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I am submitting herewith a thesis written by Connie Lynn Hall entitled "Anatomical Alterations of the Pelvis: The Significance When Determining Childbirth and Sex." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

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ANATOMICAL ALTERATIONS OF THE PELVIS: THE SIGNIFICANCE WHEN DETERMINING CHILDBIRTH AND SEX

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ABSTRACT

Research concerned with the osteological alterations in the pelvic girdle thought to be associated with pregnancy and parturition is fairly recent. Much of the research in this area has dealt with the osteological alterations seen on the anterior and posterior pubic facies. The research on the sacroiliac joint has leaned toward the preauricular sulcus of the ilium. Consequently, data pertaining to the osteological alterations thought to be associated with pregnancy and parturition seen on the lateral margins of the anterior face of the first through third sacral vertebrae are not complete. It is my intention in this thesis to demonstrate what changes thought to be associated with pregnancy and parturition may be seen on the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae, in particular the sacrum.

The skeletal material used in this thesis consists of 61 males and 51 females (12 years and older) and 115 of undetermined sex (under 12 years of age) Arikara American Indians from the Mobridge collection housed in the Osteological Laboratory of the Department of Physical Anthropology at the University of Tennessee, Knoxville, and in the Department of Physical Anthropology at the Smithsonian Institution, Washington, D.C.

Osteological alterations of the pelvic girdle thought to be associated with pregnancy and parturition include new bone formation and

bone resorption in the form of depressions, pits, cavities and grooves. The presence, position and frequency of the changes seen in the pelvic girdle thought to be associated with pregnancy and parturition were visually noted. The size (length, width and depth when applicable) of the alterations were determined through measurements. In an attempt to explain how and why these changes may be present, hypotheses were proposed.

The data suggest that osteological alterations seen on the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae in female skeletal material are associated with pregnancy and parturition. The changes associated with pregnancy and parturition are seen on those areas of the bone that are subject to great stress during pregnancy and parturition: the sites of attachment for the interpubical ligaments, the sacroiliac ligaments, the uterine ligaments, the perineal muscles and the anterior abdominal muscles. The changes similar to those associated with pregnancy and parturition were not seen in any of the skeletal material under the age of 12 years and were rarely seen in the male skeletal material over the age of 12. If changes thought to be associated with pregnancy and parturition had been present in skeletal material under the age of 12 years and no explanation could be offered then our assumptions of associating alterations in the pelvic girdle with pregnancy and parturition would be wrong. The presence of changes similar to those associated with pregnancy and parturition in some of the male skeletons

may be explained through the natural stresses from physical exertion commonly experienced by both males and females. The alterations are more extensive in the female skeletal material because the effects of physical exertion are exaggerated during pregnancy. Through changes in body function during pregnancy, bone composition is altered, muscular tissue is subject to excessive strain and the blood clotting factor is hampered. The results are new bone formation and bone resorption in the form of depressions, pits, cavities and grooves.

Determination of the number of births per female was not possible because a population for which the actual number of births per female is documented was not available. As a result, the data presented in this thesis can only suggest that alterations present on the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae may help to indicate males, nulliparas (females having given no births), primiparas (females having given one birth) or multiparas (females having given two or more births).

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CHAPTER I

INTRODUCTION

I. INTRODUCTION TO PROBLEM

Osteological alterations of the pelvic girdle thought to be associated with pregnancy and parturition have been the focus of previous research in anatomy and physical anthropology (Angel 1969a, 1969b; Houghton 1974; Putschar 1976; Stewart 1957, 1970; Ullrich 1975). The particular areas of the pelvic girdle studied in these research projects are the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae.

It is my intention to demonstrate what changes may be seen in the pelvic girdle as a result of pregnancy and parturition. Special attention will be given to the sacrum, since it may be the most sensitive indicator of pregnancy and parturition.

Most research in the area of osteological alterations of the pelvic girdle thought to be associated with pregnancy and parturition has dealt with changes seen on the pubic facies (Angel 1969a, 1969b; Putschar 1976; Stewart 1957, 1970; Ullrich 1975). Research dealing with the sacroiliac joint has dealt more with the preauricular sulcus (Houghton 1974, Ullrich 1975). As a result alterations due to pregnancy and parturition have not been completely demonstrated on the sacrum. Additional data in all four areas, specifically the sacrum, are needed.

This research will be accomplished through a visual and osteometric analysis of the skeletal material from the Mobridge Site (39WW1), South Dakota. The skeletal material from the Mobridge Site consists of Arikara American Indians. The Mobridge Site (39WW1) is located in north-central South Dakota. Excavations began here in 1923 under the direction of Dr. Mathew W. Stirling (Wedel 1955). No further excavations took place until the late 1960's. Under the direction of Dr. William M. Bass of the University of Kansas (now of the University of Tennessee) 371 burials were recovered from 1968-1970 (Stewart and Ubelaker 1971). This material is now housed at the University of Tennessee. Under the direction of Dr. Douglas H. Ubelaker now of the Smithsonian Institution an additional 283 burials were recovered in 1971. This material is now housed at the Smithsonian Institution, Washington, D.C. All of this material, consisting of more than 650 skeletons, is available for study.

The presence, position and frequency of such changes as new bone formation, depressions, pits, cavities and grooves seen in the pelvic girdle thought to be associated with pregnancy and parturition were visually analyzed. The size (length, width and depth when applicable) of each alteration was determined metrically. Hypotheses explaining how and why these changes occur are proposed.

The forensic implications of an association between osteological alterations of the pelvic girdle and pregnancy and parturition will be demonstrated. Criteria used to demonstrate differences between males, nulliparas (females having given no birth), primiparas (females

having given one birth) and multiparas (females having given two or more births) can only be suggested since no population recording the actual number of births per female is available. It is hoped that the data collected for this thesis will be used as a foundation for further research.

II. AGING VIA THE OS PUBIS

Early studies using the os pubis as an indicator of age (Todd 1920, 1921, 1930) have received further explanation and various forms of revision by other researchers. The os pubis consistently overages females by approximately ten years (Gilbert and McKern 1973:31). This results from applying male standards to females.

Brooks (1955) discusses the aging techniques described and by testing Todd's procedures finds that the ages ascertained from both the os pubis and cranial suture closure for any particular skeleton were more consistent for males (plus or minus five to eight years) than for females (plus or minus five to twenty-five years). She concluded that factors other than age must be acting on the female pubic bone and that these factors should be considered when assessing the age of skeletal material. Although aware of the alterations of the pubic bone, Brooks made no attempt to attribute these changes to parturition.

Gilbert and McKern (1973) substantiate a further need for separate aging techniques for males and females when using the os pubis. Noting the osteological differences between the male and female os pubis, Gilbert and McKern developed a more accurate method to indicate age than

that devised by Todd (1921). They attribute the differences confined to the female os pubis to parturition.

III. CHANGES ASSOCIATED WITH PARTURITION

The apparent need to revise the standard aging techniques of the os pubis has resulted in the investigation of changes occurring in the pelvic girdle thought to be associated with pregnancy and/or parturition. Many studies (Houghton 1974; Stewart 1957, 1970; Ullrich 1975) have dealt specifically with changes occurring in association with parturition. Changes thought to stem from pregnancy will be discussed here because many stresses resulting in damage to the bones of the pelvic girdle occur all during pregnancy as well as during parturition.

Stewart (1957) has spent many years examining the pubic bone of several different skeletal populations. Examining the pubic symphyseal surfaces of 450 American male soldiers and both male and female Eskimo skeletons for the purpose of devising aging techniques, Stewart (1957) noted that some of the Eskimo skeletons displayed contours of the dorsal pubic margin unlike any he had been accustomed to seeing. These abnormal contours consisted of depressions (shallow, some negligible), pits, cavities and/or grooves running parallel to the dorsal margin resulting in a breakdown or lipping of the dorsal pubic margin. After careful examination of these skeletons, Stewart concluded that the differences were present in what he felt was always a female, never present in a male and rarely seen in subadult female skeletons.

Reviewing the research of Todd (1921) and Brooks (1955), Stewart (1957) found described characteristics of the pubic symphyseal dorsal margin similar to those encountered in his Eskimo series. The characteristics were described as minor by Todd (1921:37). Brooks (1955:585), although noting the relative age group for these characteristics to appear, failed to see any sex link. Stewart (1957:16) concluded, ". . . abnormalities of the pubic symphysis confined to females must be connected with child-bearing."

Further, Stewart (1970) recognized that he was embarking upon a new field; that of using the female os pubis as an indicator of parturition. Returning to his work of 1957, Stewart (1970) reexamined his casts of the os pubis from the Eskimo series. In addition, he examined the skeletal remains of the Terry collection and specimens of known parity (numbering 30) sent to him by Dr. Mant of London. He made comparisons to see if modern obstetrical practices had any affect on the degree of change occurring in the pelvic girdle associated with parturition.

