The preauricular sulcus in relation to sexual dimorphism, pregnancy and parturition in humans

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A thesis submitted in partial fulfilment of the requirements of Liverpool John Moores University for the degree of Doctor of Philosophy

June 2020

Acknowledgement

I am indebted to my Director of Studies Matteo Borrini without whom this would not have happened. Your belief in both myself and this project from its inception has encouraged and inspired me. To my co-supervisors, Costa Eliopoulos and Silvia Gonzalez I am grateful for your advice and guidance throughout this process and for understanding the constraints of being a self-funded student. A special thanks to Alison Brough for allowing me to use the computer in her office to access the software necessary to render CT Scans and guiding me through the process.

A huge thank you is extended to all my fellow postgraduate students at LJMU. Everyone in the department helped to make my time as a Postgrad a more enjoyable and memorable experience. The support system that we were able to set up to help each other through both the tough times and adventures meant a lot to me. Special mention goes to Eleanor Dove, Ian Towle, Satu Valoriani and Carla Burrell. My last recognition of a postgraduate student goes to Samuel Rennie for not only your friendship and support during the PhD but for taking the time to collect invaluable data for me in South Africa. You helped expand the scope of this research and I cannot thank you enough for that, also for not complaining when I asked you a statistics question for the 100^{th} time.

I would like to thank Elissa Menzel and Robert Kruszynski at the Natural History Museum, London for giving me access to the Spitalfields collection and Jelena Bekvalac at the Museum of London for St Brides. I would also like to extend my gratitude to Janamarie Truesdell for allowing me access to the CT Scans she collected.

To my friends outside academia, I cannot thank you enough for your continued friendship even when the PhD was consuming my life. Alice Trew and Camilla Masterson for always being there when I needed someone to complain to and listening to me talk endlessly about my research. Most of all I appreciate you for distracting me when I needed a break especially with theatre trips and musical recommendations. To Chloe Senior thank you for letting me stay with you during research trips to London and for your help finding Obstetrics and Gynaecology books, your friendship over the years means a lot to me.

My greatest thanks go to my parents Helen and Mick for their guidance and support not just throughout this PhD but my whole life, none of this would be possible without you. You have taught me the meaning of hard work and have always pushed me to be the best I can be. Thank you for believing in me, even when I did not believe in myself. Without your support both emotionally and financially this research would never have happened. I am also grateful to my brothers Chris and David for their encouragement and always looking out for me.

PhD Abstract

The present thesis proposes a new grading system for the examination of the preauricular sulcus (PAS) in humans. Previous studies concerning the variables affecting the development of the preauricular sulcus often provided conflicting results. The new grading system was developed to better describe the wide range of morphology exhibited in the trait, rather than just present or absent. It is hoped that this will lead to a better understanding of this trait. The new method ranges from grade 0 for the absence of a PAS, through to grade 4 for sulci that are deeply pitted. The main aim of the thesis was to examine the relationship between the trait and sexual dimorphism, pregnancy and parturition. This examination was carried out by the study of 894 specimens from the seven samples. The analysis indicated that sexual dimorphism has a significant effect on both the occurrence and morphology of the PAS. Females in all samples exhibited more frequent and severe expressions of the trait. The research further showed that parity status did not appear to have an effect and that there was no significant difference in either occurrence or morphology between parous and nulliparous females.

Two pilot studies were also carried out as part of the thesis. A further examination of the CT Scans was performed with additional biographical information (e.g. diet, activity level, smoking history etc.) to see their relationship with the PAS. However, the majority of variables were found to have no effect. The second pilot study performed was an examination of how a selection of effect of pelvic dimensions. Four of these measurements (Maximum Sacral Width, Sacral Width Inferior, Transverse Diameter and Bispinous Diameter) were found to be the best predictors. All these measurements are wider in females, and there was a positive correlation between their width and both the frequency of the PAS and higher grades.

The results of this thesis suggest that the development of a sulcus occurs more in females than males as a result of wider pelvic dimensions in response to evolutionary selection pressures for pregnancy and parturition. The method proposed has been tested and validated on both skeletal remains (Poulton, St Owens, Spitalfields, St Brides, Pretoria Bone Collection and Raymond A. Dart Collection) and CT Scans (from living subjects).

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Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

1- Introduction

1.1- Introduction

The inspiration for this project began with the widely debated question regarding the relationship between sex and parity status, and scars of parturition in human skeletons. The cause of these scars of parturition has been studied and debated for over a century (Derry, 1909; Cox, 1989; Ubelaker and De La Paz, 2012). The term scars of parturition refer to the collection of traits and morphologies that can be found on the pelvic girdle and have been suggested to be caused by or remodelled during pregnancy and parturition. The history of these traits will be discussed in the Literature Review in Chapter 2. One of these traits is the preauricular sulcus (PAS) which is the main focus of this study. The sulcus is situated on each *os coxa* between the auricular surface and the greater sciatic notch. It is the site of attachment for the anterior sacroiliac ligament (Finnegan, 1978). The preauricular sulcus, its history, and morphology will also be discussed in detail in Chapter 2. Although preauricular sulci have been found in other mammals and primates (Tague, 1988), they were not studied in this research. The researcher focussed solely on the trait in humans.

For this research, a new grading system to examine the PAS was developed and utilised. This new system was created as it was decided that the existing grading systems, discussed in Chapter 2, were not suitable for use in this project. Furthermore, it was designed to describe the full range of morphology seen in the sulcus, rather than treating it as binary (present or absent). This new method will be discussed in detail in the methodology, Chapter 4, however, an overview will be provided here. The new system was designed to focus on the changes in depth to the sulcus rather than the general shape and size. The grades range from grade 0 to 4. Grade 0 indicates the absence of a preauricular sulcus, grade 4 signifies a deep and pitted sulcus that has been hypothesised to occur as a result of pregnancy (Houghton, 1975). For each of the seven populations examined (Chapter 3) the differences in levels of occurrence of the PAS and distribution of grades between sexes were analysed. A series of variables (parity status, age, ancestry and location) were examined to determine their effect on the sulcus (Chapter 7).

The main focus of the present study will be on the grading system that was developed and tested on physical remains, however, firstly there were also two additional pilot case studies that were carried out as part of the PhD research. These pilot studies will be presented first in the thesis as they built up to the main research that was carried out on the new grading system (Chapter 7) and inform the overall discussion of the different morphology of the trait.

The first pilot study will be discussed in Chapter 5 and the second case study in Chapter 6. The results of these studies and their relationship to the main aims of the thesis will also be reviewed and discussed in Chapter 8. The first study was an additional examination of the St Brides collection that was used in the main PhD research. In addition to preauricular sulcus data, the individuals whose pelvic girdles were complete were articulated for measurements to be taken. These measurements were taken to analyse the difference in pelvic shape between individuals and examine the relationship to both the preauricular sulcus and parity status. Thirty-five complete pelvic girdles were used in this study. The measurements that were taken will be detailed in Chapter 5. The second study was an examination of a sample of CT Scans of living subjects' pelvic regions (Chapter 6). These scans were obtained through a collaboration with Janamarie Truesdell, a researcher at Oxford University. The scans were from patients at Churchill Hospital in Oxford who were already undergoing CT Scans of the pelvic area for a variety of medical reasons. The data were anonymised before being used in this study to protect the subjects' identities. Parity data and extra biographical information (diet, activity level, smoking history etc.) were available for all 71 scans. The preauricular sulci were graded, after which all the biographical information was examined to determine the effect that different variables may have on the PAS. These additional biographical variables were included in the hope that it might lead to a better understanding of the often conflicting and contrasting results produced when only looking at sex and parity status as variables (Chapter 2).

1.2- Justification of Research

Even though studies into the accuracy of using skeletal markers as an indicator of pregnancy and parturition are conflicting and contrasting, it is still used as a method by many biological anthropologist and archaeologists (Ubelaker and De La Paz, 2012; Maass and Friedling, 2014). Understandably, a method that could accurately predict whether an individual has previously given birth would be desired in both the bioarchaeological and forensic fields. Such a method would lead to a wider understanding and identification of not only an individual but also past populations. However, there must be a better comprehension of the relationship between 'scars of parturition' and the parity status of an individual before these methods are used. A further examination of these skeletal markers, as proposed in the present study, will aid in the establishment of a more accurate biological profile.

In addition, the trait could be used, if not successfully for the determination of parity status, for the better estimation of sex in skeletal remains. Sex estimation is one of the most important aspects of determining the biological profile of an individual (Meindl *et al.*, 1985;

Kjellstrom, 2004). All of the 'scars of parturition' have been linked to the sex of an individual and display strong signs of sexual dimorphism (Derry, 1909; Kelly, 1979; Cox, 1989). Creating a more accurate method for examining these traits, even if they are not caused by pregnancy and parturition, will lead to a useful tool in sex estimation.

Over the last century, there have been several studies which include an examination of the preauricular sulcus particularly in regards to parity status. For this project, the three 'scars of parturition' was narrowed to the sulcus as it is the most commonly preserved (Waldron, 1987). In a bioarchaeological context the other two markers, dorsal pubic pittings and the pubic tubercle are often missing or too damaged to be used. Waldron (1987) found that the pubis was only present/undamaged in roughly 30% of archaeological remains. In contrast, the PAS is often undamaged and well preserved in skeletal remains. For this reason, the sulcus was selected to be studied as the aim of the project was to create a technique that could be used in both forensic and bioarchaeology contexts.

There is currently no widely accepted method for grading the preauricular sulcus. The existing methods do not take into consideration the range of variation in the depth of the sulcus. It was for this reason that a new grading system was developed, focussing on this variation and with clear descriptions and supportive material (casts and photographs). The overall aim was to lead to a more reliable assessment of the trait. The new method will additionally aid in the correct identification of individuals and lead to a more accurate portrayal of past populations. The new grading system was created to explore the range of variation that is present in the trait rather than simply scoring presence or absence. In 2012, Klales retested the Phenice method for sex assessment (1969) to examine how the observer's results were affected by differing levels of descriptions and illustrations. It was found that more detailed and wide-ranging descriptions and illustrations increased consistency and accuracy of the results. The new grading system proposed in this study aims to make scoring the PAS more accurate in a similar way.

An additional rationale for creating a new grading system is to create a more accessible method for examination of the trait to be used also for higher educational purposes. Throughout the course of this project, many undergraduate students stated during practical demonstrations that they struggled to use the existing grading system as they were not provided with clear instruction of description of the trait. The majority of existing methods use only diagrams/drawings to depict the variation of this trait. For researchers familiar with the trait these drawings are clear however they can be difficult to understand for those who have no previous experience in the examination of the PAS. By using photographic examples and casts alongside descriptions of the grades it is hoped that the new method will be more accessible to early-stage researcher and bioarcheologists.

1.3- Aims & Objectives

Aim of the investigation: The focus of the present research is to study the preauricular sulcus and its relationship to sexual dimorphism as well as pregnancy and parturition. This relationship was examined through the creation and testing of a new grading system to better understand the morphology of the preauricular sulcus.

Research Questions:

- Is there a difference in the frequency of occurrence of preauricular sulcus in males and females?
- Does the sex of an individual have a significant effect on the morphology of the preauricular sulcus in human skeletons?
- Does parity status have a significant effect on the morphology of the preauricular sulcus in human skeletons?
- Does age, ancestry or location have a significant effect on the morphology of the preauricular sulcus?
- Do the dimensions of the pelvis have a significant effect on levels of occurrence and morphology of preauricular sulcus?
- Do certain lifestyle and biological variables have a significant effect of levels of occurrence and morphology of the preauricular sulcus observed using CT Scans?

These research questions will be formed in hypotheses to test in Chapters 5, 6 and 7. For the main body of the present research, 894 *os coxae* from seven collections were examined. Two of the collections studied were the British medieval collections of Poulton and St Owens, both undocumented and housed at Liverpool John Moores University (LJMU). The next two studied were the post-medieval collections of Christ Church Spitalfields and St Brides, both of which were documented and included parity information. Additionally, the modern South African samples of Pretoria Bone Collection and the Raymond A. Dart Collection were examined to broaden the geographical spread. Both these are documented cadaver-based collections, however only age, sex, ancestry and cause of death are recorded, not parity status. The final was a sample of CT Scans from living subjects. Chapter 3 will discuss the details of these collections further.

1.4 - Structure of the Thesis

The next chapter, Chapter 2, provides the background and literature for the main aim of this project. The chapter first details the anatomy of the pelvis, an overview of the preauricular sulcus and a review of previous literature/studies regarding the scars of parturition. Next, the chapter focusses on the process of parturition in modern humans and how it has evolved and changed through time periods. Finally, the chapter discusses the existing grading system for the preauricular sulcus. Chapter 3 describes the collections that were examined during this thesis. Chapter 4 presents the methodology used during the main portion of the study. This includes a detailed description of the new grading system that was created. Chapter 5 introduces the first pilot study for the thesis. During this additional study, the pelvic shape of 35 samples from St. Bride's collection were examined to investigate it's relationship to the PAS. The results of the pilot study are presented within the chapter and also discussed. However, they are also discussed in Chapter 8, where relevant to the main project aims. Chapter 6 is the second pilot study. In this chapter, the additional biographical information for the CT Scan samples was examined. This study was to determine whether there was a relationship between any of biographical/lifestyle variables and the sulcus. As with Chapter 6, these results are presented and discussed within the chapter but also discussed in relation to the whole thesis in Chapter 8. For both the pilot studies there were some additional background information and methodology that were not related to the main thesis results so were discussed in their respective chapters. Chapter 7 presented the main results for this project. The grading system was used to assess the difference in PAS occurrence and morphology between males and females. The new method also examined the main suggestion for the cause of these difference, parity status, as well as other possible factors, age, ancestry and location. Chapter 8 discusses the results reported in Chapter 7, as well as Chapters 5 and 6. The possible causes the variation seen in the trait across humans are discussed in relation to these results. This chapter also contains the overall conclusion for the project, bringing together and discussing the results from both pilot studies and the main research. The final portion of the chapter discusses the limitation of the current project and suggest possible further research to build upon the findings.

2- Background and Literature Review

Although there have been a number of studies (Kelley, 1979; Suchey *et al.*, 1979; Cox and Scott, 1992) of the effect of pregnancy and parturition on the human skeleton, to date no conclusive evidence has been found. However, several studies have suggested that there may be a link between scars of parturition and the sex of an individual (Angel, 1969; Houghton, 1974; Ubelaker and De La Paz, 2012). This chapter will examine previous literature and research on the links between both parity status and sex on pelvic scarring. The primary focus will be on the preauricular sulcus of the *os coxae*. Literature covering sex assessment and the process of human birth and its evolution will also be discussed. For the purposes of this study, the terms female and male will be used to signify only biological sex and not gender which was not examined.

2.1- Introduction to the Role and Shape of the Pelvis

When compared with other non-human primates the shape of the pelvis in humans is unique (Tague and Lovejoy, 1986). The human pelvis is a complex structure that plays an important role in different biological functions in the body, some of which are in direct competition with each other (Krogman, 1951; Trevathan, 1998; Rosenburg and Trevathan, 2002; Franciscus, 2009). The shape of the pelvis is vitally important to many aspects of human life; primarily bipedalism, thermoregulation, and obstetrics (Buff, 2010; Trevathan, 2011).

Tague and Lovejoy in 1986 stated that the necessity for bipedalism played the largest role in the shaping of the pelvis in humans. In order to be bipedal, the pelvis has to be strong, robust and have a shape that minimises the load (Lovejoy *et al.*, 1973; Ruff, 1998). Bipedalism in modern humans allows humans to walk upright efficiently without risking injury to the individual (Inman and Eberhart, 1953). Thermoregulation, or the ability to regulate body temperature, is another vital trait in humans that is affected by pelvic shape specifically the width and depth (Gruss and Schmitt, 2015). This is because the shape of the pelvis affects overall body shape and body surface area-to-mass ratio which impacts temperature loss through the surface of the body (Ruff, 1991; Ruff, 1994).

Lastly, pelvic shape plays a vital role in pregnancy and parturition. A less ideal pelvic shape can lead to dangerous complications for the mother and foetus (Rosenberg and Trevathan, 1995). These three main biological functions all need to be achieved, however, they all require the pelvis to be a slightly different shape to be fulfilled. As a result, a compromise in shape, that is seen in the modern human pelvis, is favoured by selection (Gruss and Schmitt, 2015).

2.2- Anatomy of the Skeletal Pelvis

This section will detail the anatomy that makes up the pelvic girdle and the birth canal. Three bones comprise the human pelvis or pelvic girdle, they are the sacrum and the two *os coxae* (also known as the innominates) (McKern and Stewart, 1957) Additionally, the coccyx can be found on the inferior aspect of the sacrum (White and Folkens, 2005). The paired bones (*os coxae*) are curved forming both the anterior and the lateral portions of the girdle with the sacrum forming the posterior area (Figure 2.1) (Bass WM, 1987). Each *os coxa* is initially three separate bones that fuse into one during puberty between the ages of 12 and 17, this is called Tripartite fusion (Webb and Suchey, 1985; Schaefer, 2008; Schaefer *et al.*, 2009;). The bones fuse at a single primary ossification centre in the acetabulum (Cunningham, Scheuer and Black, 2016). These three bones are the ilium which is located on the superior portion of the *os coxae*, the ischium which is posterior and inferior, and the pubis which is anterior (Bass WM, 1987;). The *os coxa* each articulate to the sacrum at the corresponding auricular surface in the posterior of the pelvic girdle (Cox, 1989; White and Folkens, 2005; Rosatelli *et al.* 2006). These are the sacroiliac joints and are mostly immobile in order to provide the stability needed for bipedalism (Wang and Dumas, 1998; Cunningham, Scheuer and Black, 2016). This type of joint is a synovial plane joint (Walker, 1992; Borg-Stein *et al.*, 2005), the surface of the sacrum is covered with fibrocartilage and the auricular surface is covered with hyaline cartilage (Sachin, 1930; Maass, Cox, 1989; Maass, 2012). This joint is supported by the ventral sacroiliac ligament anteriorly and inferiorly, the interosseous ligament between the bones and the dorsal sacroiliac ligament posteriorly that becomes the sacrotuberous ligament (Bass WM, 1987; Schaefer *et al.*, 2009).

The bones further articulate anteriorly with each other at the pubic symphysis with another layer of hyaline cartilage that separates the two surfaces (Becker *et al.*, 2010). Two ligaments attach onto the bones to support the pubic symphyseal joints, these are the superior pubic ligament which attaches superiorly and the arcuate pubic ligament that attaches inferiorly (Scheuer and Black, 2004; Bekker *et al.,*2010). Like the sacroiliac joints, there is minimal movement in the pubic symphysis joints outside of pregnancy (Cox, 1989). As will be discussed in section 2.6, hormones released during the early months of pregnancy cause a softening or loosening of the ligaments leading to more movement than would usually occur (Abramsom *et al.*, 1934; Lindesey *et al.*, 1988). In non-pregnant adults, the gap between the pubic symphysis that is filled with hyaline cartilage is on average 4-6mm (Abramsom *et al.*, 1934; Garagiola *et al.,* 1989; Maass, 2012). During the final months of pregnancy, this gap widens. Within 3-6 months after birth, however, the gap closes again to an average of 4mm (Edmonds, 2007).

