacrum and ilium, and their significance." Journal of Anatomy and Physiology, 45:202-210.

Derry, D. E. 1911b "The significance of the preauricular sulcus." Anatomischer Anzeiger, 39:13-20.

Derry, D. E. 1912 "The influence of sex on the position and composition of the human sacrum." Journal of Anatomy Physiology, 46:184-192.

Derry, D. E. 1923 "On the sexual and racial characters of the human ilium." Journal of Anatomy, 58:71-83.

DiBennardo, Robert and James V. Taylor 1983 "Multiple discriminant function analysis of sex and race in the postcranial skeleton." American Journal of Physical Anthropology 61:3:305-314.

Dobzhansky, Theodosius 1968 "Adaptedness and fitness." In: Population Biology and Evolution. Syracuse University Press, Syracuse, pp.109-121.

Dobzhansky, Theodosius, Francisco J. Ayala, G. Ledyard Stebbins, and James W. Valentine 1977 Evolution. W.H. Freeman and Company, San Francisco.

Duncan, J.M. 1854 Dublin Qarterly Journal of Medical Science, 18:60.

Duncan, J.M. 1868 Researches in Obstetrics. Black, Edinburgh, p. 157..

Elftman, Herbert Oliver 1932 "The evolution of the pelvic floor of primates." American Journal of Anatomy, 51:2:307-346.

Enlow, Donald H. 1963 Principles of Bone Remodeling. Charles C. Thomas, Pub. Springfield, Illinois

Enlow, Donald H. 1976 "The Remodeling of Bone". Yearbook of Physical Anthropology, 20:19-34.

Fawcett, E. 1938 "The sexing of the human sacrum." Journal of Anatomy, 72:633.

Flander, L. B. 1978 "Univariate and multivariate methods for sexing the sacrum." American Journal of Physical Anthropology, 49:103-110.

Francis, C. C. 1952 The Human Pelvis. C. V. Mosby Co. St. Louis.

Gagnon, Mario 1986 "Sexual dimorphism of the femur, sacrum and innominate bones in Macaca mulatta." American Journal of Physical Anthropology, 69:2:203 (Abstr).

Gejvall, N. G. 1970 "The Fisherman from Barum-mother of several children! Palaeo-anatomic finds in the skeleton from Backaskog." Fornvannen, 4:281-289.

Gilbert, B. M. and T. W. McKern 1973 "The method for aging the female os pubis." American Journal of Physical Anthropology, 38:31-38.

Goel, V. K. and N. L. Svensson 1977 "Forces on the pelvis." Journal of Biomechanics, 10:195-200.

Grant, J. C. Boileau 1972 An Atlas of Anatomy. Sixth Ed. The Williams and Wilkins Company, Baltimore.

Gray, Henry 1977 Gray's Anatomy. T. Pickering Pick and Robert Howden (eds.). Revised from the Fifteenth English, Edition. Bounty Books, N.Y.

Greulich, W.W. and H. Thoms 1938 "The dimensions of the pelvic inlet in 789 white females". Anatomy Record, 72:45-51.

Gunn, Christine 1984 Bones and Joints. Churchill Livingstone, Edinburgh.

Hall, Kathleen 1950 "The Effect of Oestrone and Progesterone on the Histological Structure of the Symphysis Pubis of the Casterated Mouse". _Journal of Endocrinology_, 7:54-53.

Hancox, N. M. 1972 _Biology of Bone_. Cambridge University Press, Cambridge.

Heyman, J. and A. Lundquist 1932 "The symphysis pubis in pregnancy and parturition." _Acta Obstetrica et Gynecologica Scandanivica_, 12:2:191-226

Hildebrand, Milton 1974 _Analysis of Vertebrate Structure_. John Wiley and Sons. N.Y.

Hisaw, F.L. 1925 _Journal of Experimental Zoology_. 42:111.

Hisaw, F.L. 1932 _Sex and Internal Secretions_. Edgar Allen (ed.) Williams and Wilkins Company Baltimore, Chapt. 2.

Holt, C. A. 1978 "A re-examination of parturition scars on the human female pelvis." _American Journal of Physical Anthropology_, 49:91-94.