Stewart (1970) dealt specifically with the dorsal margin of the pubic symphysis and the adjacent posterior face. Because age related changes are continually taking place on the ventral margin of the pubic symphysis, Stewart feels the dorsal margin of the pubic symphysis and subsequently the posterior pubic face is the more accurate indicator of parity. He divided the changes seen on the posterior pubic face into three groups. The first group is without change. The second group displays shallow depressions and/or grooves running parallel to the articular surface. Because the depressions and grooves are often slight

Stewart feels that many times it could have been his imagination due to dorsal margin lipping and not an actual depression or groove he was seeing. For this reason, the percentage of individuals falling into the second group may often be exaggerated. The third group represents very definite scarring ranging from distinct to unmistakable cavities. Because there are many factors involving parturition and its affect on the pelvic girdle that have not yet been explored, Stewart feels forensic implications should be guarded.

Houghton (1974) feels that the preauricular sulcus of the ilium is the more accurate indicator of parity. The sacroiliac joint, positioned in the direct line of the transfer of body weight, is subject to a tensile strain (Evans 1957:96). This is exaggerated during pregnancy. Studying 119 skeletons, Houghton noted two distinct types of preauricular grooves. The first he described as the "groove of pregnancy." This ". . . gives the impression of being formed by the coalescence of a series of pits, or small craters, in the bone . . ." (Houghton 1974:381). The second type of groove he described as the "groove of ligament." This

> . . . is a narrow, short, straight-edged and shallow groove at the antero-inferior margin of the joint. Sometimes it is wider, extending laterally to the small tubercle situated almost a centimetre from the inferior margin of the joint, and in such cases, has a rather rough lateral edge. . . . (Houghton 1974:381)

Houghton suggests that the lateral margins of the anterior face of the sacrum may also be affected by pregnancy and parturition because "The same physio-pathological changes affecting the ilium affect the

attachment of the ligaments to the sacrum, but here the signs seem to be less constant and less reliable" (Houghton 1974:383).

Ullrich (1975) described changes that may be seen in the pelvic girdle associated with pregnancy and parturition. Changes including new bone formation, impressions, pits and grooves were described for the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae (Ullrich 1975:27-32). The changes were then categorized into one of four or five groups for each of the four areas to show a progression from bone exhibiting no change to bone exhibiting various degrees of change associated with pregnancy and parturition. The first group for each area was designated to characterize males and nulliparas. The next four or five groups for each area were designated to characterize primiparas or various degrees of multiparas.

CHAPTER II

OSTEOLOGICAL ALTERATIONS OF THE PELVIC GIRDLE DUE TO PREGNANCY AND PARTURITION

I. INTRODUCTION

During pregnancy and parturition bodily functions of the abdominal and pelvic cavities are altered. The mineral content of the bone and blood may be altered because of the increased demands made on the mineral and vitamin content (Kimber et al. 1961:514, McLean and Urist 1961:116). The ligamentous attachments of the muscles, the pelvic joints and the pelvic viscera are subject to strain due to many changes occurring in the body during this time. As a result of these changes, direct or indirect damage may be sustained to the pelvic bones. It is my intention to explain what changes thought to be associated with pregnancy and parturition may be present in the pelvic girdle.

The bone structure and composition, in conjunction with the actions of hormones, minerals and vitamins present during pregnancy may be altered. This may occur through the direct action of the hormones, minerals and vitamins or by the action of or the damage to the muscles and blood. Putschar (1976:589) suggests that, ". . . changes of the bone relief are mainly caused by and secondary to alterations of the cartilaginous and ligamentous components. . . ." Direct changes include bone demineralization, such as osteoporosis and osteomalacia (Morse 1969:27). Indirect changes stem from perforating tears of the

muscles and ligaments and hemorrhaging of the blood vessels (Greenhill and Friedman 1974:98, Putschar 1976:589, Ullrich 1975:25).

II. BONE COMPOSITION AND STRUCTURE

Bone composition in its natural state is 25 percent water, 30 percent organic material and 45 percent inorganic material. The organic elements determine the structure of the bone and the inorganic elements determine the hardness (Luck 1950:22).

Bone structure is of two types: cancellous and compact. The difference between these two types of structure lies in the degree of thickness and spacing of the trabeculae. Cancellous bone (found in the vertebral column and the innominates) has very thin trabeculae closely spaced. Compact bone has very thick trabeculae with large spacing. Porosity is greatest in cancellous bone (Luck 1950:31).

Bone hardness is determined by its mineral content. If a mineral or vitamin deficiency occurs the bone hardness may be affected. A deficiency may be the result of an improper intake of vitamins, the actions of hormones or the effects of disease. One or several bones may be involved.

III. HORMONES, MINERALS AND VITAMINS

Hormones secreted during pregnancy may cause changes to occur in the skeleton. Direct influence results in bone demineralization. Indirect influence through the muscles and blood results in new bone formation or bone resorption.

Adrenocorticotropin (ACTH) regulates the secretion of cortisone, increasing its production during stress situations. An excessive amount of cortisone, likely to result from the stresses of pregnancy, disturbs bone metabolism. The result is an insufficient amount of bone matrix. Severe osteoporosis, most seriously affecting the bones of the skull, spine and pelvis will result (Morse 1969:27).

Parathormone, a parathyroid hormone, also acts directly on bone. Through its regulation of the calcium levels in the blood, parathormone exerts action on the bone by stimulating osteoclastic resorption with a solution of the inorganic materials (McLean and Urist 1961:119). Hyperparathyroidism increases the blood calcium level and may result in generalized osteoporosis or muscular weakness (Kimber et al. 1961:424). Hypoparathyroidism decreases the blood calcium level and may result in tetany. Tetany is characterized by intermittent spasms or by a state of constant muscular contraction of the voluntary muscles. If this occurs during labor, a forceful delivery resulting in muscular lacerations will occur (Arnold 1968:298, Greenhill and Friedman 1974:663, Kimber et al. 1961:129).

Calcium is present in both the skeleton and the blood. In the skeleton, calcium is in part responsible for the degree of bone hardness. In the blood, calcium acts as a clotting agent. Calcium ". . . is related to normal permeability of cellular membranes, excitability of muscle . . . and must be present in ionic form for normal blood clotting" (Kimber et al. 1961:514). Because calcium requirements increase during pregnancy, a partial depletion may occur near term.

If the depletion is not replenished osteomalacia will develop with each successive pregnancy (Luck 1950:277). A low calcium level is usually not a problem because, "Most healthy adults are able to adapt to low intakes of calcium, provided that there is no deficiency of vitamin D" (McLean and Urist 1961:137).

Vitamin D is necessary for the absorption of calcium from the intestines and the level is usually sufficient in the adult body. The level of vitamin D is not sufficient in teenagers who are still providing for their own needs or in women who receive an improper intake of minerals and/or vitamins during pregnancy. Since the women in my sample are Indians, who often began having children as soon as possible and who did not have the advantage of modern obstetrical care, this could be important when interpreting the data (Stewart 1957:16-17). A deficiency of vitamin D often produces severe osteomalacia during the first pregnancy. According to McLean and Urist (1961), a hyperfunction of the parathyroid to mobilize calcium from the bones follows a vitamin D deficiency.

Iron functions in maintaining the necessary level of bone mineralization and in acting as a blood clotting agent. The high rate of iron lost during pregnancy may result in a marked osteoporosis. Anemia, also the result of an iron deficiency, retards the blood clotting factor. During and following delivery when hemorrhaging most often occurs, anemia results in an inability to control bleeding. Bone erosion may occur (Falls and Holt 1961:34-35, Kimber et al. 1961:690).

The actions of hormones, minerals and vitamins during pregnancy may lead directly to a demineralization of the skeleton. Having demineralized bones increases the effects of muscular and vascular stress. Indirectly the actions of hormones, minerals and vitamins may cause muscular weakness or spasms or a loss of the blood clotting factor. In the case of muscular weakness or spasms, strain is placed on the muscular and ligamentous attachments. The result is new bone formation to assure proper bone reinforcement for the attachments. If the strain is excessive, to the point of rupture and hemorrhaging of the muscle and its vessels, osteoclastic resorption will occur. A hindrance of the blood clotting factor during pregnancy and delivery will result in bone erosion.

IV. PREGNANCY

Relaxin, secreted all during pregnancy, relaxes the ligaments and cartilage of the pelvic joints in preparation for parturition. The pubic symphysis is most responsive to this hormonal action, the result being a separation of the pubic symphysis of 10 millimeters by term (Gilbert and McKern 1973:36).

Muscular and ligamentous strain resulting from hormonal secretions and the increased pregnant uterine weight produce changes on the anterior pubic face in the form of new bone formation. The sites of attachment for the anterior abdominal muscles and the anterior pubic ligaments, the pubic and superior margins, are affected. With additional pregnancies, this new bone formation is extended more and more laterally from the original sites of attachment.