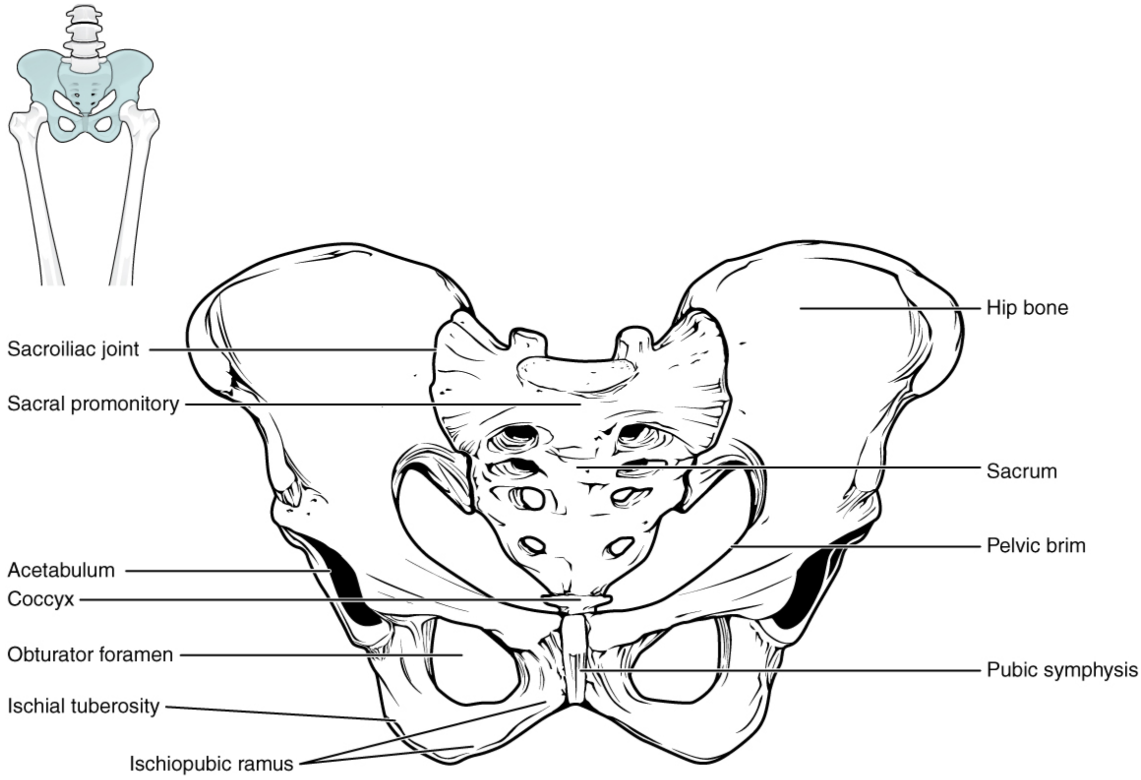


Figure 2.1: The bony pelvis

(Image taken from: https://upload.wikimedia.org/wikipedia/commons/3/3f/807_Pelvis.jpg)

Once the pelvis is fused it can be divided into two sections, the 'true' and 'false' pelvis. These are also referred to as the lesser and greater pelvis (Tague, 1989). The 'false' pelvis is the area above the pelvic brim, marked by the superior aspect of the sacrum and the linea terminalis (iliopectineal line). The 'true' pelvis is inferior to this point and is known as the birth canal (Walrath *et al.*, 2003; Kurki 2007) (Figure 2.2). The true pelvis is further split into three planes. The first is the inlet, which is at the point of the pelvic brim between the sacral promontory and the superior of the pubic symphysis, the second is the midplane, which is at the point of the ischial spines, and the final plane is the outlet that is the point of the ischial tuberosity (Kurki 2007; Trevathan, 2011). The three planes will now be discussed in more detail (Figure 2.2)

The Pelvic Inlet

The anteroposterior diameter of the pelvic inlet or brim is defined as reaching between the superior section of the pubic symphysis and the midpoint of the promontory of the sacrum (Trevethan, 2011). The edges of the inlet are bordered by the upper margins of the pubic bone, the iliopectineal line. In this plane, the normal anterior-posterior diameter is 11 cm and the transverse diameter is 13.5cm (Baker and Kenny, 2011).

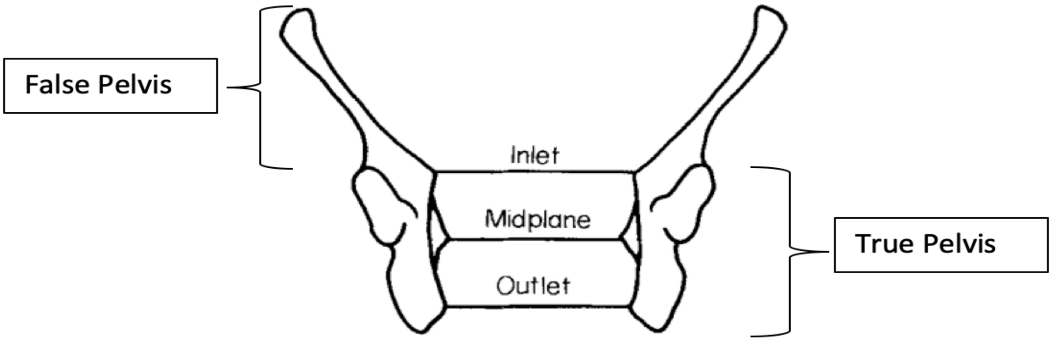


Figure 2.2: The divisions of the 'true' and 'false' pelvis. (Image adapted from Tague and Lovejoy 1986, page 241)

The Pelvic Midplane

The anteroposterior diameter of the pelvic midplane is defined as reaching between the midpoint of the pubic symphysis and the midpoint of the sacrum. The distance between the ischial spines makes the mediolateral diameter (Trevethan, 2011). In this plane, the transverse and anterior diameters are similar to each other usually, about 12cm, although there is variation. The diameter mediolaterally in the midplane is not as broad as in the inlet due to the protuberance of the ischial spines (Baker and Kenny, 2011).

The Pelvic Outlet

The anteroposterior diameter of the pelvic outlet is defined as reaching between the inferior section of the pubic symphysis and the tip of the coccyx. The outlet is bordered mediolaterally by the ischial tuberosity and the ischiopubic rami (Trevethan, 2011). In this plane the anteroposterior diameter is 13.5cm and the transverse is 11cm. The transverse diameter is initially the largest in the inlet plane however, as the pelvis narrows mediolaterally it becomes the smallest. The pelvic canal ends with a larger anteroposterior diameter, which is crucial to the mechanism of birth (Baker and Kenny, 2011).

2.3- Sex Assessment from the Pelvis

In order to establish the identity of an individual, one of the most important aspects is the identification of the sex (Meindl *et al.*, 1985; Kjellstrom, 2004) and it would be best to establish this before attempting to look for evidence of pregnancy and parturition. Humans are a sexually dimorphic species (Tague, 1992; Scheuer, 2002) and to understand the evidence that may be left behind from pregnancy the biological differences between males and females must first be understood. Scheuer (2002) noted that although the bones of a male's skeleton are usually larger than those of a female, the main differences occur in the skull and pelvis. The bones that make up the pelvic girdle are the most sexual dimorphic bones in the human body (Bruzek, 2002; Kurki, 2007). These are the preferred skeletal elements used in sex assessment (Iscan and Derrick, 1984); however, where the cranium is also present it should be used in conjunction (Meindl *et al.*, 1985). The use of skull traits is vital in cases where the sex is indeterminable from the pelvic girdle alone or the bones are missing or too damaged to give an accurate assessment of sex. Numerous traits can be used to establish sex and the literature surrounding the most frequently used pelvic features will be examined here. Meindl *et al.* (1985) found that when using a combination of features from both the cranium and post-cranium the accuracy of sex assessment from skeletal remains was 98%.

For this study, only adult remains from the undocumented samples were used, as sex assessment techniques for sub-adults are not as accurate or widely accepted (Hunt, 1990; Mittler and Sheridan, 1992). Tague (2000) found that the dimensions of the female pelvis are on average larger than that of males. Sex assessment methods from the pelvis are split into two main categories; metric and non-metric. For this present study, non-metric traits were used. This involves observing features on the pelvis and categorising them into female or male expressions of the trait rather than taking measurements (Klales, 2012).

A common technique used is the Phenice Method that involves examining the ventral arc, the subpubic concavity and the ischiopubic ramus. This was first developed by Phenice in 1969. Subsequently, the method was tested by Maclaughlin and Bruce (1990) who put the accuracy at 59%. However, Sutherland and Suchey (1991) stated the accuracy was 96% and Ubelaker and Volk (2002) found the method to be accurate 88.4% of the time and to be slightly more accurate in females than males. This approach has been widely used across a range of temporal and geographical samples and has been found to be one of the most accurate and reliable techniques (Klales, 2012). This was one of the methods used to assess sex on the undocumented populations in this research. The details on how to use the Phenice Method will be discussed in Chapter 4 (Methodology). The limitations with the approach for this research is that the *os pubis* can often be damaged in the archaeological record. For example, Waldron (1987) stated that preservation of the pubis is only approximately 30% in archaeological samples.

Another non-metric dimorphic trait used for estimating sex is the greater sciatic notch (Singh and Potturi, 1978; Walker, 2005). This technique was particularly useful as the notch is located next to the PAS; therefore in the vast majority of cases, there was a notch present and mostly undamaged. This technique was used in conjunction with other methods to establish sex for the undocumented collections in this study.

Although there are methods for establishing the sex of an individual from the long bones and the cranium, the primary traits used in the present research were from the pelvic girdle. A selection of cranial traits was also examined in this research in order to establish sex in a small number of cases (Aćsádi and Nemeskéri, 1970; Buikstra and Ubelaker, 1994; Walker, 2008).

2.4- Overview of the Preauricular Sulcus

The PAS is located on the *os coxae* between the auricular surface and the greater sciatic notch (Finnegan, 1978) (Figure 2.3). The sulcus is characterised as a depression in the bone at the site of the attachment for the anterior sacroiliac ligament (Bruzek, 2002).

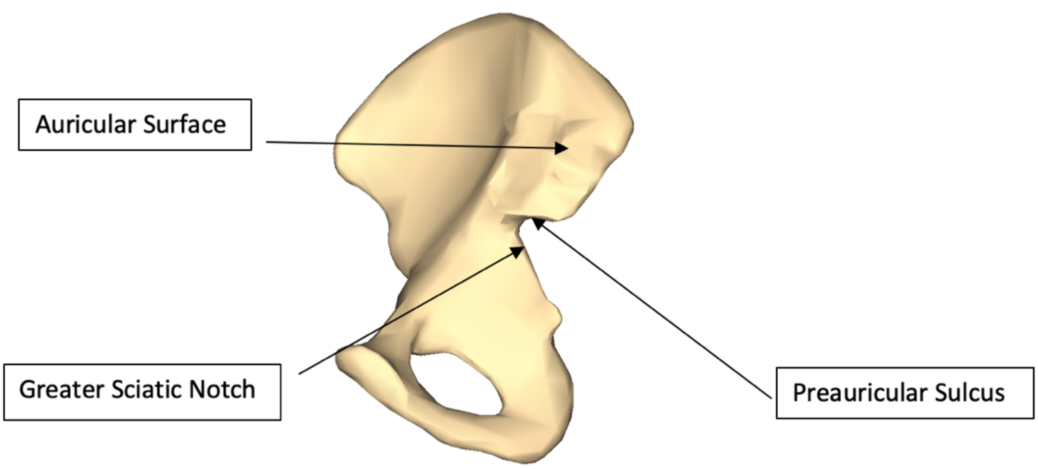


Figure 2.3: The medial view of the location of the preauricular sulcus on a right *os coxae* (Image adapted from https://upload.wikimedia.org/wikipedia/commons/3/3e/Hip_bone_-_close-up_-_medial_view_%28right_hip_bone%29.png)

It is found in both sexes although is more commonly found in females (Houghton, 1975; Cox, 1989). It is this observation that has led to the suggestion of its link to pregnancy and parturition which will be tested in this study. Although there have been many studies in this area there is currently no consensus on this topic (Ubelaker and De La Paz, 2012). The PAS is sometimes referred to in the literature as the preauricular groove although for this thesis it will be referred to as the preauricular sulcus or PAS. The sulcus is typically a groove or series of pits on the bone. These pits can range from very small and shallow depressions (1-2mm in depth) on the bone to larger and deeper ones (greater than 5mm depth) (Milner, 1992). The trait is the site where the anterior sacroiliac ligament inserts into the bone. It is thought that when changes occur to this ligament during pregnancy and parturition they cause bone remodelling at the site of attachment that can be seen in the form of a PAS (Angel, 1969; Houghton, 1975).

The person that is usually credited with first drawing attention to the preauricular sulcus, or the 'sulcus preauricularsis', is anatomist Zaaijer in 1866 (Ubelaker and De La Paz, 2012). Zaaijer, along with other authors Löhr, Aeby, and Virchow, noticed both the change to the bone that occurs in this region and the amount of variation that is seen between individuals. Zaaijer himself observed a sulcus in 23 out of 26 females that he studied and Löhr in 41 of 59 females and only 19 of 31 males. However, neither appeared to call attention to it being more common in females than males (Derry, 1909). Derry agreed with an earlier interpretation of Aeby that the PAS may be associated with parity. He hypothesised that the softening and loosening of ligaments (due to the release of the hormone relaxin which will be discussed later in the chapter) that occur during pregnancy could lead to the development of a more defined PAS.

2.5- Scars of Parturition

Forensic anthropologists, anatomists, and clinicians have long suggested that pregnancy and parturition may leave a scar on the skeleton, especially in the *os coxae*, "As a result of pregnancy the pelvic bones undergo changes which are permanent or fade only in old age" (Gornall *et al.* 1975, p.665). However, no widely accepted method has been established to examine these scars. The phrase scars of parturition was first used by Stewart (1970). It is sometimes written in text with quotation marks however for this present study they will not be used. One of the traits that are most commonly linked to parity status is the preauricular sulcus. The idea that it may be possible to use this trait to establish whether an individual is parous (has given birth) or nulliparous (has never given birth) has been around for more than a century (Ubelaker and De La Paz, 2012). Other common traits that have been linked to scars of parturition are dorsal pubic pitting, the pubic tubercle (Figure 2.4), 'osteitis pubis' and separation of the pubic symphysis (Maass, 2012; Cox, 1989). Although the focus of this study is about the link between PAS and parity, these other morphologies will also be discussed as the majority of studies focus on a combination of these features rather than just one.

Whilst working on skeletal remains in Cairo, Derry (1909) noticed that the PAS occurred more often in females than males. He suggested that it may be linked to the sex of the individual and parturition, which had also previously been proposed by Aeby in 1858 (Ubelaker and De La Paz, 2012). Smith in 1940 agreed with this assessment believing that a well-developed groove was an indicator of pregnancy. Derry confirmed that the sulcus was the site of attachment of the sacroiliac ligament. He suggested that the bone remodelling may be linked to changes caused by softening of this ligament. This hypothesis was further investigated by others in the field including the anatomist Todd in the 1920s. Todd recognised the difficulties in assessing the parity status in the female skeletons in most collections but argued that "I do not believe that pregnancy and child-birth leave any permanent stamp upon the skeleton" (Todd, 1921, p.40), although this was in relation to all changes to the pelvis during childbirth and not specifically about the PAS. In 1957 however, a paper by Stewart stated that he felt Todd had been too quick to dismiss the effect of pregnancy and parturition on the skeleton. He suggested that it was likely the females in Hamann-Todd Human Osteological Collection (Cleveland Museum of Natural History) were nulliparous, as otherwise the bodies would have been claimed by their children instead of remaining in the collection.

Stewart emphasised that scientific evidence supported the theory that the pelvic joints softened during pregnancy. He also highlighted the importance of remembering that in recent times obstetric care had changed dramatically. Therefore the skeletons found in the archaeological record and the skeletons from modern times could be very different. He argued that this needed to be taken into account when observing the differences between the skeletons from these different time periods. In 1970 he used the example that Eskimo individuals had a greater number of scars of parturition than the individuals from the modern samples from the Robert J. Terry Anatomical Skeletal Collection, housed at Smithsonian National Museum of Natural History. He also noted in his examinations it appeared that some women could give birth multiple times without showing any signs of scaring (Ubelaker and De La Paz, 2012).

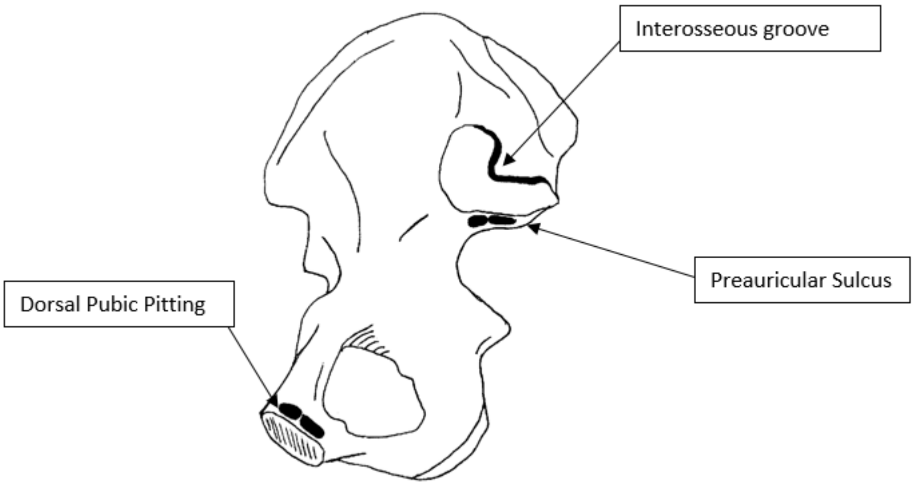


Figure 2.4: The medial view of the location of three of the traits on a right *os coxae* that are linked to possible scars of parturition (Image adapted from Kelley 1979, page 549)

In 1969 Angel, an anatomist who worked at the Smithsonian with Stewart published a paper on the topic. He suggested a method to not only recognise whether an individual had ever been pregnant and undergone parturition but also to estimate how many children they had given birth to. He proposed that by counting the number of pits on the dorsal pubic surface it was possible to calculate this. For instance, if there were five pits on the bone then the female had given birth to five children. For proof of this theory, he used the pelvic bones of eight females with known parity information. There was one in the sample that did not fit his theory accurately. The pelvic bone had very deep pitting but the individual had only given birth twice, Angel maintained that the individuals were either pathological or had given birth more times than recorded.

This theory was widely discredited. As part of his research in 1970, Angel was sent the photographs of the skeletal remains of a pelvis without any of the biographical or identifying information. Angel concluded that according to his method the pelvis belonged to that of a woman who had given birth to 13 children, however, this turned out to be incorrect as the skeleton belonged to a male instead (Ubelaker and De La Paz, 2012). Although there was mounting evidence to suggest that Angel's method was incorrect, as his predictions of parity status did not consistently match with known records, he again insisted that the records themselves must be wrong and that the women in question must have had more children than were recorded. In 1971 Angel went further in his claims about the effect of pregnancy and parturition on the female skeleton by arguing that parity led to a formation of a spike on the pubic tubercle. The remains examined came from the archaeological site of Lerna in Greece.

Gilbert and McKern in 1973 published their research into ageing from the *os pubis* in female skeletal remains. They examined 140 female individuals that had documented parity status. Even though their focus was on the changes related to ageing that occur over time, they recognised the role that parity might have. They concluded that it did not seem possible to accurately estimate the number of pregnancies an individual had experienced. However, they suggested that the *os pubis* of parous females may have an older appearance than they actually are.