Houghton, P. 1974 "The relationship of the pre-auricular groove of the ilium to pregnancy." _American Journal of Physical Anthropology_, 41:381-390.

Houghton, P. 1975 "The bony imprint of pregnancy." _Bullatin N.Y. Academy of Medicine_, 51:5:655-661.

Howells, W.M. and H. Hotelling 1936 "Measurements and correlations on pelves of Indians of the southwest." _American Journal of Physical Anthropology_, 21:91-106

Hoyme, L.E. 1957 "The earliest use of indices for sexing pelves." _American Journal of Physical Anthropology_, 15:4:537-546.

Hoyme, L.E. 1963 _Human Skeletal Variation_. Ph.D. dissertation, Oxford University.

Hrdlička, A. 1939 Practical Anthropometry. 2nd ed., Wistar Institute. Philadelphia.

Ince, J.G.H. and M. Young 1940 "The bony pelvis and its influence on labour: A radiological and clinical study of 500 women." Journal of Obstetrics and Gynaecology of the British Empire, 47:130-190.

Işcan, M. Y. 1986 "Comparison of the Hamann-Todd and Terry Collections: A test of techniques on the determination of race, sex and stature." To appear in Race Identification from the Human Skeleton, G. W. Gill and J.S. Rhine (Eds.) Maxwell Museum, University of New Mexico, Albuquerque, NM. (in press).

Işcan, M. Y. 1985 Personal Communication.

Işcan, M. Y. 1983 "Assessment of race from the pelvis." American Journal of Physical Anthropology, 62:2:205-208.

Işcan, M. Y. 1981 "Race determination from the pelvis." OSSA, 8:95-100.

Işcan, M. Y. 1981 "Metrical analysis of pelves of American Indians, Whites and Blacks." American Journal of Physical Anthropology, 54:2:239-240 (Abstr.).

Işcan, M. Y. 1980 "Differences in pelvic dimensions between American Blacks and Whites." American Journal of Physical Anthropology, 52:2:239-240 (Abstr.).

Işcan, M. Y. 1981 "Secular changes in the bony pelvis among American Blacks and Whites." Presented at the annual meeting of the Florida Anthropological Society. Cocoa Beach, Florida, March 7.

Işcan, M. Y. and T. S. Cotton 1985 "The effect of age on the determination of race from the pelvis." Journal of Human Evolution, 14:275-282.

Işcan, M. Y. and K. Derrick 1984 "Determination of sex from the sacroiliac joint: A visual assessment technique." Florida Scientist, 44(2):94-98.

Işcan, M. Y. and S. S. Dunlap 1983 "Sexing the human sacroiliac joint." American Journal of Physical Anthropology, 60:208-209 (Abstr.).

Kapandji, I. A. 1974 The Physiology of the Joints: The Trunk and the Vertebral Column, Volumn 3. Churchill Livingstone. Edinburgh.

Katz, J. Lawrence 1980 "The Structure and Biomechanics of Bone." In: The Mechanical Properties of Biological Materials. Vincent, J.F.V., and J.D. Curry (eds.). Cambridge University Press, Cambridge.

Kelley, M. A. 1979 "Parturition and pelvic changes." American Journal of Physical Anthropology, 51:541-546.

Kelso, A. J. and Wenda R. Trevathan 1984 Physical Anthropology. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Kerley, E.R. 1978 "Recent developements in forensic medicine." Yearbook of Physical Anthropology, 21:160-173.

Kim, Jae-on and Frank J. Kohout 1975 "Multiple Regression Analysis: Subprogram Regression." Statistical Package for the Social Sciences. N.H. Nie, C.H. Hull, J.G. Jenkins, K. Steinbrenner and D.H. Bent (eds.). McGraw-Hill Book Co., New York, pp. 320-367.

Kimura, K. 1982 "A base-wing index for sexing the sacrum." Journal of Anthropology, Society of Nippon, 90(Suppl):153-162.

Knoke, David 1975 "A comparison of log-linear and regression mdoels for systems of dichotomous variables." Sociological Methods and Research. 3(4)416-434.