Alterations similar to those occurring in females on the anterior pubic face may be seen in some males. Strain originating from sources other than the strain of pregnancy and parturition can be exerted onto the attachments of the anterior pubic ligaments and the anterior abdominal muscles by both males and females thus causing new bone formation. For this reason, I feel that the presence or size of the new bone formation in the area of these sites of attachment may not indicate the actions of pregnancy or parturition by themselves.

Excessive strain applied to the muscular and ligamentous attachments of the anterior pubic face may result in the attachments being pulled to the point of hemorrhaging. The result is, ". . . exostoses away from the ventral rampart . . . and characteristic pits with exostoses below the tubercle" (Angel 1969b:344). These begin to develop after the first or second birth (Angel 1969a:432).

The ligamentous attachments of the posterior pubic face are also subject to increasing strain. This produces new bone formation more and more laterally from the original sites of attachment (Putschar 1976:591). If the strain is excessive, bone resorption will occur. Bone resorption in the form of depressions, pits, cavities and grooves should never be seen in males and rarely in subadult female specimens (Stewart 1957:12). Changes of the posterior pubic face are the result of ligamentous lacerations, disintegration of the fibrocartilaginous disc, bruises caused by the fetal descension or hemorrhaging of the blood vessels.

The determination of the scars of pregnancy and parturition from the posterior pubic face, may be inaccurate. On the posterior pubic face, ". . . the bone . . . can be gradually remodeled to remove the evidence of the former presence of undermining depressions or cavities" (Stewart 1970:132).

The sacroiliac joints are not as responsive to the hormonal softening of relaxin as is the pubic symphysis. Still, the softening experienced by the sacral ligaments has the same result as that of the pubic symphysis. The strain placed on the sacroiliac joints due to the softening may result in a rupturing of the very tight ventral sacroiliac ligaments. This inevitably would produce irreparable bone resorption at the sites of attachment (lateral margins of the first, second and third alae of the sacrum and the preauricular sulcus of the ilium) in the form of pits, cavities and grooves.

Softening of the sacroiliac joints (a result of the actions of relaxin) causes an increased stress on the ligamentous attachments resulting in an increased tendency for the sacrum to be pushed between the ilia. The result is pelvic instability. McLennan and Sandberg (1974:65) suggest, ". . . pelvic instability, associated with postural lordosis occasioned by the increasingly protruding abdomen, frequently leads to a change of gait and to skeletal muscle strain." The body compensates for the protruding abdomen by throwing the shoulders back. This straightens the head and neck but exaggerates the curve in the small of the back. As a result, more of an effort is needed to hold the body erect.

The lower back muscles, under normal conditions, exhibit the highest degree of tonus in reference to the antigravity muscles (Kimber et al. 1961:125). During pregnancy, when there is pelvic instability, some of the muscles of the perineum and the sacral ligaments work together with the lower back muscles to maintain body erectness. The perineal muscles ". . . assist the associated ligaments in maintaining fixation of the sacroiliac joint by holding the posterior wall of the pelvis together . . ." (Thorek 1962:534). The excessive strain placed on the muscles and ligaments used in maintaining the erect position, results in damage to the sites of the muscular attachment. The sites of muscular attachment affected include the lateral margins of the second through third sacral alae.

Strain is also placed on the sacroiliac joints (in particular the sacrum) through the attachment of the uterosacral ligament. As the fetus increases in weight, additional support from the uterine attachments is needed. The areas affected by this attachment are the lateral margins of the second and third sacral alae.

V. PARTURITION

Parturition is divided into three stages. Dilatation is the first. This ". . . extends from the beginning of regular uterine contractions until the external os is completely dilated and flush with the channel called the parturient canal" (Greenhill and Friedman 1974:189).

The second stage of parturition is the expulsion of the infant. As the infant passes through the cervix, lacerations occur. This is usually the result of a premature bearing down effort by the patient, causing the infant to pass through a cervix not fully dilated or retracted. The lacerations incurred may be superficial or very deep, extending to the uterus and vagina. Hemorrhaging often occurs, resulting in bone erosion (Falls and Holt 1961:43).

The pelvic fascia, distended circularly, is stretched longitudinally. As a result, "The two levator ani pillars are parted and the intercolumnar fascia, which holds them in their relations to the rectum, vagina, perineum and each other, is destroyed" (Greenhill and Friedman 1974:657). The pelvic floor is also fully distended during labor to allow the passage of the fetus (Arnold 1968:298). Still, lacerations frequently occur during the first delivery. These may be the result of a premature bearing down effort, a prolonged labor or excessive rigidity.

Damage to the urogenital diaphragm occurs because of a lack of muscular tissue, causing this diaphragm to dilate poorly (Greenhill and Friedman 1974:221). If the damage is left unrepaired, the urogenital diaphragm will be destroyed, the pelvic viscera may herniate, and the pelvic floor may lose its supportive ability (Greenhill and Friedman 1974:657, Arnold 1968:287, Kimber et al. 1961:692).

Lacerations of the perineum are severely exaggerated if the muscles are not fully relaxed. Lacerations of the perineum due to

parturition are often seen in athletic women. Since the skeletons from my sample consist of Indian women, who often led ". . . a vigorous existence throughout their pregnancies . . ." (Stewart 1957:17), this may be of importance. Alterations thought to be associated with pregnancy and parturition may be exaggerated in the females in my sample because of the possibility of the overdevelopment of the perineal muscles due to their vigorous existence, leading to a difficult and traumatic birth.

Tears occurring in the pelvic floor usually affect the vagina. Vaginal lacerations are usually small but hemorrhaging is almost always severe. Damage may be incurred if a forceful contraction is made before the cervix is fully dilated and retracted; "The vagina may actually be torn from its facial moorings" (Greenhill and Friedman 1974:663).

The interpubical ligaments are often stretched during parturition. Lacerations caused by a forceful delivery, an abnormal softening of the joint due to an excessive secretion of relaxin which may result in a complete separation of the joint (Falls and Holt 1961:326) or a large fetus will occur. As a result, ". . . smashed disc particles and disintegrated cartilage masses may be pressed from the eminentia retropubic into the dorsal symphyseal ligament" (Ullrich 1975:24). The ligaments may be torn from the periosteum, causing ". . . an active lacunar bone resorption in the adjacent regions . . ." (Ullrich 1975:25).

As already noted, relaxin causes a relaxation of the sacroiliac joints. This ". . . relaxation of the joints during pregnancy is

followed by a hyperanemia of the joint capsules and ligaments as well as by minor hemorrhages at the bone/cartilage interfaces during parturition" (Ullrich 1975:25). Relaxation of the sacroiliac joints may result in hemorrhage or slipping of the joints during labor (Greenhill and Friedman 1974:675). Slipping of the sacroiliac joints may result in the ligaments being pulled from their attachments and the cartilage being lacerated. Bone resorption will occur. Damage to the sacroiliac joints may also be the result of a forceful traction which may cause the lower uterine segment to be pinned between the bony parts resulting in ". . . perforating tears . . . between the fetal head and prominent bony points such as the ischial spine and the sacral promontory" (Greenhill and Friedman 1974:662).

Forceful deliveries resulting in excessive damage are quite common. Usually the result of a premature bearing down effort by the patient, a forceful delivery may also be the result of other factors. Forceful delivery on the part of the obstetrical practitioner has the same results as a forceful delivery caused by the patient. Tetany may also cause a forceful delivery. Tetany, the result of an insufficient blood calcium level, may also result from muscular shock. Tetany occurs "If stimuli are applied to a muscle in such rapid succession that each occurs before the fibers have relaxed from the one preceding . . ." (Kimber et al. 1961:129). Under such conditions, ". . . the cells will remain in a state in which no relaxation is apparent" (Kimber et al. 1961:129). Tetany results in a state of constant muscular contraction or sporadic

muscle spasms. Tetany ". . . is commonly observed during pregnancy" (McLennan and Sandberg 1974:70).

VI. POSTPARTUM

Afterbirth (placental stage) is the third stage of parturition. During this time ". . . the uterus resumes contractions . . ." (Falls and Holt 1961:34). Through these contractions, the vessels of the pelvis are constricted, thereby stopping the flow of blood. Falls and Holt (1961:34) state, "Relaxation of the uterine wall before the vessels have been firmly occluded leads to postpartum hemorrhage of the atonic type." An atonic type of postpartum hemorrhage is the most common type of obstetrical hemorrhage, occurring in 9 out of 10 cases. Uterine relaxation is the result of an incomplete placental separation, prolonged labor, excessive distention of the uterus, shock or exhaustion (McLennan and Sandberg 1974:388-389, Falls and Holt 1961:42). Uterine relaxation is further complicated by hemorrhage ". . . caused by tears or blood dyscrasia" (Falls and Holt 1961:35).

Although major vascular tears are rare during labor, they do occur. The uterine artery, because of its position along the lower uterine segment, is vulnerable to cervical tears and uterine ruptures (Falls and Holt 1961:2). Less common is a tear in the neck of the circumflex artery. If a tear in the circumflex artery occurs, hemorrhaging will be profuse (Kimber et al. 1961:690).