In 1976 Putschar published his article in English about the relationship between parturition and the pubic symphysis. In line with his previous work (published in German) he once again stated that hormones released during the early months of pregnancy cause loosening of the ligaments. He concluded that delivery of a full-term neonate would always leave immediate evidence in the form of some damage to the pubis. However, he recognised that the level of damage would be different depending on several factors; such as the dimensions of the maternal pelvis, the age of the mother and the size of the neonate's cranium. When discussing the long term effect of parturition he concluded that delivery of a mature foetus would cause a permanent loosening of ligaments, especially around the pubic symphysis.

In 1975, Houghton wrote a paper suggesting again that pregnancy and parturition did affect the PAS and that it left scars on the bone that could be observed. He proposed that rather than the size or shape being an indicator it was instead the depth and more importantly the changes in depth that were the best indicators. Houghton accepted that PAS were seen in both males and nulliparous females but stated that the nature of the sulcus or groove would be different from that of a parous female. He classified the grooves into two types; grooves of ligaments (GL) and grooves of pregnancy (GP). GLs were for sulcus that had a shallow, smooth and consistent depth and these would be found in males or nulliparous females. GPs which were indicators of a parous female would have a rougher texture to the floor of the sulcus, with pits or channels and multiple changes in depth. It is this paper and theory that was the inspiration for the present study, the grading system which was created to capture the changes related to the GL and GP grooves.

Like many others before him, Ashworth was interested in the effect that pregnancy and parturition may have on skeletons. In 1976 he published a study on scars of parturition in “Pre-Columbian and Colonial Peruvian Mummies”. He agreed with Harris and Murray (1974) that any scars of parturition may be part of an inflammatory disorder called ‘osteitis pubis’. This condition is more common in males particularly athletes, or men having undergone operations on their prostate or bladder. They suggested that the main cause of this condition was a repetition of minor trauma to the pelvis and led to pain over the pubis. Ashworth felt that too much walking or movement during pregnancy as well as the parturition itself might be similar to the trauma seen in men. This trauma is especially evident after the first trimester when the ligaments have loosened and the excess weight and pressure of the foetus in the pelvis are present. Harris had noticed that women with multiple pregnancies sometimes showed pubic lesions similar to those of ‘osteitis pubis’ which Ashworth agreed with. Ashworth studied 86 female mummies and found signs of ‘osteitis pubis’ in 72.3% of Pre-Columbian mummies and 57.6% of Colonial mummies. These results demonstrated that the living conditions of different populations may affect the occurrence of ‘osteitis pubis’ and by extension any scars of parturition. Ashworth remarked that there was a large difference in the environmental conditions of the two groups. With the Pre-Columbian group having more access to food and ‘healthier’ living conditions than the Colonial mummies. This lifestyle was established through the use of the archaeological record to look at grave goods, food offerings, pathologies and trauma to the bone as well as Harris Lines. He also highlighted that it was interesting that the ‘healthier’ (Pre-Columbian) of the two populations showed more scarring but stated that the exact cause of the condition was unknown (Ashworth, 1976).

In the late 70s, the Hamann-Todd Collection was used in two separate studies to further investigate scars of parturition. The first study was carried out by Adams Holt in 1976. Adams Holt used the Hamann-Todd Collection as he felt that previous studies had used skeletal remains that did not have an adequate level of parity information about the individuals. He studied 68 female pelves that had known obstetric histories. It should be noted that according to Adams Holt himself these medical records and analysis of parity came from the autopsies and examination of the soft tissue which is an “imperfect” (Adams Holt, 1976, p. 92) way to assess parity status but he felt that it was an acceptable method. The Adams Holt paper focussed on pitting on the dorsal surface of the pubic symphysis. He found that there was no statistical difference in the presence of this pitting (or scarring) between parous and nulliparous females. Of the nulliparous females, 14.5% showed small scarring and 23.4% showed medium to heavy pitting. In parous females, 12.9% showed small scarring and 18.9% medium to large scarring. He did observe however that in the sample of the nulliparous females who showed scarring there were higher levels of obesity and/or pathologies. This suggested that scarring could occur for a variety of reasons but not discounting that parity could be one of them (Adams Holt, 1976).

In 1979 Kelley used the same collection in an attempt to improve upon Adams Holt’s research. Kelley’s selection criteria for the female skeletons studied was stricter than Adams Holt’s. He only used individuals listed in the collection as “certainly has had (or not had) children" (n=198). Adams Holt, however, had also used females listed as "probably has had (or not had) children" (Kelley, 1979, p. 541). Kelley also examined more traits on the pelvis linked to parity than just dorsal pubic pitting. Two of the structures that he observed were the PAS and the interosseous groove. The location of these three features is shown in Figure 2.4. Bony lipping of the dorsal pubic margin and sacral pitting were also examined but disregarded from the final results for inaccuracy. His results disagreed with Adams Holt's assessment that medium to large scarring of the dorsal pubis occurred in similar rates between nulliparous and parous females. Instead, he found that it occurred infrequently in nulliparous females and suggested that when it did, it was due to another type of trauma. To examine the PAS Kelley used Houghton's 1975 classifications of GL and GP. He concluded that GL grooves occurred 2.5 times more frequently in nulliparous females than in parous ones. His results also showed that GP grooves occurred twice as frequently in parous females (43.9%) than nulliparous (20.6%) although noted that the occurrence rates in nulliparous females were higher than expected. For the interosseous groove, he observed similar results to the PAS. Kelley hypothesised that using all three traits together gave the most reliable assessment of parity status but argued that the PAS is the most precise indicator of parturition (Kelley, 1979). His research also showed that there was no statistical difference found between the White individuals (n=75) and Black individuals (n=123). He further proposed that age was a factor in scarring believing that the more elderly females showed less scarring as ageing appeared to reduce these signs. Overall Kelley concluded that "There is no doubt that pits and grooves located in the regions examined in this study correlated with pregnancy and parturition" (Kelley, 1979, p. 544).

One of the largest studies into this topic was carried out by Suchey *et al.* in 1979. The authors studied 486 modern American females with known obstetric history to examine the relationship between dorsal pitting of the pubic symphysis and parity. The individuals came from autopsies carried out at the Los Angeles County Department of Chief Medical Examiner-Coroner, with the majority of the autopsies taking place in the summer of 1977. The results showed that there was a weak correlation between dorsal pitting and the number of full-term pregnancies an individual had experienced. However, this correlation was not strong enough to be used to estimate the number of pregnancies. As with many previous studies they observed multiple instances of nulliparous females having medium to large levels of scarring and parous females having no or little scarring. They did, however, note that age appeared to be a factor in dorsal pitting. The authors found that in nulliparous individuals absence of dorsal pitting was more common in those younger than 30 than over 30. The relationship between the pubic bones and the effects of parturition was additionally examined in 1980 by Bergfelder and Herrmann using a sample of 49 pairs of female pubic bones with parity documentation.

They also determined that there was no conclusive evidence of a relationship between parity and pubic pitting.

A Michigan State University PhD thesis by Dunlap from 1981 focussing on the PAS, studied 67 females and 30 males of known parity status. He, like other researchers, concluded that it was not possible to predict parity from scars of parturition but did believe that a groove of pregnancy was linked to obstetric events noting that they were not found in male individuals. He argued that obstetric events were one of the causes of sulcus development along with the angle of the greater sciatic notch, as he observed a correlation between the wideness of the PAS and this trait, and lumbosacral anomalies (Cox, 1989; Ubelaker and De La Paz, 2012).

A study published by Owsley and Bradtmiller in 1983 on two female Arikara skeletons introduced a new feature into the topic of scars of parturition: Schmorl's nodes. They found that the usual factors leading to Schmorl's nodes, trauma to the vertebrae and osteoarthritis, did not appear to be present in these cases. They instead suggested that along with PAS presence and pubic pitting there may be a link between Schmorl's nodes and parity. However, they concluded that this link was limited especially in the case of Schmorl's nodes.

In 1989, Cox completed her PhD thesis at University College London on scars of parturition in the Christ Church Spitalfields sample. She examined 94 female skeletons that she established the obstetric histories of. Her thesis examined all the different traits that have been linked to scars of parturition. The results found that there was no correlation between parity and these scars, particularly PAS and sacral scarring. She further reiterated this conclusion in articles published in 1992 and 2000.

In the same year (1989) Spring *et al.* examined 300 radiographs taken of the sacroiliac region to investigate the relationship between the PAS and parity. Their sample was 110 adult males and 190 adult females, with all the females having parity information available. Their results concluded that the PAS was not a reliable indicator of parity, however, they suggested that a deep sulcus was a reliable tool for sexing as they were only found in females. As part of their study, they were able to take radiographs of six women before and after being pregnant, they found no difference in the sulci between the two radiographs.

Schemmer *et al.* (1995) also used radiographs to study the relationship between parity and PAS. In the article, the authors used the term 'paraglenoid sulcus' instead of preauricular sulcus. They examined the radiographs of 70 adult females and found that there was a statistically significant relationship with parity, finding only deep grooves in parous females. Tague (1988) further studied the relationship between the PAS and parity status in both humans and nonhuman mammals. He used three samples; human Amerindian skeletal remains, Chimpanzee (*Pan troglodytes*) and Western Gorilla (*Gorilla gorilla).* He examined the role of hormones in pitting but concluded that it was unlikely that it was an indicator of parity. However, he indicated that further study was required to understand the relationship between oestrogen and the preauricular area. It should be noted that Chimpanzee and Gorilla pelvic morphology and neonate cranial size are different from humans (Figure 2.6) (Rosenburg and Trevathan, 2002). Results from examining their remains should be view in caution when compared to human skeletons.

Snodgrass and Galloway in 2003 summed up the interest in this topic by writing “Parity indicators in human skeletal material are highly desirable yet elusive” (Snodgrass and Galloway, 2003, p.1226). Their study examined the paired pubic bones of 148 modern women with known parity information looking at the pubic tubercle and dorsal pubic pitting. Their results suggested that there was no relationship between changes to the pubic tubercle and parity. They found that in younger females there was a relationship between dorsal pitting and the number of births. They also observed that in older females (over 50 years old) there was no correlation between the number of births and pitting however there was with BMI, suggesting that although parity may play a role in dorsal pubic pitting body mass could as well.

In both a 2012 thesis and 2016 article Maass studied the scars of parturition to better understand their relation to parity and examine other factors that may be affecting them. In their article, Maass and Friedling (2016) recognised the limitations of many of the previous studies regarding scars of parturition. They noted that some of the studies of this area were on undocumented or unreliably documented collections. This assessment agrees with Ubelaker and De La Paz, 2012 (p.870) who stated: “Although much of the research has been conducted using documented skeletal collections and scientific methods, many publications base their findings on conjecture with little scientific or empirical evidence to support their claims”. Maass’s research, however, aimed to address the problems regarding accurate parity information by instead focussing on other factors that may affect the scars including; sex, age, body mass, and pelvic shape. The study examined; dorsal pubic pitting, the pubic tubercle, the preauricular sulcus, the interosseous groove, and the iliac tuberosity. They found evidence of scars in both sexes however found that they occurred less frequently and were less severe in males than females. They also observed that age had no effect on the scars in either sex. Maass and Fielding concluded (2016) a more likely cause of scarring may be weight-bearing and the stability of the pelvic girdle. The noted that the female pelvis requires more ligament stabilization which they proposed leads to more scarring.

They also argued that in some male pelves the weight-bearing strain may be enough to cause scarring. Both this article and the earlier thesis examine how specific pelvic measurements and shapes, and body mass may relate to the preauricular sulcus morphology. This will be expanded and discussed in greater detail in Chapter 5, the pilot study about pelvic shape and Chapter 6, the pilot study using CT scans with more biographical information including body mass.

McArthur *et al.* (2016) carried out a study focused on using CT scans to assess the relationship between dorsal pubic pitting and birth. They examined the CT scans of 311 female subjects with information regarding parturition and 48 males. They classified the pitting into grades (0 = not present, 1 =faintly present, 2 =present and 3 = prominent). Their results found no males showing pubic pitting. They concluded that there was a positive statistically significant relationship between prominent pits and larger numbers of births. Although it was not the focus of the study they also examined the presence of PAS between the two samples (those with prior history of parturition and those without). They observed that there was no statistically significant difference between the two groups.

In an effort to better understand the contradicting and contrasting results from the multiple previous studies already conducted on the topic of scars of parturition McFadden and Oxenham published a meta-analysis review on the topic in 2018. They highlighted that meta-analysis reviews are frequently used in other fields such as medicine but not commonly in bioarchaeology. The results found that neither dorsal pubic pitting or the preauricular sulcus were predictors of parity status. However, it should be noted that only a small number of studies (n=11) were included, for this meta-analysis only one from each skeletal collection could be analysed. As there are only a small number of skeletal collections worldwide with parity information this may have affected the results.

Another area of interest in the topic of scars of parturition is the separation of the pubic symphysis. A study of 10 instances of this occurring during parturition was published in 1933 by Boland where he suggested that although the condition was not a common occurrence caused by delivery there were cases of it happening. He further suggested that it was not reported more due to a lack of recognition rather than frequency, this theory was later supported by Lindsey *et al.* (1988). In 1996 Kowalk *et al.* emphasised the rarity of this condition but demonstrated the lack of consistency regarding the subject, “the prevalence has been reported to range from one in 521 to one in 20,000”(Kowalk *et al.*, 1996, p. 1746). He also suggested that the cause of this separation when it did occur may be linked to the production of hormones such as progesterone and relaxin during pregnancy which had been noted by previous authors such as Abramson (1934). A study by Thorp and Fray (1938) found that in 44% of the parturition cases they studied the pubic symphysis widened, but not separated, by 5mm on average. However, Ohlsen (1973) concluded that there was no correlation between a widening of the pubic symphysis and parturition.

Ubelaker and De La Paz (2012) reviewed the literature surrounding scars of parturition. They summarised "the research and discussion… suggest that pregnancy and parturition can produce skeletal alterations; however conclusive evidence that these alterations can be diagnostic of parity status is lacking" (p.869). Although there have been many studies into the links in the relationship between scars of parturition and parity status many of these have similar problems and limitations. A large majority of these studies were conducted on samples where the parity status was often unclear or unknown. Without comprehensive testing of the methods on collections where the full medical history and parity status of the females studied is known it is not possible to truly understand the link between scarring and parity status. Similar limitations were encountered during this PhD research as few collections have complete parity history for the females, a large number of skeletal remains collections are undocumented. Those that are not, often only have data such as sex, age at death and sometimes cause of death. Even in cases where parity records were able to be established this was mostly done using parish and church records. It is important to note that miscarriages and stillbirths would not be recorded in the majority of cases but would likely still have a similar effect on the skeleton as successful births.

In conclusion, current research seems to suggest that pregnancy and parturition may cause some changes to the skeleton however the extent of these changes is unknown. They also may not cause changes in every case and would not be uniform. In almost all other aspects of the human skeleton, there is a large amount of variation and it would make sense that in the case of parity status this would also be true. Many factors such as environment, genetics, the size of both the mother and foetus, the pelvic morphology of the mother and the nature of the pregnancy itself, along with multiple other factors, could all have an effect on any scarring that could occur.

2.6- The Role of Hormones in Scars of Parturition

As stated previously the PAS is the site of attachment for the anterior sacroiliac ligament. It is thought that during pregnancy this ligament is loosened to widen the birth canal in preparation for parturition. These changes could cause the remodelling of the bone that can be observed (Maass, 2012).

During the first trimester of pregnancy, there is an increase in the secretion of the hormones oestrogen, progesterone and relaxin (Ambramson *et al.*, 1934). These hormones especially relaxin are suggested to cause the softening of the ligaments of the pelvis. This is necessary to widen the birth canal at the pubic symphysis and sacroiliac joints in order to prepare for parturition (Lindsey *et al.*, 1998). Relaxin is secreted by the corpus luteum and placenta in human females and is a polypeptide hormone (MacLennan, 1991). Studies of the hormone levels in parous females have found that levels increase during the 10^{th}-12^{th} week of pregnancy, reaching its peak around approximately 20 weeks, finally returning to the normal level after labour (Heckman and Sassard, 1994, Becker *et al.*, 2010). This softening of ligaments coupled with; an increasing strain on them from the weight of the developing foetus and increased lumbar lordosis is thought to lead to bone remodelling at ligament attachment sites or scars of parturition (Putschar, 1976).

2.7- The Process of Parturition

The process of giving birth in human females is complicated and not without risk and strain (Oxorn and Foote, 1975; Marieskind, 1979). In order to understand the effect that parturition may be having on the human skeleton, it is first important to understand the details of it. This section will discuss the biological and mechanical process that the mother's body and foetus go through to have a successful birth. The process of birth usually involves three rotations of the foetus for it to safely pass through the birth canal (Trevathan, 2011). The soft tissues that also make up the birth canal will not be discussed in this thesis as they are not preserved and found in the fossil record. Only the bone elements will be discussed, as they are relevant to the research. The bony birth canal will be referred to as simply the birth canal going forward. The birth canal in humans, in fact in all primates, is divided into three separate planes; the inlet, the midplane and the outlet (Rosenburg and Trevathan, 2002). The diagram of these planes in three primate species including human can be seen in Figure 2.5. Full descriptions of the planes were discussed above in section 2.2.

The three rotations result in the head of the neonate facing posteriorly, however, rotating to face laterally as the rest of the neonate is birthed (Edmonds, 2007). It is this unique set of rotations that is part of the reason humans seek to give birth with assistance as opposed to solitary like most other primates (Trevathan and McKenna, 1994). In other non-human primates, the mother will reach down once the neonates head is birthed and assist by removing the umbilical cord from around their throat in some cases as well as guiding the foetus from the birth canal (Trevathan, 1998). However in humans due to the neonates head facing the opposite direction to the mother this is not possible, in fact, it could lead to damage to their spinal cord due to the angle of the neonate. Instead, human females routinely have assistance during birth from either family members, midwives, nurses or doctors. Cases of solitary human birth are rare and are usually due to circumstance rather than preference (Rosenburg and Trevathan, 2002).