Krogman, W.M. and M. Y. Iscan 1986 The Human Skeleton in Forensic Medicine. Charles C. Thomas, Springfield, Illinois.

Krukierek, S. 1951 "The sexual differences in the human pelvis." Gynecologia, 132:92-110.

Kuhns, J. G. 1935 "Pelvic inclination in relation to stability of hip joint." Physiotherapy Review, 15:16-18.

Lewontin, R. C. 1978 "Adaptation." Scientific American, 239:3:213-230.

Little, Kitty 1973 Bone Behaviour. Academic Press. London.

Lohr, Pipin 1894 "Ueber den sulcus praeauricularis des Darmbeins und ahnliche Furchen anderen Knochen." Anatomischer Anzeiger, 9:521.

Lovell, Nancy C. 1985 "A new test of Phenice's method for determining sex from the Os Pubis." American Journal of Physical Anthropology, 66(2)198-199 (Abstr.).

Lynch, F.W. 1920 "The pelvic articulation during preganacy, labor and puerperium." Surgery, Gynecology and Obstetrics, 30:575.

MacConaill, M. A. and J. V. Basmajian 1969 Muscles and Movements: A Basis for Human Kinesiology. The Williams and Wilkins Company, Baltimore.

Matthews, W. and J.S. Billings 1891 "The human bones of the Hemenway Collection in the United States Army Medical Museum in Washington." Member of the National Academy of Science, 6:139-286.

Maxwell, Alice F. 1938 "Abstract of Discussion", (of Joints During Pregnancy, Thorp and Fray, 1938). Journal of American Medical Association, 111:1165-1166.

Mayr, E. 1962 "Accident or design:The Paradox of Evolution." In: The Evolution of Living Organisms. Royal Society of Victoria. Melbourne University Press, Melbourne. pp. 1-14.

Mayr, E. 1963 Animal Species and Evolution. Harvard University Press, Cambridge.

Mayr, E. 1970 Population, Species and Evolution. Harvard University Press, Cambridge.

Mayr, E. 1983 "How to carry out the Adaptationist Program?" The American Naturalist, 121(3) 324-334.

McKern, T. W. and T. D. Stewart 1957 "Skeletal age changes in young American males." Quartermaster Research and Developement Command Technical Report, EP-45, Natick.

Mednick, L. W. 1955 "The evolution of the human ilium." American Journal of Physical Anthropology, 13:2:203-216.

Meindl, R. S., C. O. Lovejoy, R. P. Mensforth, and L. D. Carlos 1985 "Accuracy and Direction of Error in the Sexing of the Skeleton: Implications for Paleodemography." American Journal of Physical Anthropology, 68:79-85.

Mengert, W. F. 1936 American Journal of Obstetrics and Gynecology, 31:775.

Mengert, W. F. 1956 "Discussion of Ulfelder H.: Mechanisms of pelvic support in women." American Journal of Obstetrics and Gynecology, 72:863.

Miles, Judith 1986 "An almost perfect pubic index." American Journal of Physical Anthropology, 69(2)240-241 (Abstr.).

Meindl, R.S. and C.O. Lovejoy 1985 "Accuracy and direction of error in the sexing of the skeleton: Implications for paleodemography." American Journal of Physical Anthropology, 66(2)205 (Abstr.).

Morton, D. G. 1942 "Observations of the development of pelvic conformation." American Journal of Obstetrics and Gynecology, 44:799-819.

Muller, H. J., et al. 1949 "Natural Selection and Adaptation". Proceedings of the American Philosophy Society, 93:459-519.

Nemeskeri, J. 1972 "Die archaologischen und anthropologischen Voraussetzungen palaodemographischer Forschungen." Praehistorische Zeitschrift, 47:5-46.

Nicholson, C. 1945 "The two main diameters at the brim of the female pelvis." Journal of Anatomy, 79 (Part 3):131-135.

Nie, Hull, Jenkins, Steinbrenner and Bent (Eds) 1975 SPSS Statistical Package for the Social Sciences. McGraw Hill Book Co.

Ohlsen, Hans 1973 "Moulding of the pelvis during labour." Acta Radiologica Diagnosis, 14:417-434.