VII. SUCCESSIVE PREGNANCIES

Complications noted in this thesis are further exaggerated with additional pregnancies. Repeated stress of the muscles necessitates reinforcement at the sites of attachment. The stress lessens the strength and supportive value of these muscles. This is especially true if these muscles have been damaged during previous pregnancies. The anterior abdominal muscles often reach a point of total relaxation due to lacerations and/or stretching. The results are an excessive strain of the muscular attachments resulting in an increasingly difficult labor and a change in the direction of delivery (Greenhill and Friedman 1974: 103). Changes in the uterine fibers also occur with additional pregnancies;

> Fatty and fibrotic degeneration may be noted in some cases, resulting in replacement of the muscle fibers by connective tissue. These anatomical changes interfere with physiological uterine contractions and predispose to postpartum hemorrhage. (Falls and Holt 1961:3)

The pelvic joints are also subject to excessive wear with additional pregnancies, leaving ". . . the pelvic joint permanently . . . loosened. This is particularly true of the symphysis pubis . . ." (Putschar 1976: 593). At the sacroiliac joints,

> After several or hard childbirths, the disintegrated masses emerge from the bulged joint capsule, mainly in the region of the sulcus preauricularis of the ilium and the adjacent region of the sacrum, into the tissue part of the periosteum, there forming debris cysts, which cause lacunar bone resorption. . . . (Ullrich 1975:25)

VIII. CONCLUSIONS

Damage may be seen in the pelvic girdle of all primiparas because "Virtually every vaginal delivery produces some variety of physical trauma to the lower generative tract . . ." (McLennan and Sandberg 1974:398). The evidence of physical trauma becomes more evident with additional pregnancies; "In multiparas one always observes fresh additional tears from the most recent pregnancy superimposed on old, unhealed tears" (Putschar 1976:592).

The effects of excessive or insufficient amounts of hormones, minerals and vitamins can alter bone hardness. The result is bone demineralization. Bone demineralization can exaggerate the effects of muscular lacerations and hemorrhaging. Exaggeration of the effects from muscular lacerations and hemorrhaging, due to bone demineralization, may explain why osteological alterations of the pelvic girdle are more evident in females than in males. Muscular stress and hemorrhaging, which can be found in both males and females (including lower back muscle and perineal muscle strain due to maintaining body erectness and anterior abdominal muscle and interpubical ligamentous strain) under normal conditions can result in alterations to the bones of the pelvic girdle. When the effects of pregnancy and parturition (bone demineralization due to excessive or insufficient amounts of hormones, minerals and vitamins; muscular lacerations and hemorrhaging) are found in addition to stresses normally taking place in the pelvic girdle, it is realistic to hypothesize that the alterations resulting from

muscular and hemorrhagic stresses will be exaggerated from those of normal conditions.

Indirectly, an excessive or insufficient amount of hormones, minerals and vitamins may also affect bone. Muscular weakness and spasms cause an excessive strain to be placed on the muscular attachments resulting in new bone formation to assure proper reinforcement at the sites of attachment. Excessive or insufficient amounts of hormones, minerals and vitamins may also affect the blood clotting factor. If hemorrhaging is not controlled, bone erosion will occur.

Many of the lacerations occurring during pregnancy also occur during parturition. Muscular and ligamentous strain occurring during both pregnancy and parturition result in new bone formation to reinforce the sites of muscular and ligamentous attachment. Hemorrhaging also occurs both during pregnancy and parturition. During both, the result is bone resorption (depressions, pits, cavities and grooves). Because pregnancies become more complex as they increase in number (the muscles are losing their supportive value), the complications resulting from pregnancy also become more complex. As a result, the alterations occurring in the pelvic girdle in association with pregnancy and parturition become more exaggerated with each additional pregnancy.

Because the sample used for this thesis consists of skeletons having no obstetrical records, the determination of an association between the alterations of the pelvic girdle and an actual number of births per female cannot be made. Until documented populations recording the actual number of births per female are available only

hypotheses describing how and why alterations associated with pregnancy and parturition occur on the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae can be made.

CHAPTER III

DATA

I. METHODS AND MATERIALS

The skeletal remains of 51 females and 61 males (12 years and older) and 115 of undetermined sex (under 12 years of age) Arikara American Indians from the Mobridge Site (39WW1), South Dakota, were analyzed to determine if an association exists between alterations sometimes seen on the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae of female skeletal material and pregnancy and parturition. The relative age (newborn-12, 12 years and older) and the sex of individuals over the age of 12 years were recorded for each skeleton. The sex of the individuals was determined from visual analysis of the pelvis and skull (Krogman 1962). The age was determined through dental eruption of the second permanent molar (Schour and Massler 1941). The male skeletal material (12 years and older) was analyzed for comparative purposes to determine if changes thought to be associated with pregnancy and parturition were present. The skeletal material of individuals under 12 years of age was analyzed so that if changes thought to be associated with pregnancy and parturition were present, these changes could be eliminated from the data because the concern here is with

changes occurring in the pelvic girdle associated with pregnancy and parturition.

Changes thought to be associated with pregnancy and parturition seen on the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae were recorded. These changes include new bone formation and bone resorption in the form of depressions, pits, cavities and grooves. The changes were first analyzed visually. Then measurements using sliding and coordinate calipers were taken. The length, width and depth, when applicable, of the new bone formation and the bone resorption in the pelvic girdle were measured in millimeters (mm). The changes were then categorized into one of four groups for each of the four areas (see below). This was for the purpose of demonstrating a progression from bone exhibiting no change, group 0, to bone exhibiting various degrees of change thought to be associated with pregnancy and parturition, groups I, II, and III. The first group for each area (0) classifies males and nulliparas. The second group (I) for each area classifies primiparas. The third group (II) for each area classifies primiparas (possibly associated with a difficult labor) or multiparas. The fourth group (III) for each area classifies multiparas. These classifications are only suggestions because actual documentation (recording the number of births per female) is not available. The details of these groups are given in their appropriate section. The percentage of individuals exhibiting features characteristic of each of these groups for each of the four areas is given in Tables I, II, III and IV.

TABLE I

NUMBER AND PERCENTAGE OF INDIVIDUALS FROM THE TOTAL SAMPLE WITH FEATURES CATEGORIZED FOR THE ANTERIOR PUBIC FACE FOR EACH GROUP

	SUBADULTS		MALES		FEMALES	
STAGE	N affected	%	N affected	%	N affected	%
0	115	100	38	62.2	21	41.2
I	0	0	18	29.6	16	31.3
II	0	0	5	8.2	8	15.7
III	0	0	0	0	6	11.8
TOTAL	115	100	61	100	51	100

TABLE II

NUMBER AND PERCENTAGE OF INDIVIDUALS FROM THE TOTAL SAMPLE WITH FEATURES CATEGORIZED FOR THE POSTERIOR PUBIC FACE FOR EACH GROUP

	SUBADULTS		MALES		FEMALES	
STAGE	N affected	%	N affected	%	N affected	%
0	115	100	58	95.0	21	41.2
I	0	0	3	5.0	17	33.3
II	0	0	0	0	8	15.7
III	0	0	0	0	5	9.8
TOTAL	115	100	61	100	51	100

TABLE III

NUMBER AND PERCENTAGE OF INDIVIDUALS FROM THE TOTAL SAMPLE WITH FEATURES CATEGORIZED FOR THE PREAURICULAR SULCUS OF THE ILIUM FOR EACH GROUP

STAGE	SUBADULTS		MALES		FEMALES	
	N affected	%	N affected	%	N affected	%
0	115	100	61	100	26	51.0
I	0	0	0	0	13	25.4
II	0	0	0	0	6	11.8
III	0	0	0	0	6	11.8
TOTAL	115	100	61	100	51	100

TABLE IV

NUMBER AND PERCENTAGE OF INDIVIDUALS FROM THE TOTAL SAMPLE WITH FEATURES CATEGORIZED FOR THE LATERAL MARGINS OF THE ANTERIOR FACE OF THE FIRST THROUGH THIRD SACRAL VERTEBRAE FOR EACH GROUP

STAGE	SUBADULTS		MALES		FEMALES	
	N affected	%	N affected	%	N affected	%
0	115	100	60	98.4	33	64.7
I	0	0	0	0	8	15.7
II	0	0	1	1.6	5	9.8
III	0	0	0	0	5	9.8
TOTAL	115	100	61	100	51	100

II. ANTERIOR PUBIC FACE

The anterior pubic face exhibits change with age and function. Stresses of pregnancy and parturition may have a major influence on changes on the anterior pubic face because physiological changes are occurring in the body during the time of pregnancy and parturition. Based on the data collected for this thesis and the changes suggested by other research (Angel 1969a, 1969b; Putschar 1976; Stewart 1957, 1970; Ullrich 1975) present in the preceding chapter, the stage of development of the changes on the anterior pubic facies associated with pregnancy and parturition are categorized below.

0: Lines of muscle attachment are rounded; pubic tubercle exhibits slight bulging; surface is depressed and porous (Fig. 1,0).