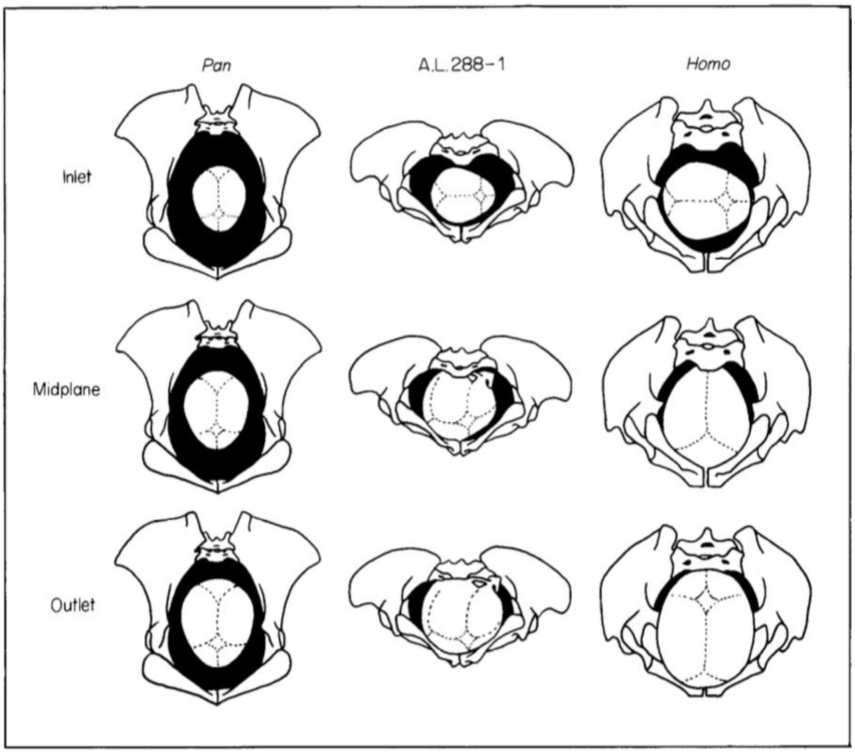


Figure 2.5: Diagram of the birth process in three primate species (*Pan troglodytes, Australopithecus afarensis* and *Homo sapiens)*. (Image taken from Tague and Lovejoy, page 247)

The shape and size of the female pelvis are thought to play a large role in the process of giving birth (Trevathan, 2011). Large variability can be found in the human female pelvis, however, they are typically categorised into four different shapes: Gynaecoid, Android, Anthropoid and Platypelloid (Caldwell and Moloy,1933). Gynaecoid which is the most suited for childbirth has a round pelvic inlet. Android is typically smaller than Gynaecoid and has a triangular-shaped inlet. Anthropoid pelvis have a smaller transverse than the antero-posterior diameter. The final pelvic shape is the Platypelloid, which is rare, has a significantly larger transverse diameter than antero-posterior (Cox, 1989). The differences between these shapes and their significance will be discussed in greater detail in Chapter 5 (St Brides Pelvic Shape Analysis).

As the foetus head moves through the birth canal the shape is vital for success. Typically the head will be narrow mediolaterally and long anteroposteriorly. The unfused cranial sutures in foetus allow for flexibility in the skull as it passes through the birth canal (Trevathan, 2011). As the clavicles of the foetus are already beginning to ossify the shoulders present a challenge to the birth process. The width mediolaterally in the shoulders is wider than the neonate's head making the three rotations even more essential (Rosenburg and Trevathan, 2002).

The main movements of labour that lead to the three rotations are; engagement, flexion, descent, internal rotation, extension, external rotation and expulsion (Edmonds, 2007; Trevathan, 2011). During engagement the first of the rotations occur, the head revolves so that the longest diameter (sagittal) aligns with the largest diameter of the mother's inlet (transverse). This process can take place days before full labour begins. The next rotation of the neonates head happens during the internal rotation. Taking place within the birth canal, the head must rotate for the sagittal diameter to pass safely through the midplane and outlet that is anteroposteriorly longer but mediolaterally shorter. The rotation means that the narrow frontal bones of the neonate face the sacrum of the mother causing the foetus to leave the birth canal facing posteriorly (called 'occiput anterior' presentation). This presentation is the most common in non-breech births (where the post-cranium exits the birth canal first). The last rotation occurs during external rotation after the neonates head has left the mother's body. The foetus then rotates a final time to allow the shoulders to pass safely through the narrow mediolateral dimension of the midplane and outlet (Edmonds, 2007; Trevathan, 2011).

2.8- The Evolution of Parturition in Humans and Problems Associated with it

The focus of this thesis is to create a new anthropological method for grading the preauricular sulcus to be used for forensic and bioarchaeological purposes. The study of the evolutionary implications of childbirth in humans and current maternal mortality rates are related to the study topic. However, as they are not the focus only a brief overview will be summarised here.

The process of giving birth in modern humans is particularly difficult (Oxorn and Foote, 1975; Marieskind, 1979). Compared with other species human parturition is a long and painful process that has a moderately high level of injury or death. It also leads to the birth of relatively helpless infants when compared to other species (Dunsworth and Eccleston, 2015). This can be seen across the world but especially in developing countries where the maternal death rate is much higher than in countries with more developed healthcare systems (World Health Organisation, 2005; 2006). In some of the poorest populations in the world, it has been suggested that one in every six women die as a result of pregnancy and parturition (Ronsmans *et al.*, 2006). WHO (The World Health Organisation) defines maternal mortality as "the death of a woman whilst pregnant or within 42 days of delivery or termination of pregnancy, from any cause related to, or aggravated by pregnancy and its management, but excluding deaths from incidental or accidental causes" (Say *et al.*, 2014, p.323).

In many skeletal collections, the average age at death for females is significantly lower than in males (MacDonell, 1913; Wells, 1975). Wells *et al.* suggested that these differences were due to parturition related deaths (Wells *et al.*, 2012). Compared with other primates the human birth process is complicated and more dangerous. Great apes do not require the three birthing rotations detailed in section 2.7 and have a larger birth canal to neonate cranium ratio than humans (Trevathan, 1988) (Figure 2.6).

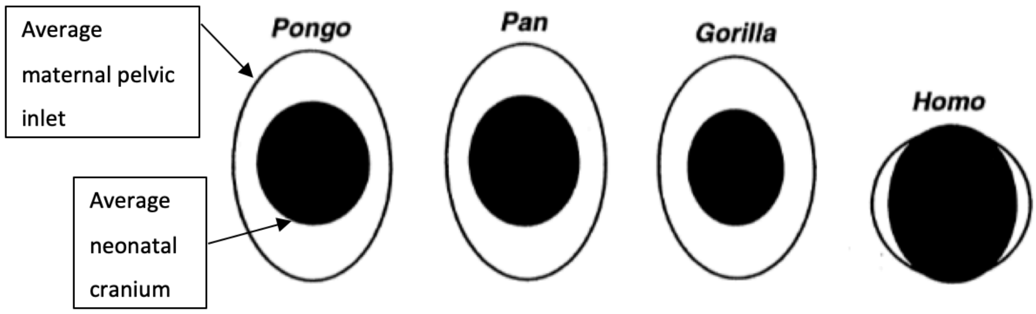


Figure 2.6- The relationship between maternal pelvic inlet size and neonate's head size. In three great apes (*Pongo, Pan* and *Gorilla*) and humans (*Homo*). (Image adapted from Rosenberg and Trevathan 2002, page 1200)

Until recently the literature surrounding the difficulty humans encounter giving birth have all suggested that it is caused by what is known as the 'Obstetrical Dilemma'. This term was first described by Washburn in 1940. This name refers to the competing selection pressures between bipedal locomotion and the process of birthing a large-brained foetus (Meindl *et al.*, 1985; Rosenberg, 1992). The theory proposes that in order to become bipedal, the shape of the hominin pelvis had to change drastically. To support the lumbar vertebrae in an upright position for bipedal locomotion to occur it was necessary for the pelvic canal to become narrower, constraining the birth canal. However, a wider pelvic canal is required for an easier birth with fewer risks and complications for both the mother and the foetus. These two traits compete against one another, especially as hominins brain size increased (Gruss and Schmitt, 2015). This idea was developed further by Trevathan (1988) suggesting that the broad dimensions of the foetus shoulders were also a factor alongside encephalisation. The hypothesis was also supported by DeSilva (2011) who theorised that the overall body size of the neonate may be a factor and not just cranium size. She also suggested a midwifery hypothesis related to this model. As discussed in section 2.7 modern human females rarely give birth alone, instead commonly having some kind of birthing attendant present. She hypothesised that this was due to the constraints placed on the birth canal due to the 'Obstetrical Dilemma'. The theory also suggests that the reason modern human infants are born in a less developed state to other species is to ease the strain on the birth canal (Wells, 2017).

The next evolutionary model was proposed by Wells *et al.* (2012). This theory shares some similarities with the 'Obstetrical Dilemma' model in that it suggests that changes to pelvic shape during evolution directly affects the parturition process. However, Wells *et al.* hypothesised that recent environmental factors, not bipedalism, had a large influence on pelvic morphology. These factors included adaptation to changes in climate and poor nutrition. The authors argued that hominins had been bipedal for so long, at least 4-5 million years (Lovejoy, 2005; Grabowski *et al.*, 2011; Fischer and Mitteroecker, 2015) that any obstetrical compromise would have been resolved long ago.

The final model was proposed by Dunsworth *et al.* (2012) and is called the Energetics of Gestation and Growth model (EGG). This theory, unlike the two previous models, suggests that instead of pelvis shape being a constraint on neonatal size it is an adaptation to it. The authors hypothesise that the birth process begins when the mother can no longer produce enough energy to grow the foetus further. They suggest that the size of the pelvis is simply a response to this energetic limit. They highlighted the large variability in pelvic size to suggest that the shape of many maternal pelves could support a larger foetus but the mother's energetics could not. These three evolutionary models are the main theories for how the process of childbirth has evolved in hominins to form the pelvic shape that is present in modern humans.

2.9- Birth in the Post-Medieval Period

In Chapter 3 the histories of the collections examined will be discussed. However, the only temporal and geographical region (except modern) where parity information was available for this study are post-medieval Britain. Therefore, this section will detail the process of pregnancy and parturition in these specific populations. Both collections are from post-medieval London and are relatively middle-class populations for their time periods. Detailed histories of both collections will be discussed in Chapter 3 however here an overall history of what a typical woman would experience giving birth in this time period will be discussed.

Since this time period, our understanding and knowledge of pregnancy and parturition have greatly increased. During this time there was still a large amount of mystery around the process of childbirth and particularly why some led to disastrous consequences to both the mother and foetus. Although pregnancy was seen as a natural progression to marriage Cox

(1989) suggests that there was still a large amount of fear regarding it. This was due to the high maternal mortality rate. It is likely that most women becoming pregnant would know relatives or friends that had either died or were left with lasting medical complications as a result of pregnancy (Carter and Duriez, 1986). The birth records from the time period do not record where the births took place however it is likely that the majority occurred at home without the presence of a doctor. Birth would have been extremely painful at the time with little or no painkillers. It appears that any pain relief that was administered were herbal remedies (Carter and Duriez, 1986). There was no set position for women to give birth in with it likely depending on individual preference. Some of the positions include standing, squatting, kneeling or lying in bed (Cox, 1989).

As stated previously maternal mortality was relatively high, especially compared with the standards of today. It is difficult to ascertain the exact maternal mortality rate as the death records were not always accurate. The term ‘childbed’ is often seen listed as a cause of death; however, this is not always from the parturition itself but also complications after the birth (Cox, 1989). One of the leading causes of maternal mortality is Puerperal fever (now known as post-partum sepsis) which is often caused by poor hygiene during the birthing process. The lack of cleanliness and hygiene are likely to have played a large role in the maternal mortality rates, especially in large towns or cities. Carter and Duriez (1986, p. 42) described how suddenly Puerperal fever could develop after birth “in the morning they are cheerful and smiling, and seem to be well, yet they are consumed by fever, pulse rapid, features pale and shrunken, and death is written on their foreheads. They sink and die without a struggle.”

Schofield (1985) used the Parish Registers and Bills of Mortality (death certificates) to estimate a maternal death rate for this time period. His figures examined the number of times out of 1000 that parturition resulted in the death of the mother. In London from 1700-1749 he estimated it at 14.5 per 1,000, from 1750-1799 11.4 per 1,000, 1800-1849 9.2 per 1,000. These figures for London were slightly higher than elsewhere in England. Scholfield also states that in the 1930s the maternal death rate was approximately 4.5 per 1,000 dropping substantially to 0.1 per 1,000 in the 1980s. As of 2013, the maternal mortality rate in the UK was 9 per 100,000 deaths (Knight *et al.*, 2015).

2.10- Existing Grading Systems for the Preauricular Sulcus

Bruzek (2012) proposed a grading system, however, this system was for the whole preauricular surface area not specifically the preauricular sulcus which made it unsuitable for the present study. Buikstra and Ubelaker (1994) detailed classifications for the sulcus types. This classification is for use as a sexing method and not as a link to pregnancy and parturition.

The grading system ranges from 0-4 and although mentions the depth of the sulci focuses more on the size and shape. It is this focus on the size and shape that made it unsuitable for use in this study. This study aimed to expand on Houghton’s 1975 classification of GL and GP grooves and investigate the causes of the dimorphism in depth.

When studying sex assessment Phenice (1969) recognised the wide variation between males and females. He noted that most individuals would not be the perfect representation of either the male or female form. He concluded that a more detailed study of these traits would lead to greater accuracy. Klales’ *et al.* 2012 study agreed with this noting “simply scoring the extremes of a trait fails to encompass the range of variation found” (p.106). Their study was to present an updated method of sexing the human *os coxae* using Phenice’s nonmetric traits. Klales *et* al. (2012) used the three Phenice traits; the ventral arc, the subpubic concavity and the medial aspect of the ischial-pubic ramus. However, rather than the original two expressions of this trait (either present or absent), the authors used five categories to encompass the wide range of variability seen. The authors' results showed that the use of this wider and more detailed grading system provided a more accurate assessment of sex. It is using this rationale that the author for the present study proposes a more detailed grading system for the PAS than simply Houghton’s GL and GP grooves.

3- Materials

3.1- Introduction

This chapter will discuss the skeletal and CT Scan collections that were used in this study. Six separate anthropological samples were examined for the purposes of the present study as well as one sample of CT Scans from living subjects. Of the skeletal samples, four are from British medieval populations and the other two are from modern South African collections.

The majority of the samples are represented by British populations, two were medieval (undocumented collections) and two were post-medieval. The two medieval samples were Poulton and St Owens, both of which are housed at Liverpool John Moores University (LJMU). The post-medieval collections, Christ Church Spitalfields and St. Brides, are both housed in London and curated through the Natural History Museum and the Museum of London. There was limited parity information available for the two London samples, which will be discussed in section 3.6.

The South African samples were the Pretoria Bone Collection and the Raymond A. Dart Collection, which were included to broaden the geographical region and diversity of the samples tested. Although age, sex, ancestry and cause of death were documented, there was no parity information available for the South African data.

There was a seventh and final sample that was examined in this study. Unlike the rest of the collections, these were not skeletal remains, they were instead CT scans taken from living subjects. The scans were collected as part of research undertaken at Oxford University by then-doctoral candidate Janamarie Truesdell.

3.2- Medieval British Samples

3.2.1- Poulton

The skeletons in the Poulton Skeletal Collection have been excavated from the Poulton archaeological site. Poulton is a rural farming hamlet in Cheshire, which is situated in the North-West of the UK. This site is located just south of Chester (approximately 3 miles) and near the Welsh-English border. Although the skeletons in this sample are considered medieval, the site itself is multi-period spanning almost 900 years. The first known reference to Poulton is from 1086 in the Domesday Book. This manuscript is Britain earliest public record and contains a survey of England and parts of Wales (Morgan, 1978).

The main focus of the site excavations is to find the Cistercian Abbey that is thought to have been built there in roughly 1153, although the exact location has been lost (Emery, 2000). It is believed that this Abbey did not occupy the land for long as the monks that inhabited it were moved in 1214 to Dieulacres. Excavations began at the site in 1995 as part of the Poulton Research Project, led by head archaeologist Mike Emery. The remains of some kind of ecclesiastical structure were uncovered; however, this was not the 'lost Abbey'. It was discovered instead to be a small chapel. This chapel appears to have been in use from 1250 through the English Civil War, where it was used both as stables and as a lookout point for armies, to 1719 where it was reported to have been in disrepair (Emery, 2000).

Surrounding this chapel is a burial ground, which appears to have been frequently used during the chapel's active period. It is estimated that up to 1200 people could have been buried in these grounds during this period. The Poulton Research Project has been excavating these skeletons since 1995 through to the present day (Emery, 2000). This has been done in partnership with Liverpool John Moores University where the majority of the skeletons are stored, forming the Poulton Skeletal Collection. As of 2018, approximately 900 skeletons have been excavated alongside additional disarticulated human remains. A small number of the skeletons recovered were sent to Staffordshire to be reburied in the Mount St. Bernard's Monastery (Emery, 2000). The skeletal material from this site is not the best preserved although, when the burials are untouched, the remains are largely in good condition. However, in the majority of cases, the burials were later disturbed by other interments leading to poor preservation and fragmentation of the bones. It is estimated that only about 30% of the burials had 75% or above of the skeleton complete (Burrell & Carpenter, 2013). There are multiple reasons for the taphonomic changes to the bone, one reason is the overcrowding of the burial site meaning that new graves were dug on top of and intersecting others. This was especially common in the burial areas situated to the south and west of the chapel. A majority of the burials have been found close to the surface (approximately 40 cms) which means they could have been damaged more easily, especially as the site was farming land before the excavations began (Burrell & Carpenter, 2013). As this burial site was on Christian grounds, the majority of the remains were found in an east-west orientation as expected. In order to gain a clearer history and timing of the site, four of the skeletons have been radiocarbon dated, one of them twice. The first skeleton to undergo radiocarbon dating was SK53. The dates that were collected from this radiocarbon dating provided a large range of error and did not help to clear up the history of the site, as three sets of dates were found. These dates are 1531-1537, 1635-1670 and 1780-1799. Later in 2012, this skeleton was radiocarbon dated again, this time using the tooth roots. There were still multiple dates, however, they were much closer in range this time (1470-1520 and 1560-1630). A second skeleton was also examined at the same time: SK535 that was dated between 1280-1320. Burrell *et al.* (2016) radiocarbon dated two more skeletons as part of a project examining Paget's disease of bone in the sample. These skeletons were SK750 and SK463, both of which gave multiple dates although within a relatively short time period. SK750's dates were 1285-1330 and 1340-1395, whereas SK463's were 1275-1310 and 1360-1385 (Burrell *et al.* 2016). These dates have provided useful information into the history of the site and the period in which the area around the chapel was used as an active burial ground.

3.2.2- St Owens Church Cemetery

The second of the British medieval samples that were used in this study originate from St Owens Church, Southgate Street, Gloucester and it is housed at Liverpool John Moores University. This assemblage comprises of skeletons that were excavated on two separate occasions, in 1983 and 1989 both times by the Bristol and Gloucester Archaeological Society. During the first excavation in 1983, 71 skeletal remains were recovered and a further 225 in 1989. However, these are only a small number of the overall remains that were buried on this site. The first excavations were given the classification code of 13/83 and the second 3/89. Archival records suggest that there were some coffin burials, however, the majority were shroud burials.

The city of Gloucester itself resides in the county Gloucestershire in the South of England, near the border to Wales. Like Poulton, the first known record of Gloucester is in the Domesday Book (Morgan, 1978). Gloucester has a long history of archaeological finds with the first recorded one taking place in 1806 when beneath the Guildhall on Eastgate Street a mosaic was found (Atkins, 1992). Gloucester is originally thought to have begun life as a Roman town during the mid-1st century A.D, considered to be one of three major ports in Britain at the time (Atkins and Garrod, 1990) and was a thriving town. The town was later captured in 577 by Anglo-Saxon Invaders and became head of the surrounding district, however by this time the town was beginning to fall into decay and disrepair. Gloucester appears to have been regenerated by the 10th century when it was given administrative and military status and new buildings were being built in the town. After the Norman Conquest, the town became even more of a military stronghold with a castle being built due to its position near the River Severn and the crossing into South Wales (Herbert, 1988). The area was acquired in 1137 by the Llanthony Priory, following the building of many churches in the area including St Owens in 1100 (Bryant and Heighway *et al.*, 2003). The town continued to flourish partly due to its favourable geographical position and trade in the form of cloth and ironworks with Bristol and further afield (Herbert, 1988). Although there were periods of economic fluctuations in keeping with the rest of England, Gloucester overall has endured through the centuries to survive as a city today.