Ortner, D. J. and W. G. J. Putschar 1981 Identification of Pathological Conditions in Human Skeletal Remains. Smithsonian Institution Press, Washington D.C.

Owsley, Douglas W. and B. Bradtmiller 1983 "Mortality of pregnant females in Arikara villages: osteological evidence." American Journal of Physical Anthropology, 61:3:331-336.

Oxorn, Harry 1980 Human Labor and Birth. Appleton-Century-Crofts, New York.

Phenice, T. W. 1969 "A newly developed visual method sexing the os pubis." American Journal of Physical Anthropology, 30:297-301.

Putschar, W. G. J. 1931 Entwicklung, Wachstum und Pathologie der Beckenverbindungen des Menschen, mit besonderer Berucksiehtigung von Schwangershaft, Geburt und ihren Folgen. Gustav Fischer, Jena.

Putschar, W. G. J. 1976 "The structure of the human symphysis pubis with special consideration of parturition and its sequelae." American Journal of Physical Anthropology, 45:589-594.

Reynolds, E. 1947 "The bony pelvis in prepuberal childhood." American Journal of Physical Anthropology, 5:165-200.

Reynolds, E. 1945 "The bony pelvic girdle in early infancy." American Journal of Physical Anthropology, 3:231-354.

Reynolds, E. 1931 "The evolution of the human pelvis in relation to the mechanics of erect posture." Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, 11:5:255.

Reynolds, E. and E. A. Hooton 1936 "Relation of the pelvis to erect posture: An explanatory study." American Journal of Physical Anthropology, 21:253-278.

Roberts, R.E. 1934 "Discussion on the physiology and pathology of the pelvic joints in relation to childbearing: A radiological investigation." Proceedings of the Royal Society of Medicine, 27:1217.

Robinson, John T. 1972 Early Hominid Posture and Locomotion. The University of Chicago Press, Chicago.

Russel, J. G. B. 1965 "Gas in the sacro-iliac joint in pregnancy." Journal of Obstetrics and Gynaecology of the British Commonwealth, 72:797.

Russel, J. G. B. 1969 "Moulding of the pelvic outlet." Journal of Obstetrics and Gynaecology of the British Commonwealth, 76:817-820.

Sashin, David 1930 "A critical analysis of the anatomy and the pathologic changes of the sacro-iliac joints." Journal of Bone and Joint Surgery, 12:891-910.

Schulter-Ellis, F. P. and L. C. Hayek 1984 "Predicting race and sex with an acetabulum/pubis index." American Journal of Physical Anthropology, 63:2:216 (Abstr.).

Schulter-Ellis, F. P. and L. C. Hayek 1985 "Sexing Indian skeletons with the acetabulum/pubis index." American Journal of Physical Anthropology, 66:2:227 (Abstr.).

Schultz, A. H. 1930 "The skeleton of the trunk and limbs of higher primates." Human Biology, 3:303.

Selby, Samuel M. 1973 Standard Mathematical Tables. The Chemical Rubber Company.

Seligmann, S. B. 1935 "Articulatio sacro-iliaca accessoria." Anatomischer Anzeiger. 79,225-241.

Snell, Richard S. 1978 Atlas of Clinical Anatomy. Little, Brown and Company. Boston.

Snelling, Frederick G. 1870 "Relaxation of the pelvic symphysis during pregnancy and parturition." American Journal of Obstetrics and Diseases of

Women and Children, 2(4):561-596.

Spring, D. B., G. N. Bender and C. O. Lovejoy 1984 "The radiographic preauricular groove: its non-relationship to pregnancy." American Journal of Physical Anthropology, 63:2:220-221 (Abstr.).

Stebbins, G. L. and F. J. Ayala 1981 "Is a new evolutionary synthesis necessary?" Science. 213:967-971.

Steinbock, R. Ted 1976 Paleopathological Diagnosis and Interpretation. Charles C. Thomas, Publisher Springfield, Illinois.

Stewart, T. D. 1938 "Accessory sacro-iliac articulations in the higher primates and their significance." American Journal of Physical Anthropology, 24:43-55.

Stewart, T. D. (ed.) 1952 Hrdlicka's Practical Anthropometry. 4th Ed. The Wistar Institute of Anatomy and Biology. Philadelphia.