I: Lines of muscle attachment are irregular; pubic tubercle is bulging; pitting (average size is 2mm × 2mm × 2mm) may be present along the superior margin (Fig. 1,I).

II: Lines of muscle attachment extending laterally with each additional pregnancy; two or more pits exhibited along superior and symphyseal margins (average size is 3mm × 3mm × 2mm); superior margin and pubic tubercle bulging (Fig. 1,II).

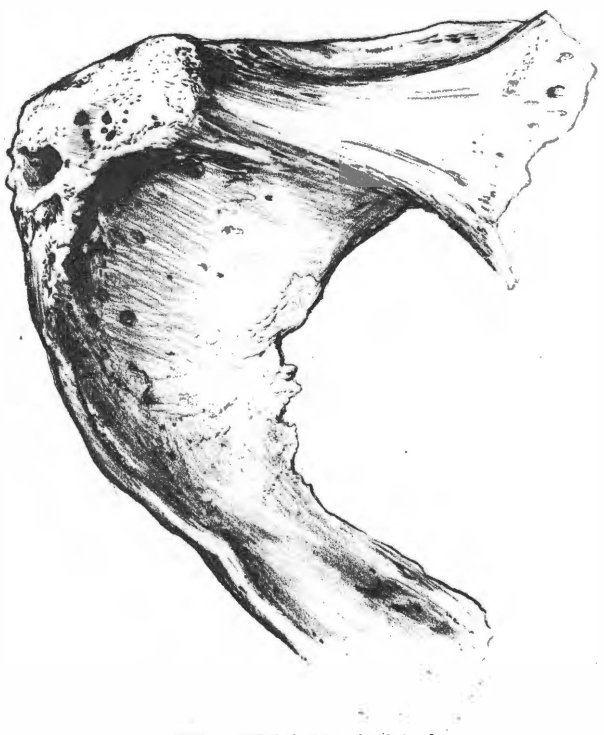
III. Lines of muscle attachment extending laterally with each additional pregnancy; coalesced pitting in the form of cavities and grooves exhibited along superior and symphyseal margins (average size is 6mm × 4mm × 3mm); pubic tubercle, superior and symphyseal margins are lipping (Fig. 1,III).



0: B7 A/B (F301)



I: B2 B (F201)



II: B26 H (F201)



III: B2 A (F101)

Fig. 1. Changes of the anterior pubic face associated with pregnancy and parturition.

The anterior pubic face undergoes changes due to age and function all during life. This is evident in both males and females. For this reason, Stewart (1970:132-133) suggests, ". . . it is not as easy to distinguish abnormal from normal changes on the ventral side of the symphysis. . . ." This is evident from the data. The individuals in my sample under the age of 12 years exhibit no changes of the anterior pubic face similar to those associated with pregnancy and parturition. The male skeletal material does, however, exhibit changes similar to those associated with pregnancy and parturition. Pitting, in the early stages, is common among males. This suggests that males are at one time or another subject to some degree of muscular and ligamentous lacerations and also that pitting present on the anterior pubic face is not entirely the result of pregnancy and parturition. Approximately 37.8 percent (23 of 61) of the males in my sample exhibit pitting along the superior margin of the anterior pubic face. The average size of these pits is 2mm × 2mm × 2mm. Five of these males exhibit larger pits, the average size is 5.5mm × 3.1mm × 2.6mm. Pitting seems to correspond to increasing age (evidenced through bone deterioration) as does the development of the pubic tubercle. The pubic tubercle bulges in 47.5 percent (29 of 61) of the adult males in my sample; this is extensive in 24.5 percent (24 of 61) of the males. Various degrees of change associated with pregnancy and parturition are seen on the anterior pubic face of 58.8 percent (30 of 51) of the adult females in my sample. These changes have been described on page 28. An analysis of the data collected on the anterior pubic face for the 61 males

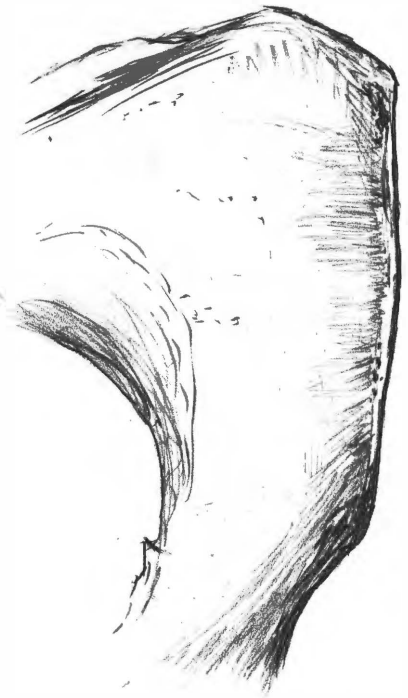
and 51 females in my sample demonstrates that the degree of change seen on the left side of the anterior pubic face usually corresponds to the same degree of change seen on the right side of the anterior pubic face. The degree of change differs between the two sides in only 6.6 percent (4 of 61) of the males and 7.8 percent (4 of 51) of the females.

III. POSTERIOR PUBIC FACE

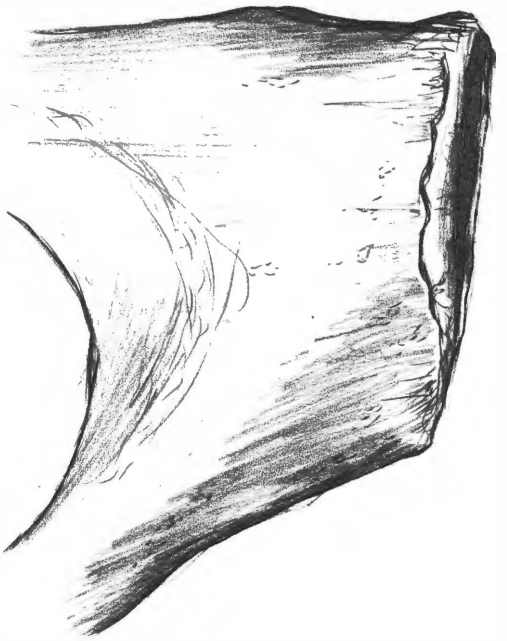
The posterior pubic face has about reached its limit of growth by the childbearing age (Stewart 1970:132). As such, the posterior pubic face exhibits change more from function than from age. The dorsal pubic margin varies from straight to irregular. This margin is subject to the same types and degrees of strain in both males and females, producing similar alterations, usually lipping. Stewart (1970:132) suggests that ". . . localized extra lipping seems to develop sometimes in connection with the scars of parturition." Based on the data collected for this thesis and the changes suggested by other research (Angel 1969a, 1969b; Putschar 1976; Stewart 1957, 1970; Ullrich 1975) present in the preceding chapter, the stage of development of the changes on the posterior pubic facies associated with pregnancy and parturition are categorized below.

0: Symphyseal margin formation is caused by age; depressions and pits are absent (Fig. 2,0).

I: Symphyseal margin is irregular, lipping; series of shallow depressions are present, length and width varies (Fig. 2,I).



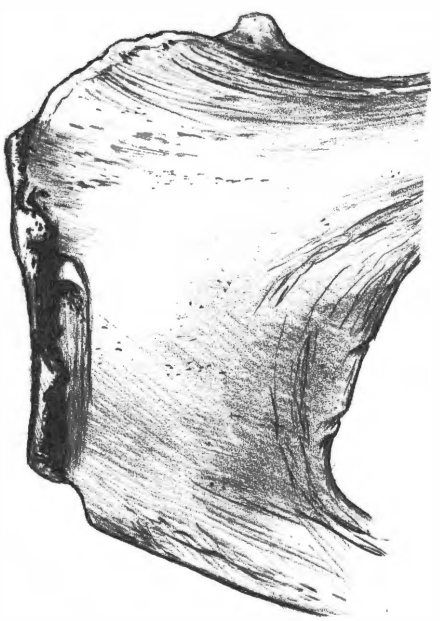
0: B7 A/B (F301)



I: B27 E (F302)



II: B4 B (F101)



III: B2 A (F101)

Fig. 2. Changes of the posterior pubic face associated with pregnancy and parturition.

II: Symphyseal margin is lipping extensively; two or more pits may be present on the face, average size of the pits is 4mm × 3mm × 3mm; transverse ridges bisect the pits (Fig. 2,II).

III: Symphyseal margin breaking down; pits have coalesced to form cavities (average size is 8mm × 5mm × 3mm) or grooves (average size is 15mm × 5mm × 3mm); the impressions of the previous pits are visible within the cavities and grooves (Fig. 2,III).