St Owens church was located on Southgate Street in the city centre of Gloucester. As stated above, it was built in 1100 and was still in use until 1643. The church was demolished in 1847 when the docklands were extended. Nothing remains above ground of the structure today. Not much is known about the St Owens site and the skeletons, with little having been published. However, it appears many of the burials were shrouded with a few coffins and were typical Christian burials (Atkins and Garrod, 1990). The skeletons are housed at LJMU where they are used for both teaching and research projects.

3.3- Post-Medieval British Samples

3.3.1- Christ Church Spitalfields

The Christ Church Spitalfields sample (which will further be referred to as simply Spitalfields) is stored at the Natural History Museum in London, UK. The samples have been taken from the crypts beneath Christ Church, Spitalfields; 968 skeletons were excavated between 1984 and 1986 (Cox and Scott, 1992). The area of Spitalfields is in central London, between Shoreditch and Whitechapel. The church is located at the corner of Commercial Street and Fournier Street and still stands today (2020), although it was renovated in approximately 1850 to update it to more modern ecclesiastical standards. The church was built between 1714 and 1729 and originally had instructions that no intra-mural burials were to take place there. However, this did not hold (Adams and Reeve, 1987). The first burial was on 8th July 1729 just three days after the consecration of the church took place. It is thought that approximately 68,000 funerals took place at Spitalfields. However, the exact number buried in the churchyard and interred in the crypts is unknown, although the number in the crypts was at least 1,000. The final burial took place in February 1859. All the coffins after 1813 were lined with lead leading to the very good preservation of the bones held inside. Even though there were multiple vaults within the crypts, these were mostly full. As a result of this overcrowding led to the coffins in some places being stacked on top of each other. When the crypts were sealed in 1867 charcoal and sand were placed in between the stacked coffins in a 'sanitizing' layer (Adams and Reeve, 1987).

The excavation (1984-1986), which was directed by Jez Reeve for the Incumbent and Parochial Church Council, represented the first scientific excavation of a church crypt in Britain. A large collection of biographical and environmental data regarding the site was collected between 1987 and 1988, funded by English Heritage (Cox, 1989). During the excavation, great care was taken to ensure the correct biographical information from the coffin plates stayed with the correct individual. The same identification numbers are still used today, and the skeletons are labelled with the abbreviation 'CAS' followed by a number. During the excavations, 968 interments were found and excavated from coffins, 387 of which had plates attached to them identifying the individuals. It was these skeletal remains that were examined in this study.

The parish of Spitalfields was first created from the Manor of Stepney, which was owned between 1550 and 1720 by the Lords Wentworth. The name "Spitalfields" itself means "land belonging to a hospital" (Cox, 1989, p.72). It stands on the site of St. Mary Spital, which had previously been the largest medieval hospital in the city of London. However, the first known use for the site was as a Roman cemetery.

During the mid-17th century, the area became known as "Petty France", due to a large percentage of the population being the descendants of French Huguenot immigrants. Of the 387 named skeletons, it was found that 161 were French. These settlers had fled France in the 1550s due to religious persecution especially following the Massacre of St. Bartholomew in 1572. Many of these immigrants brought with them the skills to help the budding silk industry and turned the area into a thriving business for weavers and similar industries. As a result, most of the inhabitants lived a comfortable middle-class lifestyle (Mays, 2012). The occupations were able to be established for just over 60% of the documented samples. There was a large number of professions (over 60) but the majority were merchants or master silk weavers, some other jobs listed are silk dyer, carpenter, butcher, surgeon, sugar refiner and member of parliament (Cox, 1989).

3.3.2- St Brides Church

The second post-medieval collection examined also originates from a church in London, UK. The St Brides skeletal sample is from St Brides Church, Fleet Street and is composed of the 227 individuals who were interred in the crypts under the church. An assemblage from the Lower St Brides Churchyard, Farringdon is also stored at the church. However, this sample was not examined for this study, only the Fleet Street collection. In this present research, any reference to St Brides will only refer to the Fleet Street crypt collection. This skeletal assemblage is curated through the Museum of London. However, the remains themselves are still stored at St Brides Church, which remains active today. This documented collection contains skeletal remains from the 18th and 19th centuries(Gapert, Black and Last, 2008). The crypts were excavated starting in the 1950s by Professor W. J. Grimes acting on behalf of the London Roman and Medieval Excavation Council, following the damage that the church suffered during a night of heavy air raid bombing on 29th December 1940. The church itself is believed, according to legend, to have been built on the site of either a shrine to a Roman deity or a Roman temple. It is thought that the church itself was established on Fleet Street after the Roman period in the 5th century when there was an Irish settlement near the site. However, the church has gone through multiple iterations since then (Harvey, 1968). The church itself is mentioned as a grant (London Survey Committee, 1944) given by Henry II, who reigned from 1154-1189 (Brooke and Brooke, 1946), to the Templars. The original structure was destroyed in 1666 by the Great Fire of London and was rebuilt by Sir Christopher Wren (Harvey, 1968).

The excavations uncovered the remains of the foundations of a Roman *villa* along with the remains of a Roman woman. However, there were also skeletons from a more recent historical period that were utilised for the present study. The excavators found seven sealed crypts and vaults, which had been sealed in 1854 on an Act of Parliament along with ruling that there could be no more burials within city limits. One of the vaults contained a large number of disarticulated skeletons where the long bones and skulls have been placed together in groups; it is thought that a number of these skeletons could have been victims of the plague. The skeletons that comprise the St Brides Fleet Street sample were also found in one of these crypts. They were found in coffins with many having lead engraved plaques detailing their names, ages, and dates of death. The first individual died in 1659 and the last in 1852, two years before the crypts were sealed. Upon discovery of the skeletons, the Home Office consulted with Professor Wood Jones, of the Royal College of Surgeons, and Dr J. C. Trevor, Director of the Duckworth Laboratory at Cambridge University, to decide what should be done with the newly discovered skeletons. Trevor and Jones argued that they should not be reburied and should instead be used for research purposes stating that it was ”outstandingly the most important collection in the world” (Harvey, 1968, p.63).

3.4- Modern South African Samples

The most recent two skeletal samples studied for this research were from South Africa, the Pretoria Bone Collection and the Raymond A. Dart Collection. The data from these assemblages were collected by the then-doctoral candidate at LJMU, Samuel Rennie. Before going to South Africa, he was trained by the author in the use of the grading system and given both the photographs and descriptions in Chapter 4 along with plaster cast models of the grades. An inter-observer error test was also carried out to ensure reliability between results collected with the other samples by the author. The results of Cohen’s Kappa test showed an almost perfect agreement ($k=0.875$, $p<.001$.) (Appendix 9). Cohen’s Kappa test is discussed in further detail in sections 4.6 and 7.2. Photographs of the South African samples were also taken and were studied by the author to check the agreement of the grades. As stated above, these data were included in the study to widen the range of ancestry that was examined in this research. Both collections contained a mixture of skeletons from both white and black South Africans. Although both collections are documented, no parity information was available for use.

3.4.1- Pretoria Bone Collection

The Pretoria Bone Collection refers to the sample housed at the University of Pretoria in the Department of Health Sciences and is made up of 290 complete skeletons, 704 complete skulls and 541 complete postcranial remains. The history of the Pretoria Bone Collection begins with the creation of the Medical School and the Department of Anatomy at the University of Pretoria in 1942. The assemblage began its life as a teaching aid for the students of medicine, dentistry and other healthcare fields such as nursing. The skeletons that had a known age, sex and population affinity are used in this research collection with any of an unknown origin being used in the student-teaching collection (L'Abbé, Loots and Meiring, 2005).

There are two sources from which the skeletons in this collection come, they are either donated by the individuals themselves before dying or they are given to the university as an unclaimed body. The South African Human Tissue Act of 1983, which allows individuals to donate their body for research purposes, also states that anybody who is not claimed by friends or family within 24 hours, is handed over to a university or other institutions to be used for research. Despite the fact that the identity of these cadavers is known, in many cases, they are classified as unclaimed. As of 2003, there were 6476 cadavers in the collection, most of which were unclaimed. For the last ten years, 67 cadavers were donated on average annually. There are two ways a donation can occur; either from the individuals themselves registering before death that they want their body to be donated or as long as they did not explicitly state otherwise, a family member can choose to donate the body. Once a body is given to the hospital as unclaimed a family member or friend can still claim it at any time. However, this does require them to prove a relationship to the individual sometimes with the involvement of a magistrate (L'Abbé, Loots and Meiring, 2005).

The bodies are first taken to the Department of Anatomy, where they are entered into the cadaver registry and given an accession number. This number is recorded with the biographical information accompanying the body, such as name, sex, age, cause of death, weight and height, last address, population affinity and which hospital the body came from. After this process, the bodies are embalmed and held in storage for 1-2 years, after which time they will be used in dissections. Once dissection of the cadaver is completed, the skeleton is then macerated and depending on the condition of the bones, either become part of the Student-Teaching Collection or the Pretoria Bone Collection used for research. The same accession number that is given when they first arrive at the University is used for the bone collections.

3.4.2- Raymond A. Dart Collection

The final skeletal sample examined in this research was the Raymond A. Dart collection, housed in the School of Anatomical Sciences at the University of Witwatersrand, Johannesburg, South Africa. This collection is one of the largest documented skeletal assemblages in the world, consisting of over 2,500 modern human skeletons and, like the Pretoria Bone collection, mostly originates from cadavers. Also, like the above sample, the cadavers either were donated knowingly or were unclaimed bodies from nearby hospitals given to the university under the Human Tissue Act. Before 1992 the majority of the bodies were from unclaimed individuals, however since then this has been in decline and most are bequeathed knowingly either before death by the individuals themselves or by their families after death (Dayal et al., 2009). The collection was begun in the 1920s by Raymond A. Dart himself, who was the head of the Anatomy Department at Witwatersrand at the time (Tobias, 1991). Dart was a gifted anatomist who used a dissection technique that caused minimal damage to the bones. It was using this method that he was able to begin the creation of a cadaver-based skeletal collection. The cadavers themselves were originally used for teaching anatomy and by medical students, after which they were macerated and added to the growing skeletal assemblage (Dayal et al., 2009). Dart retired in 1958, at this time there were approximately 1,000 skeletons in the collection. However, his protégé Philip Tobias who took over carried on Dart's work and continued to grow the collection (Štrkalj and Pather, 2012). It was upon Dart's retirement that it was named in his honour.

Unfortunately, in 1959, an accident befell the collection not long after Tobias took control. At the time it was being stored in the basement of the Wits Medical School when it was flooded by a burst water pipe. During the flood, many of the skeletal remains were dislodged from their boxes and floated in the water. The bones were removed from the basement and taken to the roof to dry. However, due to both the flooding and drying processes, some of the remains were co-mingled. This was before any of the remains themselves had been labelled or marked so it was not possible in most cases to know the origin of the bones. This mixing has never been able to be undone and researchers have noted problems with using the skeletal remains that date prior to 1959. The exact number of skeletons affected is not known, the collection at the time contained 1,265 skeletons. However, as a result of this incident, a new storage facility in the Anatomy Department was built to house the remains. Tobias also focussed his time on expanding the collection and making the representation more equal (Dayal, 2009).

The collection contains a wide range of individuals with different population affinities in keeping with modern-day South Africa. Dayal (2009: 327) described the collection stating, "the South African populations from which the Dart Collection is derived are extremely diverse in their culture, linguistics, biology, and genetics." Due to the changing nature of policies regarding the classification of population affinity, the designations of the different groups have changed over time. However, they are currently classified into census categories. These groups are South African African, South African White, South African Coloured (a formal term in South Africa for those of mixed ancestry) and South African Asian/Indian. They are also in some cases listed with the 'tribe' from which they originated. However, the accuracy of this is unknown as some of the 'tribe' classifications were given due to surnames or other contextual information rather than being recorded on death certificates (Dayal, 2009). The groups selected for this study were South African African (titled South African Blacks in this research for clarity) and South African Whites. The terms African Ancestry and European Ancestry are commonly used to refer to such populations. However, the previous terms are the official terms that are used in the collections and in research published regarding them which is why they have been chosen to be used in this thesis.

3.5- CT Scans from Living Subjects

The seventh and final collection that was examined for this study was not a skeletal sample but instead, a collection of Computed Tomography (CT) Scans from modern living subjects. The scans were obtained for use in the thesis through a collaboration with Janamarie Truesdell, a then-doctoral candidate at the University of Oxford, UK. This section will give a brief overview of the data and how the scans were taken. The scans were then rendered using imaging software. The process will be detailed in the methodology section of Chapter 6, the pilot study focussing on CT Scans and their additional biographical information.

The CT scans were taken on-site in the Radiography department at Churchill Hospital, Oxford, UK. They were obtained over a period of seven months (September 1st, 2014- March, 31st, 2015). The original sample size was 1,238 adult individuals, however, for this project, only 75 were used. This was due to the fact that CT Scans were not the main focus of the investigation, but instead a pilot study to test the suitability and accuracy of their use in a forensic context. The samples given to the author comprised of 25 parous females, 25 nulliparous females, and 25 males. All the samples used in this collection were on European Ancestry. The CT scans were randomised before being given to the author and any identifying information (e.g names and addresses) about the individual was also removed to allow for anonymity. Once the CT scans were rendered and the assessment of the PAS grade was completed, the biographical information (age, sex, parity status and other variables) was provided. The biographical information was obtained through interviews conducted by Janamarie Truesdell with the subjects themselves about their medical history and lifestyles. The scans were all undertaken in the Radiology Department of The Churchill Hospital using one of two Light Speed Multi-Detector Volumetric Computed Tomography (VCT) machines (Truesdell, 2016). When the data was collected in the initial project full ethical approval was granted by both the National Research Ethics Services (NRES) and the Oxford University Hospital NHS Trust (OUH). The OUH further granted approval for the data collected by Truesdell to be shared and published as long as it was anonymised (Truesdell, 2016).

3.6- Establishment of Parity Information

As discussed in this chapter three of the samples had parity information available for the individuals examined. This section will detail the methods used to retrieve this information. For the main results of the present study, parity history was recorded as a simple presence or absence. In Chapter 6 more information on parity for the CT Scans individuals were used.

Christ Church Spitalfields: For this sample, the parity information was established through the use of Cox's thesis (1989). In volume 2 of her thesis she detailed all the individuals she examined, giving their skeleton number, name and parity status. However, the parity information was not examined by the author before data collection. A list of these individuals was provided to the Natural History Museum and Curatorial Assistant Elissa Menzel. As only females were studied for this sample all the individuals had parity status information available. After data collection the parity information was added to the excel spreadsheet used for recording as either; had given birth or had not given birth.

St Brides: For this sample, parity information was established through the use of parish records after data collection was completed. The records are stored through the London Metropolitan Archive, (available at: https://www.cityoflondon.gov.uk/things-to-do/london-metropolitan-archives/Pages/default.aspx). The parish records have been digitised and stored on Ancestry (available at https://www.ancestryinstitution.co.uk). Using the names of the female individuals a search was carried out through these digitised record for birth certificates listing them as the mother. Death certificates were also examined in case of instances were pregnancy and parturition lead to death. There were not reliable parish records available for all of the individuals in which case they were not included in the parity section of this study.

CT Scans: After the CT Scans were rendered (Chapter 6) and an assessment of the PAS was made the excel spreadsheet with the biographical information was accessed. The spreadsheet contained the information collected by Truesdell about the number of births, pregnancies and caesarean history. For the main study only whether they had ever given birth or not was included, however for the pilot study the additional information used (Chapter 6). The information was gathered by Truesdell through interviews of the subjects.

4- Methodology

4.1- Introduction

This chapter aims to explain the methodology used during this study. The main focus of the chapter will be on explaining the new grading system that was developed by the author of the present study. In 2014 the author carried out a pilot study as an undergraduate research dissertation that created this new methodology for examining the PAS. This was developed as it was assessed that no existing scoring systems were suitable for the current project. The grading system was developed to be simple to use and does not require specialist equipment. It was designed to be unambiguous and easily taught, even to none experts in osteology.

During the project six different skeletal collections were examined, four of these samples were documented and two were unknown. For the two unknown samples, they were aged and sexed using established techniques. The estimated ages and sexes were also compared with the results from other forensic anthropologists to validate the results and ensure their accuracy. The methods that were used to estimate the age and sex will be discussed. The final sample examined was a selection of CT Scans from living subjects, the methodology for this sample will be discussed in Chapter 6.

For four out of the six skeletal samples studied, measurements were also taken for the length and the width of the PAS in individuals where that was possible. The methods used for this will be discussed along with the limitations and problems encountered. For all the collections only one *os coxa* from each skeleton was examined, which is a common method for scoring antimeres in osteology (Irish, 2005). In the majority of cases, this was the left *os coxa* however in cases where the left was not present or damaged then the right was used instead. Individuals with observable pathologies on the *os coxa* were not included in the sample.

4.2- The Grading System

For this study, a new grading system was developed for the PAS. This was based on a theory proposed by Houghton (1975), who suggested that the morphology of the PAS was linked to pregnancy and parturition. He classified the PAS into two separate categories: a groove of ligament (GL), not thought to be linked to parity status and a groove of pregnancy (GP). The author theorised that it was not the size and shape of the sulcus that was an indicator but the changes in depth. However, he suggested no further way to classify or describe these differences other than GL or GP. The present researcher's new grading system was developed based on this theory, in order to expand upon Houghton's original idea and further examine the morphology of the PAS. The grading system was developed for the present study with grades that range from 0-4.

In regard to the differences between the grades, the idea was to create a system that could be used without any specialised equipment or requiring in-depth knowledge and familiarity with the PAS. A detailed written description and photographic examples are included to enable the user to assess the grades of the PAS in question. The grades can be assigned using a combination of sight and touch. Although the changes in depth should be assessed from sight, touch can also be used to establish the depth for the dry bone samples. For certain specimens on visual examination they appear very consistent, however when running a finger along the floor of the sulcus small but important changes in depth can be felt. In some cases, it was found to be beneficial for the researcher to close their eyes and rely only on their touch to examine the bone surface as it allowed them to more freely feel the changes in the bone. It was not possible to use the touch method with the CT scan specimens, however this will be discussed more in Chapter 6. The technique is non-destructive and can be used on any specimen as long as the area for the PAS is present. The grading system was designed and applied using the St Owens skeletal sample, as it was the most easily accessible at the time. A selection of male (n=20) and female (n=20) specimens were examined first. This was to gain an overview of the range of general PAS morphology that can be present. These were not graded at the time of examination. Detailed notes and photographs were taken to be used as a reference whilst the grades categories were established. Using this selection, it was agreed that there would be five categories overall and specifications were decided for each grade. The specimens were then re-examined and categorised. This was done in order to better prepare the researcher for the range of potential PAS that may be seen in other individuals.

The five grades proposed will now be discussed in detail. All the photographs displayed below are from left *os coxae* in the Poulton skeletal sample, with a red circle showing the area that is being examined.

4.2.1 - Grade 0

This grade is for the absence of a preauricular sulcus. The area where the PAS is usually displayed must be present and undamaged. However, there is no sulcus. The area between the auricular surface and the greater sciatic notch is completely smooth with no changes in depth or pits.