Stewart, T. D. 1954 "Sex determination of the skeleton." American Journal of Physical Anthropology, 12:385-392.

Stewart, T. D. 1957 "Distortion of the pubic symphyseal surface in females and its effect on age determination." American Journal of Physical Anthropology, 15:9-18.

Stewart, T. D. 1968 "Identification by the skeletal structures." In: Gradwohl's Legal Medicine. Camps, F.E. (ed.). J. Wright and Sons, Ltd., Bristol, England. pp. 123-154.

Stewart, T. D. 1969 "The effects of pathology on skeletal populations." American Journal of Physical Anthropology, 30:443-450.

Stewart, T. D. 1970 "Identification of the scars of parturition in the skeletal remains of females."

In: Personal Identification in Mass Disasters. Stewart, T. D. (Ed.), Washington, D. C., National Museum of Natural History, pp. 127-134.

Stewart, T. D. 1979 Essentials of Forensic Anthropology: Especially as Developed in the United States. Charles C. Thomas, Publisher Springfield, Illinois.

Straus, W. L. 1927 "The human ilium: Sex and stock." American Journal of Physical Anthropology, 11:1:2-28.

Straus, W. L. 1929 "Studies on primate ilia." American Journal of Anatomy, 43:403-460.

Suchey, J. M. 1979 "Problems in the aging of females, using the os pubis." American Journal of Physical Anthroplogy, 51:467-470.

Suchey, J. M., D. V. Wisely, R. F. Green and T. T. Noguchi 1979 "Analysis of dorsal pitting in the os pubis in an extensive sample of modern American females." American Journal of Physical Anthropology, 51:517-523.

Swanson, S.A.V. 1980 "Articular Cartilage." In: The Mechanical Properties of Biological Materials. Vincent J.F.V. and J.D. Curry (eds.) Cambridge University Press, Cambridge.

Tague, R. G. 1985 "Inferences concerning bone resorption at the pubis and preauricular area." American Journal of Physical Anthropology, 66(2)237 (Abstr.).

Templeton, Alan R. 1982 "Adaptation and the integration of evolutionary forces." In: Perspectives on Evolution. Roger Milkman (ed.) Sinauer Associates, Inc., Mass.

Thoms, H. 1915 American Journal of Obstetrics, 72:121.

Thoms, H. 1936 "Relaxation of the symphysis pubis in pregnancy." Journal of American Medical

Association, 106:1364-1366.

Thoms, H. 1942a "The clinical application of roentgen pelvimetry and a study of the results in 1,100 White women." American Journal of Obstetrics and Gynecology, 42:957-975.

Thoms, H. 1942b "Discussion of Morton, D.G.: Observations of the development of pelvic conformation." American Journal of Obstetrics and Gynecology, 44:818.

Thoms, H. and W. W. Greulich 1940 "A comparative study of male and female pelves." American Journal of Obstetrics and Gynecology, 39:56-62.

Thoms, H. and H. M. Wilson 1938 "Roentgen methods for routine obstetrical pelvimetry." Yale Journal of Biology and Medicine, 10:432-444.

Thomson, A. 1899 "The sexual differences of the foetal pelvis." Journal of Anatomy and Physiology, 33:359-380.

Thorp, D. J. and W. E. Fray 1938 "The pelvic joints during pregnancy and labor." Journal of American Medical Association, 111:1162-1166.

Todd, T. W. 1920 "The male white pubis." American Journal of Physical Anthropology, 3:285-335.

Todd, T. W. 1923 "Age changes in the pubic symphysis." Journal of Anatomy, 57:274-294

Todd, T. W. and A. Lindala 1928 "Dimensions of the body: Whites and American Negroes of both sexes." American Journal of Physical Anthropology, 12:35-119.

Torpin, T. W. 1951 "Roentgenpelvimetric measurements of 3604 female pelves, White, Negro and Mexican compared with direct measurements of Todd anatomy collections." American Journal of Obstetrics and Gynecology, 62:279-293.

Trotter, M. 1926 "The sacrum and sex." American Journal of Physical Anthropology, 9:445-450.