The marginal form of the posterior pubic face can give the impression of undermining depressions (Stewart 1970). As a result, the determination of pregnancies on the basis of these possible undermining depressions could provide erroneous results. Again, this is evident from the data. Changes of the posterior pubic face similar to those associated with pregnancy and parturition were not present on any of the skeletal material under the age of 12 years, but approximately 8.2 percent (5 of 61) of the adult males in my sample do exhibit depressions along the symphyseal margin of the posterior pubic face. As evidenced through bone deterioration, the depressions seem to correspond to increasing age. The female skeletal material in my sample exhibits changes associated with pregnancy and parturition on the posterior pubic face in 58.8 percent (30 of 51) of the skeletons. The presence of these changes does not seem to correspond with increasing age as it does in the males indicating that factors responsible for the presence of these changes may occur at any age of the adult life. A description of the changes present in the female skeletal material is on pages 31-33. An analysis of the data collected

for the male and female skeletal material in this thesis indicates that the degree of change seen on the left side of the posterior pubic face differs from the right in 3.3 percent (2 of 61) of the males and 11.8 percent (6 of 51) of the females in my sample. An analysis of the data on the anterior and posterior pubic facies shows that the changes similar to those associated with pregnancy and parturition seen on the anterior pubic face are the same as on the posterior pubic face in 65.6 percent (40 of 61) of the males in my sample (Table V). An analysis of the data on the anterior and posterior pubic facies shows that the degree of alterations associated with pregnancy and parturition seen on the anterior pubic face is the same as on the posterior pubic face in 58.8 percent (30 of 51) of the females in my sample (Table VI).

IV. PREAURICULAR SULCUS OF THE ILIUM

The preauricular sulcus of the ilium is the site of attachment for the sacroiliac ligament. Because this region is in the direct line for the transfer of body weight, considerable strain is placed on this ligamentous attachment. When body weight increases and the center of gravity changes during pregnancy it becomes increasingly difficult to hold the body erect. Also during this time, when the sacroiliac joint is relaxing due to the effects of relaxin, walking becomes difficult. During parturition the sacroiliac joints experience ligamentous lacerations and hemorrhaging at the bone/cartilage interfaces due to the fetal descension. Because of the difficulties in holding the body erect and in walking during pregnancy and the complications of

TABLE V

NUMBER AND PERCENTAGE OF MALE INDIVIDUALS WITH THE SAME DEGREE OF ALTERATION SIMILAR TO THOSE ASSOCIATED WITH PREGNANCY AND PARTURITION AMONG THE FOUR AREAS OF THE PELVIC GIRDLE

Areas	APF		PPF		PaS		SV	
	N	%	N	%	N	%	N	%
APF	61	100.0	40	65.6	38	62.3	38	62.3
PPF	40	65.6	61	100.0	58	95.0	59	96.7
PaS	38	62.3	58	95.0	61	100.0	60	98.4
SV	38	62.3	59	96.7	60	98.4	61	100.0

APF = Anterior Pubic Face

PPF = Posterior Pubic Face

PaS = Preauricular Sulcus of the Ilium

SV = Lateral Margins of the Anterior Face of the First through Third Sacral Vertebrae

TABLE VI

NUMBER AND PERCENTAGE OF FEMALE INDIVIDUALS WITH THE SAME DEGREE OF ALTERATION ASSOCIATED WITH PREGNANCY AND PARTURITION AMONG THE FOUR AREAS OF THE PELVIC GIRDLE

Areas	APF		PPF		PaS		SV	
	N	%	N	%	N	%	N	%
APF	51	100.0	30	58.8	18	35.3	27	52.9
PPF	30	58.8	51	100.0	18	35.3	27	52.9
PaS	18	35.3	18	35.3	51	100.0	30	58.8
SV	27	52.9	27	52.9	30	58.8	51	100.0

APF = Anterior Pubic Face

PPF = Posterior Pubic Face

PaS = Preauricular Sulcus of the Ilium

SV = Lateral Margins of the Anterior Face of the First through Third Sacral Vertebrae

ligamentous lacerations and hemorrhaging at the bone/cartilage interfaces the stresses and strains that the sacroiliac ligament is normally subject to are exaggerated. Based on the data collected for this thesis and the changes suggested by other research (Houghton 1974, Putschar 1976, Ullrich 1975) present in the preceding chapter, the stage of development of the changes on the preauricular sulcus of the ilium associated with pregnancy and parturition are categorized below.

0: a. No sulcus is present;

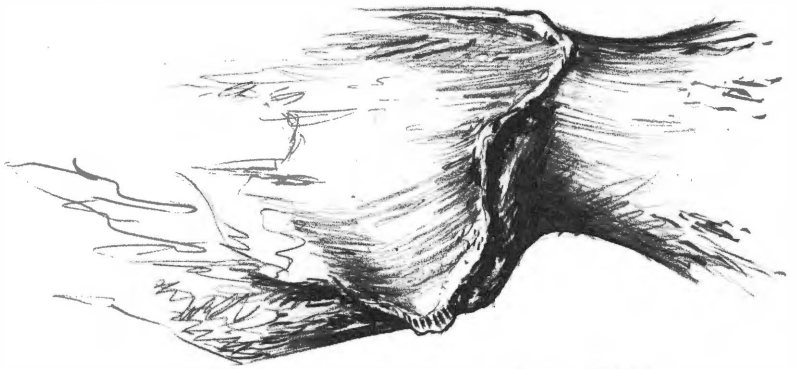
b. Inferior margin ranges from rounded to sharp; auricular margin is characteristically sharp; sulcus floor can be smooth or wavy; no pits or depressions are present;

c. One pit may be present, the average size is 2mm × 2mm × 2mm (Fig. 3,0).

I: Inferior and auricular margins are characteristically sharp; sulcus floor has at least two, possibly more, depressions and/or pits, shape is round to oval, average size is 5-10mm × 5-10mm × 2mm (Fig. 3,I).

II: Inferior and auricular margins are characteristically sharp; sulcus floor has at least two, probably more, coalesced pits, shape is oval to elongated, average size is 6-10mm × 4-6mm × 4mm (Fig. 3,II).

III: Inferior and auricular margins are characteristically sharp and lipping; sulcus floor has several coalesced cavities, shape is elongated, average size is 15mm × 10mm × 4mm (Fig. 3,III).



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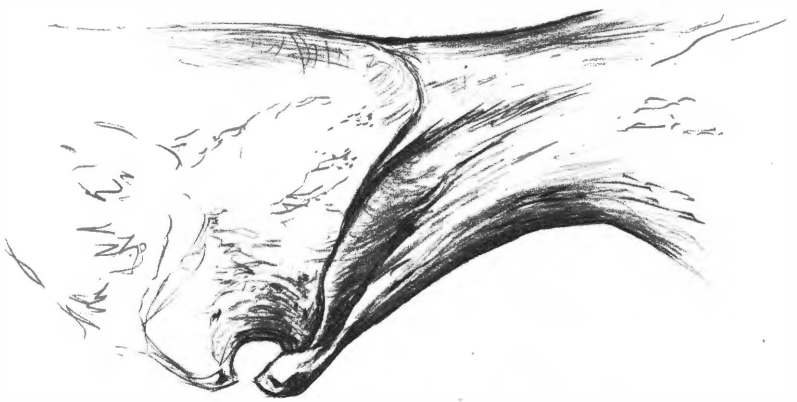

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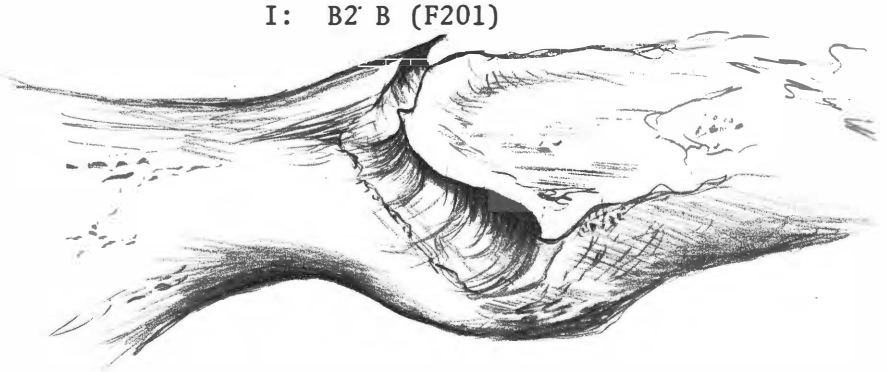

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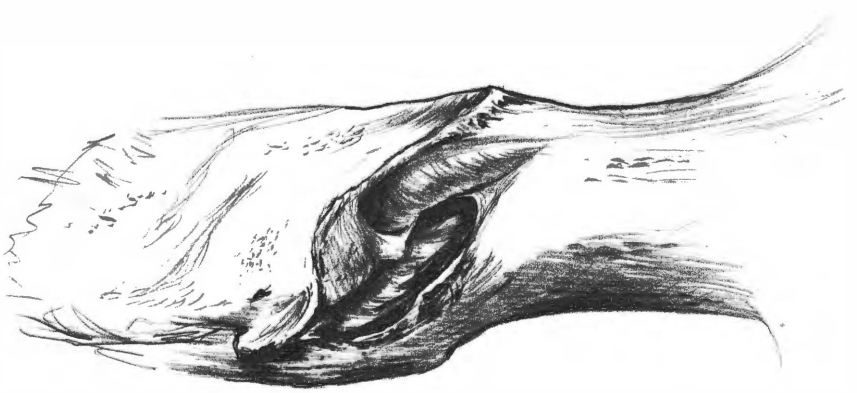


III: B19 B (F101)

Fig. 3. Changes of the preauricular sulcus of the ilium associated with pregnancy and parturition.