4.2.2 - Grade 1

The first grade for the presence of PAS is very shallow and has uniformity of depth; the floor of the sulcus will be consistent with no pits or ridges. The edges of the sulcus are often very undefined with no definite edge; this can make it challenging to take the measurements that are discussed later in the chapter. The edges are scarcely visible and often fade out rather than have a definite ridge, which is seen in the later grades.

4.2.3 - Grade 2

Grade 2 is for a PAS that has a slightly uneven floor that is not completely smooth as exhibited in a grade 1. The change in depth should only be very small, with a single pit or ridge. If there are multiple changes, then the sulcus would be a grade 3 instead of a grade 2. In the majority of specimens, the sulcus will be one consistent depth with only one change. Even if the change is only very slight but it can still be either seen or felt then it should still be included as a change in depth and categorised as grade 2 rather than a grade 1. These sulci are usually more noticeable than in grade 1, although they often still have an undefined edge. The presence of defined edges does not automatically categorise the bone as a higher grade, only the depth should be considered.

4.2.4 - Grade 3

A grade 3 sulcus is used for PAS that, although similar to grade 2, has more changes in depth and morphology. They show multiple pits, ridges or grooves that change the depth of the floor of the sulcus; these can be either smooth increases and decreases or sharp. In order to classify as a grade 3, there must be more than one change in depth. If only one is present, even if severe the specimen needs to be categorized as a grade 2 instead of 3. The edges of these grades are typically more defined than those of previous grades. Even with the lack of definite edges, the presence of multiple changes in depth allows them to be classified as grade 3. The changes in depth are usually seen in the form of pits or transverse ridges. The texture of the bone should feel very rough and uneven to the touch. These sulci are very easy to see on the bone and are unlikely to be missed even by a person with little research experience or knowledge in the area.

4.2.5 - Grade 4

The final grade is for sulcus that has a very deep, uneven and pitted surface to the floor. The depth is very inconsistent with multiple pits and channels running through the sulcus. The surface of the grade will be very rough both to touch and to observe by sight. The size and the shape are not important; they can be very small or can span the entire area between the auricular surface and the greater sciatic notch. These sulci are the easiest to detect as they look very extreme and stand out from the surrounding bone. Unlike grade 1, these sulci are very clear on the bones and are unlikely to be overlooked. Both this grade and grade 3 can appear as if part of the bone was gouged out “Sometimes the individual pits making up the groove are elongated, as though the bone has been scooped out" (Houghton, 1975, p.655-6).

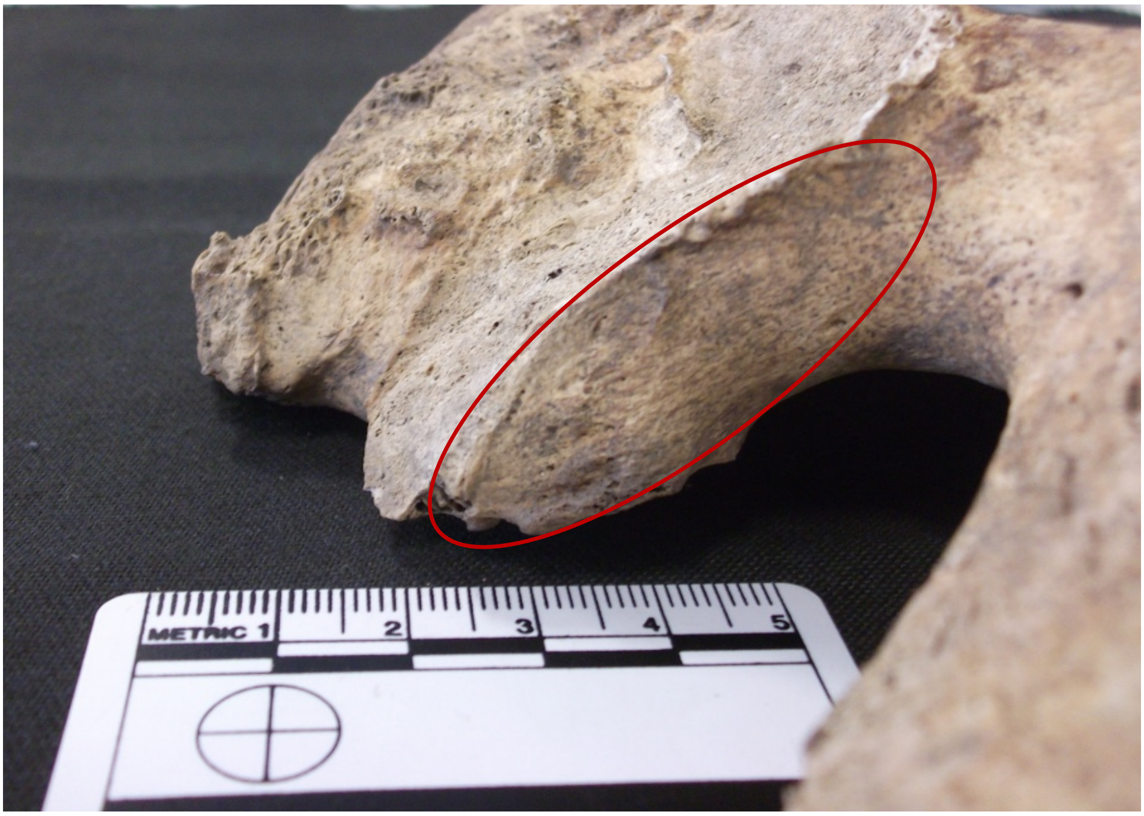


Figure 4.1- An example of a grade 0 PAS (left *os coxae*)

Figure 4.2- An example of a grade 1 PAS (left *os coxae*)

Figure 4.3- An example of a grade 2 PAS (left *os coxae*)

Figure 4.4- An example of a grade 3 PAS (left *os coxae*)

Figure 4.5- An example of a grade 4 PAS (left *os coxae*)

When using the grading systems if there is a PAS present on the bone then it must be classified into one of the 4 later grades, as a grade 0 is only used for the absence of a sulcus. No sulcus should be classified as between grades, it must be placed into a definitive grade. The size and shape of the sulcus should play no role in the decision of grade classification; neither should the edges of the sulcus. The grades should be decided on the morphology of the floor of the sulcus. Where the edges or part of the sulcus is broken or missing, the sulcus was not used in this study, as it would not be possible to accurately assess the grades. Photographs were included to show the typical appearance of the different grades; however, these are only examples and should not be taken as the only possible appearances. The changes in depth can sometimes be difficult to see in images, which is why the feel of the surface is also very important.

Where possible the age and sex of the individuals were not established until after the assessment of the grade was made, in order to try to ensure there was no bias. This could be challenging at times as the greater sciatic notch is next to the PAS so it was not always possible to avoid observing it. However, as the notch is only one of multiple traits used to establish sex, it should not have interfered with the results. For the individuals that were documented, the biographical information, including parity status, was not examined until after the skeletons were analysed.

4.3- Measurements of the Preauricular Sulcus

Houghton's paper (1975), also suggested that the length and width of the PAS has no effect and correlation with the parity status of the individual. To test this, the maximum length and width were taken using a sliding calliper. This instrument was chosen as it can take accurate measurements of small specimens and is also regularly available in a standard laboratory and easy to carry into the field if necessary. As the sulci are small, it was decided that a maximum width and length would be enough to give an accurate idea of the size. For some of the PAS, these measurements were easy to take, as there was a clearly defined edge to the sulcus. However, for other PAS it was more challenging. For PAS that did not have a clearly defined edge, the measurements were taken as close as possible to what was seen as the edge. As the study progressed, it became easier for the researcher to define where the edges were located. These measurements were taken to 2 decimal places.

After the PAS were graded, the sex and age of the individuals were then assessed for the undocumented skeletal remains, i.e. the Poulton and St Owens samples. This was done using established techniques. The following section of the chapter will discuss the techniques that were used and why these were selected. The main elements used were *os coxae.* However, the skull was also used in cases where there were insufficient *os coxae* traits to accurately determine age and sex.

4.4- Assessment of Sex

As previously stated, all the methods used for establishing the sex of the individuals are techniques that have already been tested and are commonly used by Forensic and Biological Anthropologists. For estimating sex, the most common traits used were those of the pelvic girdle. In individuals where the skull was also available this was used in conjunction. In a minority of cases, skull morphology was solely used if there were insufficient traits on the *os coxae,* due to damage and fragmentation to accurately assess sex. The features from the pelvic girdle will first be detailed and then followed by those used on the skull. Meindl *et al.* (1985) demonstrated that when used together a combination of both cranial and postcranial features gave an accuracy of 98% when estimating sex.

4.4.1 - Pelvic Girdle Traits

As discussed in Chapter 2, the *os coxae* are the most sexually dimorphic bones in the human skeleton (Tague, 1992). For this reason, they are commonly used to assess the sex of an individual. Where they are present, they should be the primary traits used to establish sex, as they were in this study.

The Greater Sciatic Notch: As the greater sciatic notch (Singh and Potturi, 1978) borders the PAS, for this research it is one of the most commonly used traits. It was rare for there to be a PAS but not the greater sciatic notch. However, there were some cases where the notch had broken or was too damaged to be accurately assessed. The technique for this trait is to examine the shape of the notch. In females, the notch is wider and more flared, while in males the notch appears narrower and more hooked in shape. The trait is given a score between 1 and 5. A score of 1 indicates the most typically female, increasing to 5 for the most typically male (Buikstra & Ubelaker, 1994). This trait should not be used on its own to establish sex but rather in combination with other traits.

The Phenice Method: This method has been tested on several collections across different populations and time periods. The Phenice Method uses a combination of three traits on the *os coxae* to estimate sex; the ventral arc, subpubic concavity and the medial aspect of the ischiopubic ramus. These morphologies are all examined individually and an assessment of sex is then made from a combination of the three. With these features, the female shows the positive expression of them whilst in males, they are more typically absent. Phenice stated that of the three morphologies the ventral arc was the most accurate whilst the medial aspect of the ischiopubic ramus was the least.

Ventral Arc: The ventral arc refers to an elevated section or ridge of bone that runs across the ventral surface of the pubis. This is more commonly seen in females than in males. To score this trait the ventral surface of the pubis should be held facing the researcher (Phenice 1969).

Subpubic Concavity: The subpubic concavity refers to the inferior border of the ischiopubic ramus. In females, this trait is concave in shape whereas in males it is straight. The dorsal surface of the bone should be examined in order to observe this trait (Phenice, 1969).

The Medial Aspect of the Ischiopubic Ramus: Directly below the symphyseal surface, the medial aspect of the ischiopubic ramus has a narrow, pinched appearance in females. In males, this bony structure is flatter and broader in shape (Phenice, 1969).

There were some cases in the Poulton and St Owens samples where the *os pubes* were damaged or missing. In these cases, cranial features were also used to assess sex and age.

As discussed in Chapter 2 of the present work, Buikstra and Ubelaker (1994) and other authors (Houghton, 1975; Kelley, 1979; Spring *et al.*, 1989; Ubelaker and De La Paz, 2012) also state that existing methods for the classification of the preauricular sulcus can be used to estimate sex. However, for the purposes of this study they were not used, to ensure the researcher was unbiased in their assessment of the PAS and subsequent grading.

4.4.2- Cranial Traits

The five methods for sex determination from the skull that were used were detailed by Buikstra and Ubelaker (1994). These are examinations of the following traits: the nuchal crest, the mastoid process, the supraorbital margins, the prominence of glabella and the mental eminence. These methods have been tested on several samples across the world. Their accuracy and validity have been proven by many authors (White and Folkens, 2005). All five traits should be used in conjunction, with no traits holding more significance than another. For each trait, a score should be given between 1 and 5 with 1 being the most female expression and 5 the most male expression. The features are described as follows:

Nuchal Crest: This trait is found on the lateral portion of the occipital bone. The surface of the bone should be felt. For score 1 the surface of the bone will feel smooth with no bony projections. It can also be observed using sight as there will be no obvious obtrusions from the bone. For the most extreme score, 5, there will be a large bony extrusion from the occipital, that is a nuchal crest. This crest can be either a ridge or just a hook. The crest will extend away from the bone and is usually well defined (Aćsádi and Nemeskéri, 1970; Buikstra and Ubelaker, 1994; Walker, 2008).

The Mastoid Process: This should be scored in comparison with the surrounding traits such as the zygomatic process of the temporal bone and the external auditory meatus. It is important to score them in proportion with these other features. The most important factor when scoring the trait is to consider the overall size and volume of the mastoid process rather than just either the length or width. For a score 1, there is a minimal mastoid process that is similar in size to that of the external auditory meatus. It should not extend far below the meatus. A score 5 indicates a mastoid process that is larger in both length and width than that of the meatus and extends below (Aćsádi and Nemeskéri, 1970; Buikstra and Ubelaker, 1994; Walker, 2008).

Supraorbital Margins: In order to score the supraorbital margin, touch is the primary sense that is used rather than sight. The researcher should run their finger along the margin of the orbit on the lateral portion of the supraorbital foramen. The margin should also be held between two fingers to assess the thickness (Aćsádi and Nemeskéri, 1970; Buikstra and Ubelaker, 1994; Walker, 2008). For a score of 1, the margin will feel very sharp to touch, where the margin is duller and thicker and rounded, the score is a 5. Buikstra and Ubelaker (1994:

page 20) describe a score 1 as having the feel of a “slightly dulled knife” and score 5 as feeling like a “pencil”.

Prominence of Glabella: In order to score this trait, the cranium should be viewed from the side, and the supraorbital region should then be compared with the drawings. For a score of 1, the glabella should be smooth in nature with little projection at the midline, and the frontal bone should appear smooth in texture with no portion extending away from the bone. In the most extreme examples of this trait, the supraorbital region will contain a protruding glabella prominence and the bone will extend away from the contour of the frontal bone. The bone will be rounded and “loaf-shaped” in projection rather than sharp. The ridges will be well developed (Buikstra and Ubelaker, 1994).

Mental Eminence: In order to score this trait, the researcher should hold the mandible in both hands with the thumbs on either side of the mental eminence. The thumbs should then be moved medially until the lateral border of the mental eminence can be felt. For a score of 1, little to no projection of the mental eminence will be able to be felt on the surrounding bone. For a mental eminence that can be felt on the anterior portion of the mandible, a score of 5 will be given (Aćsádi and Nemeskéri, 1970; Buikstra and Ubelaker, 1994; Walker, 2008).

After the sex of an individual was established, the age was estimated. The assessments were done in this order, as the techniques used to assess age from the *os coxae* are more accurate when the sex is known.

4.5 - Assessment of Age

For this study, only adult individuals over the age of 18 were to be used. For the documented collections, the museum/church records were examined. For the undocumented medieval collections of Poulton and St Owens, the age had to be established. The first aspect that was determined was whether they were over the age of 18, they were then subsequently spilt into three following categories: young adult (18-25), middle adult (25-40) and old adult (40+). To establish whether they were at least 18 years of age, the epiphyseal fusion of both the iliac crest and the ischial tuberosity were examined. The minimum age of 18 for the undocumented collections was set as it is only after this age that sex can be accurately assessed (Hunt, 1990; Mittler and Sheridan, 1992; Buikstra and Ubelaker, 1994). Only individuals that showed complete or mostly complete fusion were used in this study. The exception to this is in the cases of Spitalfields and St Brides, where the collection was documented, as age at death and sex could be accurately established. From these samples, several 17 years old and younger were included. For both the Poulton and St Owens individuals, only methods from the *os coxae* were used to establish sex as these are the most accurate and in all cases at least one of the two traits were present. The two methods used were the assessment of the auricular surface (Lovejoy, 1985) and the pubic symphysis surface (Suchey and Brooks, 1990). Using both ageing methods the individuals were then sorted into the three age categories for the statistical analysis to run. These two methods will now be discussed in detail below.

Auricular Surface: This was the primary technique used, as the auricular surface borders the PAS and in the majority of cases it was available for use. It is also considered the more accurate and reliable of the two methods (Lovejoy et al., 1985; Buckberry and Chamberlain, 2002). The method examines the changes to the auricular surface that occur over time. However, there was a small number of cases where one or both surfaces were damaged and consequently, the pubic symphysis surface was also utilised.

Pubic Symphysis Surface: This method for age estimation involves looking at the changes that occur to the surface of the pubic symphysis over time. During the analysis of the samples from Poulton and St Owens, the author found that the pubic symphysis was often missing or damaged. However, there were a minority of cases where this was used in conjunction with the auricular surface.

4.6- Statistical Analysis of Data

The data for this present study were first collected on paper and then transferred into an Excel spreadsheet. The datasheet used for collection can be seen in Appendix 1. The software program SPSS v.24 (Statistical Package for Social Sciences, IBM Corp. 2012) was used for analysis.

For this study, it was important to assess the repeatability of the grading system results to assess accuracy and precision. An accepted method for this is to conduct inter-and-intra observer error analysis using Cohen's Kappa test for repeatability (Landis and Koch, 1977). This is used to measure the level of agreement between two observers when the observed results are subjective. The results range between 0-1 with 0 indicating that any agreement was by chance and 1 indicating a perfect agreement between observers (Viera and Garrett, 2005). In order to assess the intra-observer error, the observer re-graded a subsection of the specimens (n=30) approximately six months after the original grading was conducted. For this section of the analysis, no width or length measurements of the PAS were taken, only grades as they are the main focus of the study. The skeletal remains used were from the St Owens collection housed at Liverpool John Moores University. For the Inter-observer error, 5 students all attending LJMU were used. Each student attended a different undergraduate or postgraduate course related to forensics. The courses were: Forensic Anthropology BSc, Forensic Science BSc, Bioarchaeology MSc, Forensic Science MSc, and Forensic Anthropology MSc. The students were given a data collection form and an information leaflet containing photos and descriptions of the grading system Appendix 2.

For the main results of the thesis, SPSS v.24 was also used to analyse the results. There were five main sections to the results although the statistical tests used were the same. In the first section (5.3), all seven samples were analysed separately without any of the parity information. The difference in levels of occurrence of PAS and distribution of grades between sexes in each sample was tested. Section 5.4 was used to analyse the three samples (Christ Church Spitalfields, St Brides and the CT Scans) with parity information. Again, the differences in levels of PAS occurrence and distribution of grades was tested but this time between parity status. Next (section 5.5), the results were analysed focussed on age to see the effect on PAS occurrence and morphology. Three of the British samples (Poulton, St Owens, and St Brides) were combined into one data set. Spitalfields was not included despite being a British sample as only data from female individuals were collected. Then (section 5.6), the two South African samples were compared against each other to examine the effect of ancestry on the PAS. Finally (section 5.7), the six samples with both male and female data were compared against each other to determine if the location had an effect on sulcus morphology and presence.