Trotter, M. 1937 "Accessory sacro-iliac articulations." American Journal of Physical Anthropology, 22:247-261.

Trotter, M. 1967 "Accessory sacro-iliac articualtion in East African skeletons." American Journal of Physical Anthropology, 22:137-142.

Turlk, Samuel L. 1977 Orthopaedics Principles and Their Application. 3 ed. J.B. Lippincott Co., Philadelphia.

Turner, W. 1886 "The sacral index in various races of mankind." Journal of Anatomy and Physiology, 20:317-323.

Ulfelder, H. 1956 "Mechanism of pelvic support in women: deductions from study of comparative anatomy and physiology of structures involved." American Journal of Obstetrics and Gynecology, 72:856.

Ullrich, H. 1975 "Estimation of fertility by means of pregnancy and childbirth alterations at the pubis, ilium and the sacrum." OSSA, 2:23-39.

Vayas, K. et al. 1981 "Quantitative scintiagraphy of sacroiliac joints: Effects of age, gender and laterality." American Journal of Roentgenology, 136:589-592.

Walcher, G. 1889 "Die Conjugata eines engen Beckens ist keine konstante Grosse, sondern lasst sich durch die Korperhaltung der Tragerin verandern." Zentralbl. Gyak, 13:892.

Wallace, R.B. and V.A. Wilk 1979 "Occupational Hazards." In: Trauma in Pregnancy. H.J. Buchsbaum (ed.). Saunders, Philadelphia, pp. 9:167-188.

Washburn, S.L. 1942 "Skeletal proportions of adult langurs and macaques." Human Biology, 14:444-472.

Washburn, S.L. 1948 "Sex differences in the pubic bone." American Journal of Physical Anthropology, 6:199-207.

Washburn, S.L. 1949 "Sex differences in the pubic bone of the Bantu and Bushman." American Journal of Physical Anthropology, 7:425-432.

Waterman, H.C. 1929 "Studies on the evolution of the pelvis of man and other primates." Bulletin American Museum of Natural History, 55:585.

Weed, John C. 1972 "Pelvic anatomy from the point of view of a gynecologic surgeon." Clinical Obstetrics and Gynecology, 15:1035-1047.

Weisl, H. 1954a "The ligaments of the sacro-iliac joint examined with particular reference to their function." Acta Anatomica, (Basel)20:3:201-213.

Weisl, H. 1954 "The articular surfaces of the sacro-iliac joint and their relation to the movements of the sacrum." Acta Anatomica, 22:1-14.

Weisl, H. 1955 "The movements of the sacro-iliac joint." Acta Anatomica, 23:80-91.

Weiss, G., E.M. O'Byrne and B.G. Steinetz 1976 "Relaxin: A product of the human corpus luteum of pregnancy." Science, 194:948-949.

Williams, J. 1911 American Journal of Obstetrics, 64:106.

Williams, J.T. 1922 "Normal variation in type of the female pelvis and their obstetrical significance." American Journal of Obstetrics and Gynecology, 3:345-351.

Willis, T.A. 1933 "Sacro-iliac arthritis." Surgery, Gynecology, Obstetrics, 57:2:147-155.

Wilson, P.M. 1973 "Understanding the pelvic floor."

South African Medical Journal, 47:1150-1167.

Wiltse, L.L. and C.H. Frantz 1956 "Non-suppurative osteitis pubis in the female." *Journal of Bone and Joint Surgery*, 38:A:500-516.

Wolpoff, Milford H. 1980 *Paleoanthropology*. Alfred A. Knopf, New York.

Young, M. 1940 "Relaxation of the pelvic joints in pregnancy." *Journal of Obstectrics and Gynaecology of the British Empire*, 47:493.

Young, M. and J.G.H. Ince 1940 "A radiographic comparison of the male and female pelvis." *Journal of Anatomy*, 74:374-385.

Zaaijer, T. 1866 "Untersuchugen ueber die Form des Beckens javanischen Frauen." *Gesellschaft der Wissensch zu Haarlem, D*. Vol. 24, Holland.

Zaglas 1851 "Mechanism of the pelvic articulations." *Monthly Journal of Medical Science*, Sept.:289.