The individuals in my sample under the age of 12 years exhibit no changes similar to those associated with pregnancy and parturition. The adult male individuals in my sample also exhibit no changes similar to those associated with pregnancy and parturition. Although no male skeletons in my sample exhibit features characteristic of group Oc (one pit may be present), some of the male skeletons examined by Ullrich (1975) did exhibit this feature. For this reason, the presence of a single pit was categorized as a male/nulliparas classification. The data collected on the changes associated with pregnancy and parturition occurring on the preauricular sulcus of the ilium of the 51 females in my sample indicates that 49 percent (25 of 51) of the females exhibit various degrees of these changes. The data are presented in Table III, page 27, and described on page 36. An analysis of the data collected on the preauricular sulcus of the ilium indicates that the degree of change seen on the left side differs from the right in 15.7 percent (8 of 51) of the females in my sample. The changes similar to those associated with pregnancy and parturition seen on the preauricular sulcus of the ilium in the male skeletal material are the same as on the anterior pubic face in 62.3 percent (38 of 61) and on the posterior pubic face in 95 percent (58 of 61) of the males in my sample (Table V, page 35). The changes associated with pregnancy and parturition seen on the preauricular sulcus of the ilium are the same as on the anterior pubic face in 35.3 percent (18 of 51) and on the posterior pubic face in 35.3 percent (18 of 51) of the female skeletal material in my sample (Table VI, page 35).

V. SACRUM

Like the preauricular sulcus of the ilium, the lateral margins of the anterior face of the first through third sacral vertebrae are the sites of attachment for the sacroiliac ligaments. Also attaching to this area are the uterosacral ligaments. The sites of attachment for the sacroiliac ligaments on the sacrum are subject to the same exaggerated stresses and strains that the preauricular sulcus of the ilium is subject to during pregnancy and parturition. The difficulties and complications of holding the body erect, walking, ligamentous lacerations and hemorrhaging at the bone/cartilage interfaces result in new bone formation and bone resorption at the sites of attachment for the sacroiliac ligaments. The sites of attachment for the uterosacral ligaments are also subject to increasing stress and strain during pregnancy and parturition. During pregnancy the uterine weight increases, increasing the amount of strain placed on the attachment for the uterosacral ligaments. During parturition the uterosacral ligaments are also subject to increasing strain because these ligaments help in the uterine contractions. The increased uterine weight during pregnancy and the uterine contractions during parturition also result in new bone formation and bone resorption at the sites of attachment for the uterosacral ligaments. Based on the data collected for this thesis and the changes suggested by other research (Houghton 1974, Putschar 1976, Ullrich 1975) present in the preceding chapter, the stage of development of the changes on the lateral margins of the anterior face

of the first through third sacral vertebrae are categorized below.

0: a. Lateral margins of the anterior face of the first three sacral vertebrae are smooth; no grooves or depressions are present;

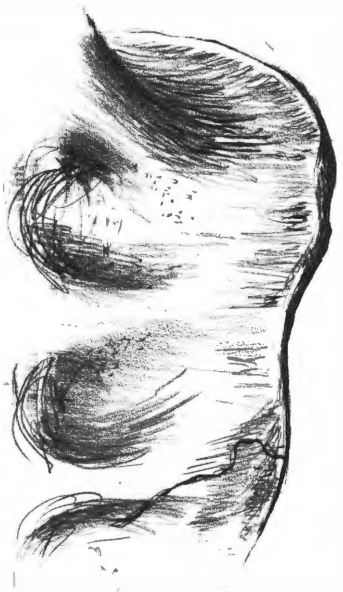
b. Narrow (less than 4mm) and shallow (less than 0.5mm) groove is present on the second ala, the second and third alae the first through third alae; depressions may be present (Fig. 4,0).

I: Wide (more than 6mm) groove is present on the second and/or third ala (Fig. 4,I).

II: Groove now has depth (more than 2mm); depressions are present (Fig. 4,II).

III: Series of pits (more than two) are present on the first through third alae, average size is 6mm × 4mm × 3mm (Fig. 4,III).

The individuals in my sample under the age of 12 years exhibit no changes similar to those associated with pregnancy and parturition. Approximately 1.6 percent (1 of 61) of the males in my sample exhibit pitting on the lateral margins of the anterior face of the sacrum in association with a wide (more than 6mm) groove. The average size of the pits is 4mm × 3mm × 1mm. This would perhaps indicate that the presence of pits in association with a wide groove does not indicate an association with pregnancy and parturition but since this is an isolated individual and not several males exhibiting this alteration perhaps the alteration can be explained through a misclassification or a pathology. The



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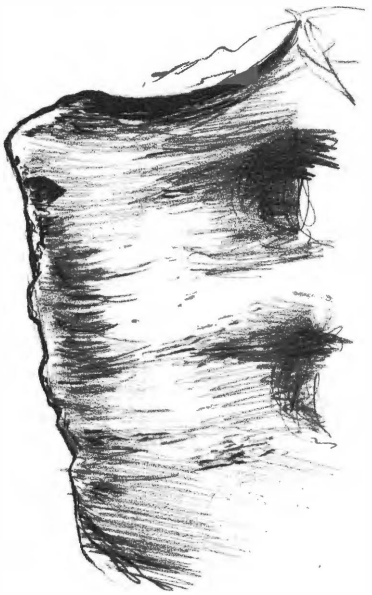

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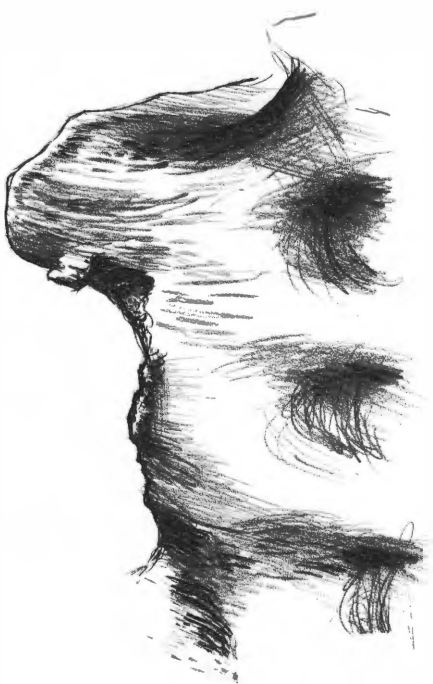

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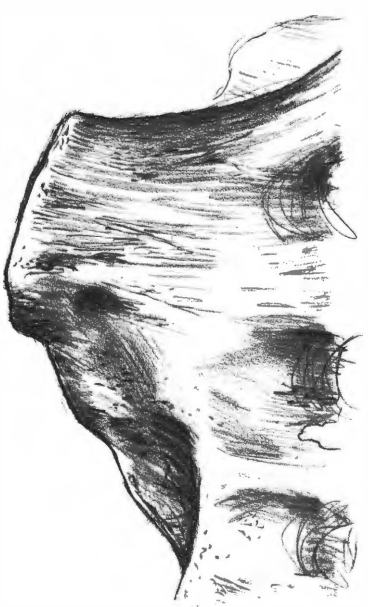

III: B4 B (F101)

Fig. 4. Changes of the lateral margins of the anterior face of the first through third sacral vertebrae associated with pregnancy and parturition.

data collected for the male and female skeletal material on the sacrum indicates that the degree of change seen on the left side of the sacrum differs from the right in 1.6 percent (1 of 61) of the males and in 11.8 percent (6 of 51) of the females in my sample. The changes similar to those associated with pregnancy and parturition seen on the lateral margins of the anterior face of the sacrum are the same as on the anterior pubic face in 62.3 percent (38 of 61), the posterior pubic face in 96.7 percent (59 of 61) and on the preauricular sulcus of the ilium in 98.4 percent (60 of 61) of the males in my sample (Table V, page 35). The changes associated with pregnancy and parturition seen on the lateral margins of the anterior face of the first through third sacral vertebrae are the same as on the anterior pubic face in 52.9 percent (27 of 51), the posterior pubic face in 52.9 percent (27 of 51) and on the preauricular sulcus of the ilium in 58.8 percent (30 of 51) of the females in my sample (Table VI, page 35).