The first statistical test performed on the data was a Shapiro-Wilk to examine whether the data were normally distributed. This test was chosen as the sample size was smaller than 2000. For all the samples the results showed that the data were not normally distributed so non-parametric tests were used for further analysis. To test for statistical difference between independent variables, two tests were used. These were Mann-Whitney U and Kruskal-Wallis. The Mann-Whitney U was primarily used to assess the differences in grades and PAS presence. Mann-Whitney U test (also known as Wilcoxon-Mann-Whitney and Wilcoxon rank-sum W tests) is the non-parametric version of an independent samples t-test (Dytham, 2011). This test was chosen to be used as it is best suited for the ordinal data. A Kruskal-Wallis test is best suited for continuous data, therefore, it was used for the length and width measurements of the PAS. This test has the null hypothesis that there is no difference between the samples and is a non-parametric version of a one-way ANOVA (Dytham, 2011). Finally, a Spearman-rank order test was performed to examine the correlation between variables. This test is the non-parametric version of a Pearson's product-moment correlation and was used because it's a more widely accepted test than Kendall's (Dytham, 2011). The statistic gives a score of -1 to 1. A score of 0 represents no correlation with -1 representing a perfect negative correlation and 1 a perfect positive correlation, they are also categorised into a weak, moderate or strong correction (Dytham, 2011). The statistical methods that were used for both the pilot projects are predominately similar, they will be detailed in Chapters 5 and 6.

5- Pelvic Shape Analysis

5.1- Introduction

This chapter will focus on one of the two pilot studies of this present study. Whilst the research here still relates to the main overall aim of the thesis it was not carried out using the exact same methodology as detailed in Chapter 4. The aim of this chapter was to examine the relationship between the shape of the pelvic girdle and the preauricular sulcus (PAS). Additionally, it was hoped that looking at differences in pelvic shape between sexes would better inform the main results chapters where the effect of sexual dimorphism on the trait will be analysed and discussed. In order to assess the PAS the new grading system (Chapter 4) was used. However, a selection of measurements related to pelvic shape and parturition was chosen to describe the overall shape of the pelvis. All the pelves used were individuals from the St Brides sample (n=35), the history of this sample can be found in Chapter 3. The 35 selected had pelvic girdles that could be fully articulated in order for the measurements to be accurately taken. The pilot study into pelvic shape and its correlation to scars of parturition is only meant to be a brief overview of the topic and not a comprehensive study of the relationship as it was not the main focus of the PhD thesis. As such only a small number of individuals from one sample were studied, as well as a selection of pelvic measurements.

For this section of the study, the 2 main hypotheses are:

- $1H_0$- The dimensions of the pelvis have no significant effect on the levels of occurrence and morphology of preauricular sulcus in male and females
- $1H_1$- The dimensions of the pelvis have a significant effect on the levels of occurrence and morphology of preauricular sulcus in male and females

- $2H_0$- Dorsal pubic pitting is not significantly effected by pelvic shape
- $2H_1$- Dorsal pubic pitting is significantly effected by pelvic shape

As discussed in Chapter 2 the main area of study into the causes of scars of parturition have been concerning pregnancy and parturition (Angel, 1969; Houghton, 1975; Kelley, 1979; Ubelaker and De La Paz, 2012). However, it has been suggested that there may be other causes for the scarring exhibited in both female and male pelves (Ashworth, 1976; Holt, 1978; Cox, 1989). One of the possible causes that has been suggested is the size and shape of the pelvic girdle (Cox, 1989; Maass, 2012).

The most direct way to assess the shape of the pelvic girdle in skeletal remains is to measure the pelvic dimensions. A number of different measurements were taken, they are detailed in the Methodology section of the chapter (5.2). Caldwell and Maloy's (1933) method for describing the shape of the pelvis was researched but found unsuitable for the present study. This technique categorised the pelvis into four different shapes (Figure 5.1). The first and most common shape is gynecoid (found in 50.5% of females), where the inlet shape is round but the anterior-posterior diameter is lesser than the transverse diameter. The next most common is anthropoid (26.5%), which has a greater anterior-posterior than the transverse diameter. The android shape (18.5%), is smaller in size than gynaecoid and is described as having a triangular shape. The final and least common of the pelvic shapes according to this classification is platypelliod (4.5%) which has a very extended transverse but a severely reduced antero-posterior diameter (Cox, 1989). Although these categories were considered when examining the pelvis it was decided that they were too subjective to be used and instead a metric approach to pelvic shape would be more accurate.

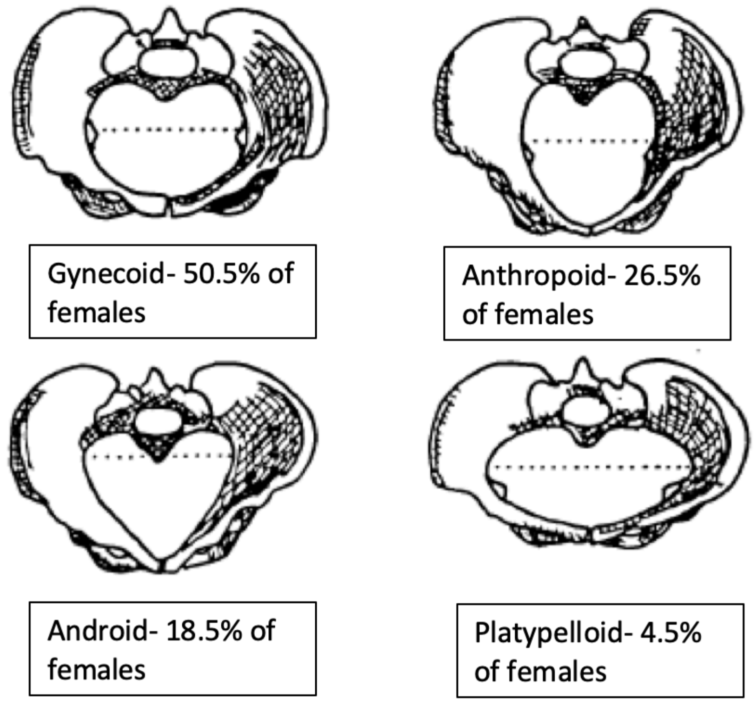


Figure 5.1- Caldwell and Maloy's (1933) pelvic shape classifications. (Image adapted from Cox 1989, page 50)

Several studies have shown that the dimensions of female pelves in the birth canal are larger than males. This is in contradiction with the rest of the skeleton where males are typically larger than females (Tague, 1992; Arsuaga and Carretero, 1994; Tague, 2000; Kurki, 2007). In 2005 Correia *et* al. suggested that the most sexual dimorphism occurred in the 'true pelvis' or birth canal. This is likely due to the selection pressures on the female pelvis that are required for parturition to take place. A wider pelvis allows for easier passage of the neonate through the birth canal and a successful obstetric outcome. In 2007 Kurki suggested that larger dimensions of the pelvis, and especially the birth canal were so important that they were protected even in small-bodied females.

Cox (1989) hypothesised that if pelvic 'scarring' was related to an obstetric event then it would be logical to find more scarring on pelves with smaller dimensions as there would be greater stress on the pelvic girdle. However, her results showed the opposite, that instead there was a correlation between severe scarring and larger pelvic dimensions. This result was also supported by Maass (2012) who found that scarring was more common in those individuals with a larger pelvis, particularly those who also had a smaller body size overall. The author suggested that this was due to females with larger pelves having more flexibility in the pelvic girdle. In response, the ligaments have to stabilise the pelvis more to allow for successful bipedalism. This extra stabilisation on the larger pelvis leads to more pronounced scarring occurring.

As detailed in Chapter 2 another area of interest in the topic of scars of parturition is pitting on the dorsal pubic symphysis. It was first described and linked to sexual dimorphism in 1854 by Luschka (Cox, 1989). Later, Putschar was the first person in the 1930s to suggest that it might be linked to pregnancy and parturition (Putschar, 1976). It is categorised as series of depressions or pits on the dorsal aspect of the pubic surface. It has been suggested that as the ligaments that attach between the pubic symphysis soften during pregnancy, an excess strain is placed upon the ligament insertion site (the PAS). It has been hypothesised that this strain from both the weight of the foetus and the movement of the neonate through the birth canal leads to remodelling of the bone in the form of pubic pits (Heckman and Sassard, 1994; Borg-Stein *et al.*, 2005). As discussed in section 2.5 of Chapter 2 several studies have been carried out into this area. Some studies (Stewart, 1957; Angel, 1969; Kelley, 1979) concluded that dorsal pitting was related to parturition whilst others (Adams Holt, 1976; Suchey *et al.*, 1979) suggested that it was not a reliable indicator.

5.2- Methodology

There were 35 pelves that were able to be fully articulated from St Brides collection (22 males and 13 females), measurements were taken in order to examine the variations in pelvic shape. There are a large number of measurements that can be taken from the pelvic girdle to assess the shape. However, the measurements taken were narrowed to nine and the presence of pubic pitting was also assessed. The measurements that were selected were accepted obstetric and gynaecological measurements from Cox's 1989 thesis. These were chosen as they were judged to best assess the shape of the pelvis in relation to parturition and give an accurate representation of the 3D dimensions of both the true (area inferior to the pelvic brim) and false (area superior to the pelvic brim) pelvis (for more detail see section 2.2).

The measurements taken were:

- **Maximum Sacral Width-** The maximum anterior breadth (Figure 5.2)
- **Sacral Width Inferior-** The diameter of the ventral sacrum at a level determined by the inferior extremity of the auricular surface (Figure 5.2)
- **Sacral Length-** From the sacral promontory to the apex of the sacral vertebra 5/6 (Figure 5.2)
- **Sacral Depth-** Using co-ordinate calliper places on the sacral promontory and the apex of the vertebrae 4, measure the maximum depth of the sacral curve (Figure 5.2)
- **Transverse Diameter-** The maximum transverse diameter at the level of the arcuate line (Figure 5.3)
- **Conjugate Diameter-** Between the dorsal margin of the pubic symphysis at the level of the arcuate line and the medial sacral promontory (Figure 5.3)
- **Bispinous Dimeter-** Measured from the inferior pelvic aspect between the transverse ridges of the ischial tuberosities (Figure 5.3)
- **Pubo-Sacro Diameter-** From the symphysis to the point where the anterior auricular point of the arcuate line intersects the anterior border of the auricular surface (Figure 5.4)
- **Ischial Spine Pubic Symphysis Diameter-** From the medial point of the ischial spine to the symphysion (Figure 5.4)

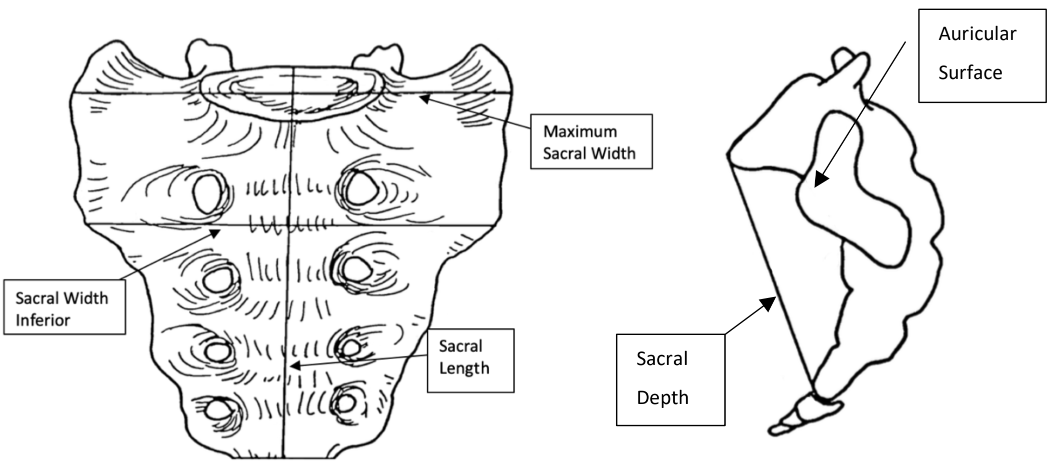


Figure 5.2- Measurements from the Sacrum (dorsal view) (Image adapted from Cox 1989, page 157)

Dorsal pubic pitting was assessed by examination of the dorsal aspect of the pubic symphysis for pits and depressions (Figure 5.4). The trait was scored as either present or absent. Dorsal pitting was examined in this pilot project but not the rest of the other samples for the present study due to preservation. In both the Poulton and St Owens samples the pubis was often not present or damaged. However, in the St Brides sample the preservation was nearly perfect. This meant that dorsal pitting could be examined.

The method of articulation that was used on the pelvic girdle was as follows: The two *os coxae* and sacrum were held together and secured in place using elastic bands; care was taken when placing them to ensure that no damage or unnecessary pressure was placed upon the bone. A small piece of foam approximately 4.0mm diameter was placed between the pubic symphysis to mimic the soft tissue that would be present in living individuals (Cox, 1989). This foam insert also stabilised the pelvis allowing for more accurate measurements to be taken. This method was chosen instead of using an adhesive that would be harmful to the bone and permanent. The above measurements were then taken from the articulated pelvis using slider callipers. The data was collected and entered directly into an excel spreadsheet.

Before the pelvic measurements were taken, the PAS was assessed using the grading system (described in Chapter 4). Age at death and sex assessment was not carried out as the collection was already documented. This biographical information was not accessed until all the data was collected in order to not bias the observation of the PAS.

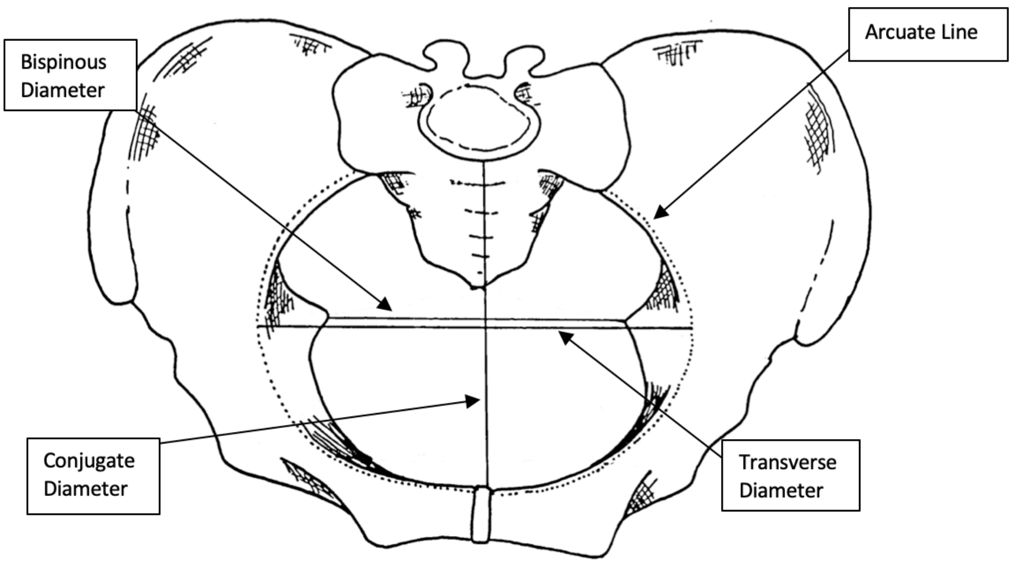


Figure 5.3- Measurements from the articulated pelvic girdle (superior view) (Image adapted from Cox 1989, page 162)

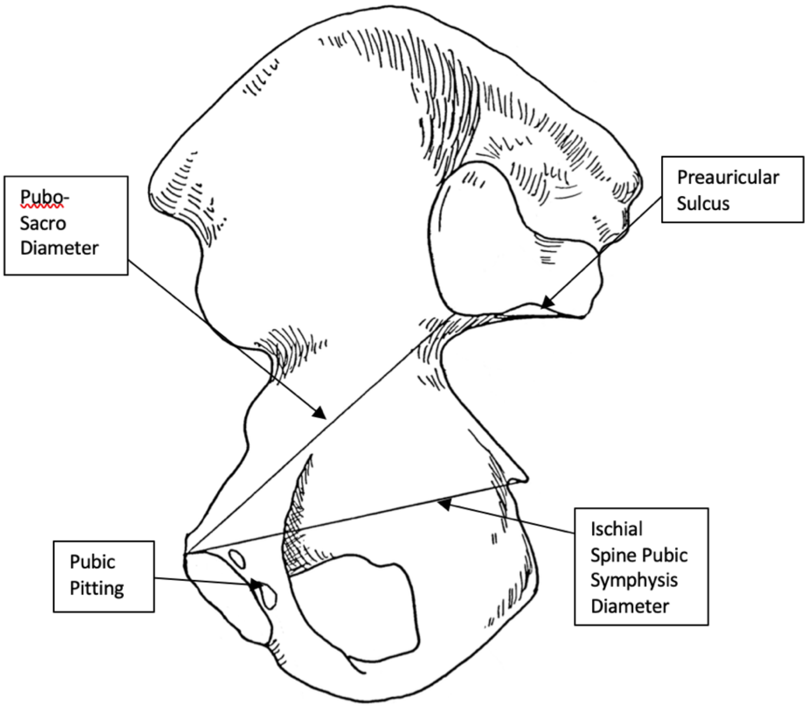


Figure 5.4- Measurements from the *os coxae* (medial view, right *os coxae*) (Image adapted from Cox 1989, page 149)

5.3- Results

This section will detail both the statistical tests carried out on the data and the results. The tests performed were largely similar to the ones used for the main body of the present study with only slight changes due to different variables. The first statistical test to be run was to check the normality of the data, using a Shapiro-Wilk test, this was selected as the sample size was smaller than 2000. The results showed that some of the variables (measurements) were normally distributed as the p-value was greater than 0.05. However, the majority of variables were not normally distributed so non-parametric tests were used going forward. A Kruskal-Wallis test was used to examine the difference between grades and pelvic shape measurements, this was chosen as it is the best suited for continuous data (Dytham, 2011). Finally, a Spearman Rank order test was run to examine the correlation between grades and the pelvic shape (Dytham, 2011). The results for both these tests for each pelvic shape measurements and ratios will be detailed below. The data recorded by the author can be found in Appendix 3. Appendix 4 shows the SPSS (IBM Corp. 2012) output tables for the statistical tests performed.

Maximum Sacral Width

The median width was 112.03mm (Figure 5.5). The Kruskal- Wallis test showed that there was a significant difference in this measurement between grades (χ^2=15.813, df=4, p=0.003). A Mann Whitney U test showed there was a statistical difference between sexes in this variable (U=48.5, p<0.001). The Spearman rank test found that there was a moderate positive correlation between grades and this variable (p>0.001, r_s= 0.528) (Dytham, 2011). There was also a moderate negative correlation between this variable and sex (p>0.001, r_s= -0.553), showing that as the sex changes from female to male the width decreased. There was also a weak positive correlation between this variable and pubic pitting (p=0.04, r_s= 0.354), showing that as the width increased there were more occurrences of pubic pitting.