CHAPTER IV

CONCLUSIONS AND SUMMARY

I. CONCLUSIONS

The data collected through visual analysis and measurements of alterations seen on the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae of 227 Arikara American Indian skeletons suggest that an association exists between alterations seen in the pelvic girdles of females and pregnancy and parturition. For example, 82.3 percent (42 of 51) of the females in my sample exhibit some degree of alteration in at least one of the four areas in the pelvic girdle. These same alterations were not seen in any skeletons under the age of 12 years and were rarely seen in male skeletal material over the age of 12 years. I feel the presence of these alterations in some male skeletons may be explained through normal physical exertion common to both males and females.

Muscular and ligamentous attachments are subject to various degrees of stress and strain during normal body functions in both males and females. The lower back muscles are subject to continual stress and strain exerted through the actions performed in keeping the body erect. The anterior abdominal muscles are also subject to continual stress and strain exerted through the actions of lifting and carrying heavy objects. At these sites of muscular and ligamentous

strain, a build up of new bone occurs to reinforce the sites of attachment. If the muscular and ligamentous attachments are pulled to the point of hemorrhaging bone erosion in the form of depressions, pits, cavities and grooves will occur. The effects of physical exertion are as likely to affect the male skeleton as they are the female skeleton. Because of the nature of the alterations similar to those associated with pregnancy and parturition seen in some of the male skeletons in my sample, I suggest that the presence of these alterations need not affect the importance of the classifications set up to categorize alterations so that an association is made with those changes and males, nulliparas, primiparas or multiparas. The data show that the most extensive alterations associated with pregnancy and parturition present in the male skeletons occur at the site of attachment for the anterior abdominal muscles and the anterior pubical ligaments: that is the anterior pubic face. As noted previously, this area is subject to much muscular and ligamentous stress and strain due to postural requirements. Therefore, I find it reasonable to suggest that alterations usually associated with pregnancy and parturition in females but also associated with the stresses and strains of everyday locomotion may occur frequently on the anterior pubic face in male skeletons. The alterations seen on the posterior pubic face observed in some male skeletons in my sample may also be explained, as suggested by Stewart (1970), by the possibility that depressions on the posterior pubic face may be the result of the imagination of the observer due to the lipping of the posterior

symphyseal margin. The alteration seen on the sacrum of one male skeleton may be the result of a misclassification of the sex of the sacrum or a pathology. Because no other alterations associated with pregnancy and parturition occur in any of the other male skeletons, I suggest that the alterations presented in this thesis seen in the skeletal material on the sacrum are associated with pregnancy and parturition.

Numerous alterations seen in the pelvic girdle of female skeletons are undoubtedly associated with pregnancy and parturition. As noted above, males and females are subject to the effects of muscular and ligamentous stress and strain, but the alterations seen in the female skeletons seem to be much more extensive than those seen in the pelvic girdle of males. The explanation is found in the actions of pregnancy and parturition. Body functions are altered during pregnancy. Changes in the hormone, mineral and vitamin levels in the body affect bone composition and structure. The direct effects of abnormal amounts of hormones, minerals and vitamins in the body are bone demineralization. Bone demineralization (osteoporosis and osteomalacia) exaggerates the effects from normal muscular and ligamentous strain. The effects from normal muscular and ligamentous strain are further exaggerated in the female pelvic girdle due to the increased muscular and ligamentous strain that accompanies pregnancy. Indirectly, the effects of abnormal amounts of hormones, minerals and vitamins in the body to bone are through the loss of the blood clotting factor. During the first pregnancy tissue is subject to considerable strain and to

lacerations resulting in new bone formation and bone resorption. These affects are increased with each successive pregnancy due to the damage caused by previous pregnancies resulting in a loss of the supportive value of the muscles and ligaments involved. Due to the added factors of bone demineralization and an increase in the muscular and ligamentous stress and strain occurring during pregnancy, it is suggested that the alterations more commonly observed in the female pelvic girdle are associated with physical exertion and are exaggerated under the influences of pregnancy and parturition.

The data presented in this thesis suggest that those alterations occurring at the sacroiliac joint are more accurate indicators of parity than those occurring at the pubic symphysis. As noted above, the adult male skeletons exhibit alterations associated with pregnancy and parturition in 37.8 percent (23 out of 61) of the total male sample. These alterations were classified as stage I in 32.8 percent (20 out of 61) of the males and as stage II in 5 percent (3 out of 61) of the males in my sample. Although the presence of these scars in males has been explained above, it should be remembered that the presence of alterations on the anterior pubic face at the stage I/II level is not indicative of a female. Only in stage III were no males classified thus the presence of parturitional scarring at this stage for the anterior pubic face would be indicative of a female. On the posterior pubic face 5 percent (3 out of 61) of the males in my sample exhibited alterations associated with pregnancy and parturition classified as a stage I. No males exhibited alterations associated with a stage II/III

classification of parity on the posterior pubic face. These data suggest that only those alterations classified as a stage II/III classification for parity on the posterior pubic face are indicative of females. The data show that 1.6 percent (1 out of 61) of the males exhibit alterations associated with a stage II classification for parity on the sacrum. The presence of this alteration has been discussed. I suggest that alterations present on the sacrum associated with a stage I/II/III classification for parity are indicative of a female skeleton. No adult male skeletons in my sample exhibit alterations associated with a stage I/II/III classification for parity on the preauricular sulcus of the ilium. Thus alterations at this site associated with a stage I/II/III classification for parity are indicative of a female. From these data, I feel it is reasonable to suggest that the alterations seen on the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae are more accurate indicators of parity and are more indicative of sex than the alterations on the pubis, particularly the anterior pubic face.

Comparing the data collected for each of the four areas in the female pelvic girdle, it is suggested that the alterations associated with pregnancy and parturition occur independently of each other in each of the four areas. For example, in only 11.8 percent (6 of 51) of the females in my sample do all four areas exhibit the same degree of alteration. The data do not suggest that one area is more progressive than the others. In any one of the skeletons, the alterations

associated with pregnancy and parturition present in the pelvic girdle may appear at any degree, in any one of the four areas, on either side. The results of these data suggest that actual assessment as to the number of births per female is impossible. A relative classification (male, nulliparas, primiparas or multiparas) based on the alterations seen in the pelvic girdle seems feasible at this time.

II. SUMMARY

Researchers in human anatomy and physical anthropology are seeking answers to questions concerning an association between alterations often seen in the female skeleton on the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae and pregnancy and parturition. Research done in this area has dealt with changes occurring on the anterior and posterior pubic facies. As a result, changes occurring at the sacroiliac joint have not been completely demonstrated. Additional data concerning alterations of the pelvic girdle associated with pregnancy and parturition are presented.

Examining 115 skeletons of undetermined sex under the age of 12 years, 61 male and 51 female Arikara American Indians over the age of 12 years, from the Mobridge Site (39WW1), South Dakota, alterations in the form of new bone formation, and bone resorption thought to be associated with pregnancy and parturition were analyzed visually and through measurements. Male skeletons in this thesis were used for

comparative analyses of the sexes. Skeletons of undetermined sex under the age of 12 years were used so that if changes thought to be associated with pregnancy and parturition were present the changes could be eliminated from this thesis because the concern in this thesis was with those changes associated with pregnancy and parturition. From these data hypotheses explaining what alterations may be seen in the pelvic girdle of the female skeletal material were presented.

Osteological alterations seen on the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae were categorized into one of four groups for each of the four areas. The four groups for each of the four areas in the pelvic girdle show a progression from bone exhibiting no change (group 0, classifies males and nulliparas) to bone exhibiting various degrees of change associated with pregnancy and parturition (groups I, II, III; classifies progressive degrees of primiparas/multiparas).

The data suggest that osteological alterations of the anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae are associated with pregnancy and parturition. The changes associated with pregnancy and parturition were not found on any of the skeletons of undetermined sex under the age of 12 years. Although alterations associated with pregnancy and parturition were present in some male skeletons, their presence may be related to the normal physical exertion common to both males and females.

The data further suggest that the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae are more accurate indicators of parity and are more indicative of sex than are the anterior and posterior pubic facies, in particular the anterior pubic face.

Because a population recording the actual number of births per female was not available to me for research, the actual assessment of an association between alterations and the actual number of births per female was not possible. Only the relative classification (males, nulliparas, primiparas or multiparas) can be made at this time based on the degree of alterations seen in the pelvic girdle.

III. RECOMMENDATIONS FOR FURTHER RESEARCH

Muscular and ligamentous attachments subject to considerable stress and strain during pregnancy and parturition involve areas of the skeleton other than those considered in this thesis. These areas include the ischial tuberosity, ischial spine, anterior superior iliac spine, iliac tuberosity, the lateral margins of the anterior face of the fourth and fifth sacral vertebrae, the medial and lateral crests of the posterior face of the sacral vertebrae, the anterior face of the coccygeal vertebrae and the xiphoid process. Researchers interested in the scars of parity should begin to look at these areas. In addition, more data are needed, involving modern documented populations, concerning the details (number of births, death during pregnancy, abortions, and vaginal or Caesarean-section deliveries) for the

anterior and posterior pubic facies, the preauricular sulcus of the ilium and the lateral margins of the anterior face of the first through third sacral vertebrae.

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VITA

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