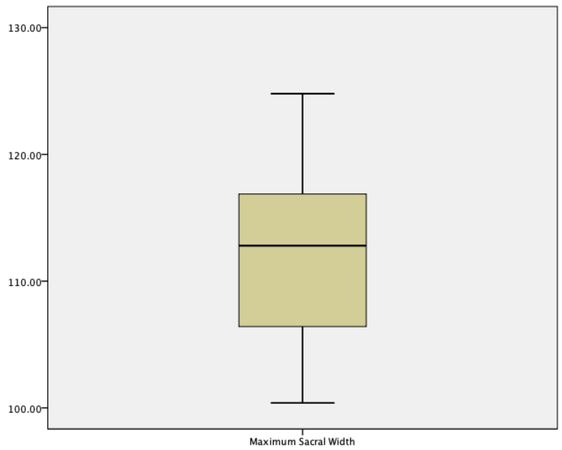


Figure 5.5- The median Maximum Sacral Width

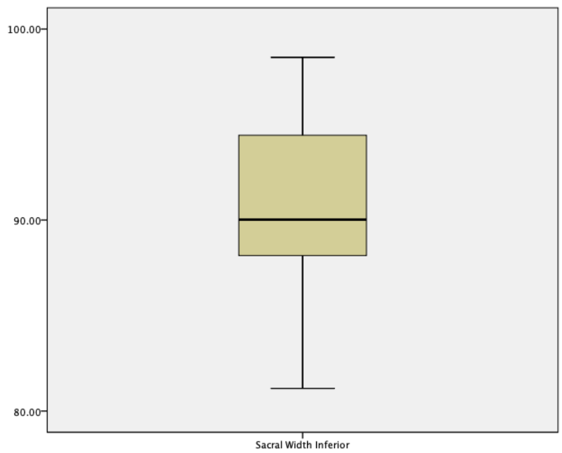


Figure 5.6- The median Sacral Width Inferiors

Sacral Width Inferior

The median width was 90.02mm (Figure 5.6). The Kruskal- Wallis test showed that there was no significant difference in this measurement between grades (χ^2=8.622, df=4, p=0.071). A Mann Whitney U test showed there was a statistical difference between sexes in this variable (U=52.0, p=0.002). The Spearman rank test found that there was a moderate positive correlation between grades and this variable (p= 0.012, r_s= 0.422). There was also a moderate negative correlation between this variable and sex (p>0.001, r_s= -0.533), showing that as the sex changes from female to male the width decreased. There was also a moderate positive correlation between this variable and pubic pitting (p=0.011, r_s= 0.433), showing that as the width increased there were more occurrences of pubic pitting.

Sacral Length

The median width was 116.00mm (Figure 5.7). The Kruskal- Wallis test showed that there was no significant difference in this measurement between grades (χ^2=9.167, df=4, p=0.057). A Mann Whitney U test showed there was no statistical difference between sexes in this variable (U=90.0, p=0.177). The Spearman rank test found that there was no correlation between grades and this variable (p= 0.137, r_s= -0.265), or between sex and this variable (p= 0.181, r_s= 0.239). There was also no correlation between this variable and pubic pitting (p=0.859, r_s= 0.033).

Figure 5.7- The median Sacral Length

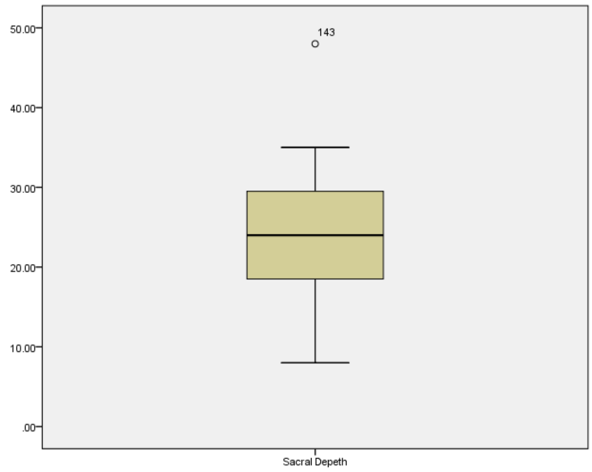


Figure 5.8- The median Sacral Depth

Sacral Depth

The median width was 25.00mm (Figure 5.8). The Kruskal- Wallis test showed that there was no significant difference in this measurement between grades (χ^2=3.0, df=4, p=0.558). A Mann Whitney U test showed there was no statistical difference between sexes in this variable (U=103.0, p=0.619). The Spearman rank test found that there was no correlation between grades and this variable (p= 0.880, r_s= 0.028), or between sex and this variable (p= 0.089, r_s= 0.627). There was also no correlation between this variable and pubic pitting (p=0.751, r_s= -0.059).

Transverse Diameter

The median width was 121.00mm (Figure 5.9). The Kruskal- Wallis test showed that there was a significant difference in this measurement between grades (χ^2=14.695, df=4, p=0.005). A Mann Whitney U test showed there was a statistical difference between sexes in this variable (U=43.0, p=0.001). The Spearman rank test found that there was a strong positive correlation between grades and this variable (p>0.001, r_s= 0.623). There was also a moderate negative correlation between this variable and sex (p>0.001, r_s= -0.586), showing that as the sex changes from female to male the width decreased. There was also no correlation between this variable and pubic pitting (p=0.109, r_s= 0.280).

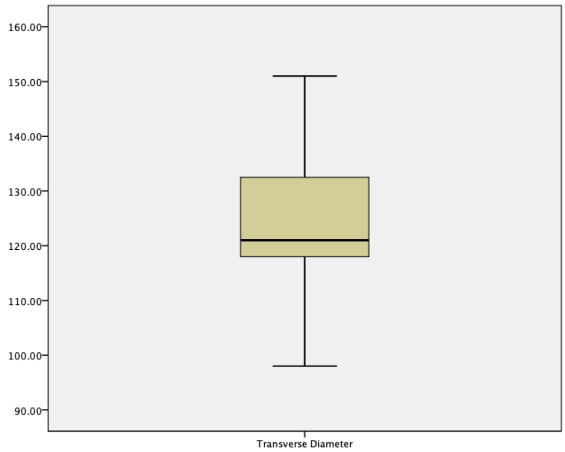


Figure 5.9- The median Transverse Diameter

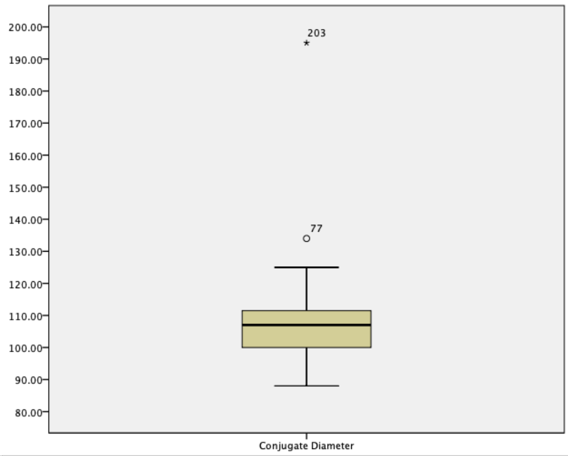


Figure 5.10- The median Conjugate Diameter

Conjugate Diameter

The median width was 107.00mm (Figure 5.10). The Kruskal- Wallis test showed that there was no significant difference in this measurement between grades (χ^2=5.119, df=4, p=0.005). A Mann Whitney U test showed there was a statistical difference between sexes in this variable (U=67.5, p=0.01). The Spearman rank test found that there was no correlation between grades and this variable (p= 0.159, r_s= 0.244). There was was a moderate negative correlation between this variable and sex (p=0.008, r_s= -0.442), showing that as the sex changes from female to male the width decreased. There was also no correlation between this variable and pubic pitting (p=0.265, r_s= 0.197).

Bispinous Diameter

The median width was 98.00mm (Figure 5.11). The Kruskal- Wallis test showed that there was a significant difference in this measurement between grades (χ^2=13.188, df=4, p=0.01). A Mann Whitney U test showed there was a statistical difference between sexes in this variable (U=28.5, p<0.001). The Spearman rank test found that there was a moderate positive correlation between grades and this variable (p=0.001, r_s= 0.525). There was also a strong negative correlation between this variable and sex (p>0.001, r_s= -0.672), showing that as the sex changes from female to male the width decreased. There was also no correlation between this variable and pubic pitting (p=0.073, r_s= 0.312).

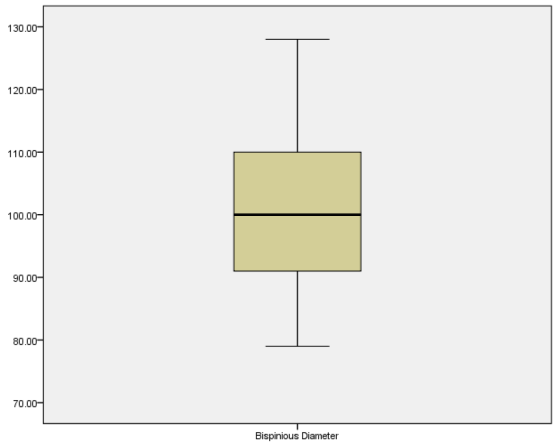


Figure 5.11- The median Bispinous Diameter

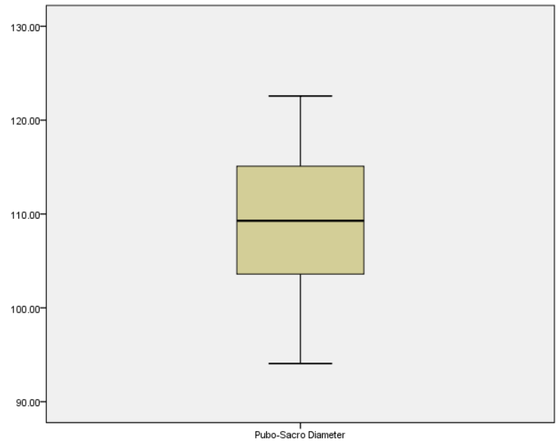


Figure 5.12- The median Pubo-Sacro Diameter

Pubo-Sacro Diameter

The median width was 109.09mm (Figure 5.12). The Kruskal- Wallis test showed that there was no significant difference in this measurement between grades (χ^2=4.699, df=4, p=0.320). A Mann Whitney U test showed there was no statistical difference between sexes in this variable (U=93.0, p=0.123). The Spearman rank test found that there was no correlation between grades and this variable (p= 0.227, r_s= 0.213), or between sex and this variable (p= 0.125, r_s= -0.268). There was also no correlation between this variable and pubic pitting (p=0.328, r_s= 0.173).

Ischial Spine Pubic Symphysis Diameter

The median width was 101.01mm (Figure 5.13). The Kruskal- Wallis test showed that there was no significant difference in this measurement between grades (χ^2=2.452, df=4, p=0.653). A Mann Whitney U test showed there was no statistical difference between sexes in this variable (U=109.0, p=0.330). The Spearman rank test found that there was no correlation between grades and this variable (p= 0.403, r_s= -0.148), or between sex and this variable (p= 0.337, r_s= 0.170). There was also no correlation between this variable and pubic pitting (p=0.724, r_s= -0.063).

Pubic Pitting against grade and sex

The Kruskal- Wallis test showed that there was a significant difference in pubic pitting presence between grades (χ^2=13.16, df=4, p=0.010). A Mann Whitney U test showed there was a statistical difference in pubic pitting presence between sexes (U=73.5, p=0.001). The Spearman rank test found that there was a weak positive correlation between grades and this variable (p=0.042, r_s= 0.042), showing that as grades increased there were more occurrences of pubic pitting. There was also a moderate negative correlation between this variable and sex (p>0.001, r_s= -0.588), showing that as the sex changes from female to male there were fewer occurrences of pubic pitting.

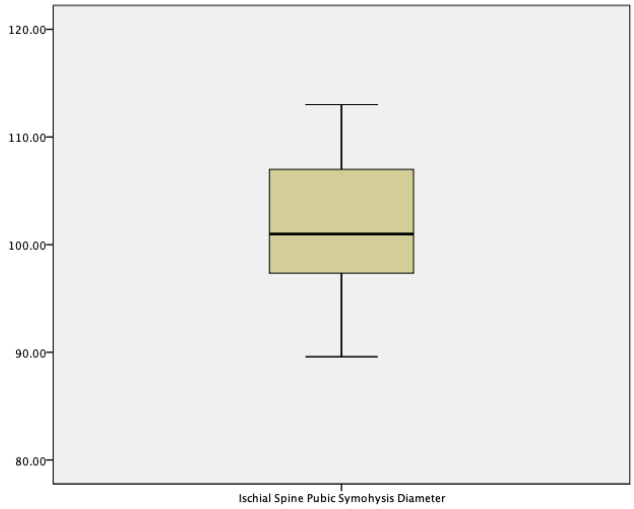


Figure 5.13- The median Ischial Spine Pubic Symphysis Diameter

5.4- Discussion

The aim of this pilot project was to examine the relationship between pelvis shape and PAS morphology. The results suggest that there is a correlation between some of the pelvic dimensions and the PAS. There was also a correlation between some of the measurements and the sex of the individual.

5.4.1- Variation in Pelvic Measurements between Sexes

The results showed that for five of the measurements of the taken there is a significant difference between sexes. (Tables 5.1). For these five measurements where there was a significant difference, there was also a correlation between the measurement and sex. For all five the correlation was a negative one which means that female measurements were wider than the males.

These results agree with previous studies that show that the dimensions of female pelves are larger than those of male (Tague, 1992; Arsuaga and Carretero, 1994; Cox, 1989; Tague, 2000; Kurki, 2007; Maass, 2012). The male and female pelvis has different requirements placed upon them, this is likely to be the cause of the differences between pelvic measurements. The male pelvis is only constrained by the need for a narrower pelvis required for bipedalism. However, the female pelvis needs to be larger than the male pelvis in order for the parturition of large-brained neonates to occur. The three measurements; the Transverse

Diameter, the Conjugate Diameter and the Bispinous Diameter all has a moderate to strong negative correlation with sex highlighting their importance in the female pelvis. The results agree with Correia *et* al., 2005 that found these dimensions showed the most sexual dimorphism. Larger diameters in these three measurements are essential for safe passage of the foetus through the birth canal, a narrower pelvis in females is likely to lead to obstetric difficulties (Trevathan, 2011). For the Maximum Sacral Width and Sacral Width Inferior, there were also moderate negative correlations with sex, meaning that the widths were greater in females than in males. It would make sense that the sacrum would be wider in pelves with a larger Transverse Diameter. Chapter 7 will further examine the differences in the occurrence and morphology of the trait between sexes.

Table 5.1- The significant differences in pelvic measurements between sexes

Measurements with a significant difference between sex	Measurements without a significant difference between sex
Maximum Sacral Width Sacral Width Inferior Transverse Diameter Conjugate Diameter Bispinious Diameter	Sacral Length Sacral Depth Pubo-Sacro Diameter Ischial Spine Pubic Symphysis Diameter

5.4.2- Variation in Pelvic Measurements Between Grades

The results showed that for four of the measurements of the pelvis taken there was a significant difference between grades (Table 5.2). For the four measurements that have a significant difference between grades, there was also a positive correlation. This means that the diameters and grades increased simultaneously. The correlations ranged from moderate to strong. As discussed in section 5.4.1, the Transverse and Bispinous Diameters are on average larger in females than in males and are important dimensions in the birth canal. Whilst it would be logical to hypothesise that smaller pelves would have more severe scarring it appears the opposite is actually true. Pelves that are larger at the birth canal showed more signs of scarring in this study. These results agree with Cox (1989) and Maass (2012) who both reached similar conclusions. Cox (1989) theorised that this was due to pelves with larger dimensions being more unstable during the transmission of weight from the trunk to lower limbs. As a result, larger pelves require more ligament stabilisation across the pelvic girdle that leads to additional bone remodelling at the attachment sites, seen in the form of 'scars of parturition'. As female pelves are typically larger than males this stabilisation occurs more frequently leading to an increase in the occurrence of scars. This may also explain the occurrence of some 'scars of parturition' in male individuals. There is potential that the males with scarring have wider/ more flexible pelvic dimensions, more similar to those of a typical female.

The results suggest that it is not the act of pregnancy or parturition that leads to a more developed PAS but rather the selection pressure on the pelvic girdle for an obstetric event. This would also explain why many nulliparous females show 'scars of parturition' despite never having given birth. This theory will be tested further in Chapter 7 when the effect of parity status on the grades of sulcus will be examined in detail. If no correlation is found between these two variables then it further supports the above explanation for the range differences in PAS morphology and occurrence.

Table 5.2- The significant differences in pelvic measurements between grades

Measurements with a significant difference between grades	Measurements with a significant difference between grades
Maximum Sacral Width Sacral Width Inferior Transverse Diameter Bispinous Diameter	Sacral Length Sacral Depth Conjugate Diameter Pubo-Sacro Diameter Ischial Spine Pubic Symphysis Diameter

5.4.3- Variation in Pubic Pitting

For this section of the study, the occurrence of pubic pitting and its relationship to the other variables was analysed. The results showed that seven of the pelvic measurements taken did not correlate with pubic pitting (Table 5.3). For the two measurements that did correlate with pubic pitting the correlation was weak (Maxiumum Sacral Width) and moderate (Sacral Width Inferior) positive (Dytham, 2011). Meaning that as the width of the sacrum increased there was more likely to be pubic pitting. However, neither of the correlation was very strong.

There was a significant difference in the occurrence of pubic pitting between sexes, there was also a moderate negative correlation. Demonstrating that females were more likely to have pubic pitting than males. This finding is in agreement with the sacral width measurements, as large diameters were more common in females than males. The results are similar to studies by (Stewart, 1957; Angel, 1969; Adams Holt, 1976; Putschar, 1976; Kelley, 1979; Suchey *et* al., 1979; Cox, 1989; Heckman and Sassard, 1994; Borg-Stein *et al.*, 2005) who although disagreeing on the cause of pubic pitting all found that they occurred more commonly in females than males.

Finally, the occurrence of pubic pitting was examined in relation to the PAS grades. The results showed a weak positive correlation between the two variables. Meaning that as the grades increased there was more frequency of pubic pitting. The results agree with Maass (2012) who found that in her modern male samples there was also a weak correlation between two variables. The relationship between the two scars of parturition suggests that when there is an increase in the strain of the sacroiliac ligaments there is usually also one on the pubic ligaments. Maass (2012) suggested that this may be necessary in order to maintain the stability of the pelvic girdle.

Table 5.3- The correlation in pelvic measurements between pubic pitting

Measurements that correlate with pitting	Measurements that do not correlate with pitting
Maximum Sacral Width Sacral Width Inferior	Sacral Length Sacral Depth Transverse Diameter Conjugate Diameter Bispinious Diameter Pubo-Sacro Diameter Ischial Spine Pubic Symphysis Diameter

5.4.4- Limitations

This pilot study focused on the dimensions of the pelvis and their relationship to PAS morphology. Body size was not considered, however studies by Maass (2012) have shown that it may be relevant in understanding scars of parturition. Her results found that scars of parturition occurred most frequently in individuals with smaller body size but larger pelvis. For future research about pelvis shape, it would be beneficial to also calculate body size.

This project only looked at the difference in pelvic shape in a European sample so does not fully depict the range of variability present in modern human pelvis. For further studies into this area of research, it would be beneficial to look at a wider geographical and temporal range as well as considering additional factors such as body size. A study by Betti and Manica (2018) took measurements of the pelvic girdle from 348 female skeletons from 24 different areas of the world. They found that there was a large level of variability in size, particularly of the bony birth canal. The results showed that there was more variation in the pelvis than in leg, arm and general body proportions. The authors found that ancestry appeared to play a role in the determination of pelvis shape. Individuals of sub-Saharan African origin typically had pelves with a greater anterior-posterior diameter in all three planes (inlet, midplane, and outlet). Conversely, those from Native American populations had a greater transverse diameter. The results suggested that those of European/North America and Asian descent placed in the middle of the range (Betti and Manica, 2018).

6- Biographical Information Analysis of Living Subjects

6.1- Introduction

This chapter will discuss the second pilot study that was undertaken as part of the present research; the project was not the main focus of the PhD, however is closely related. This study was carried out with a selection of data to test if the method was viable, with the hope that it may be able to be expanded at a later date. The project consisted of using CT scan data of living subjects' pelvis and biographical information that was obtained in collaboration with Dr Janamarie Truesdell at Oxford University in 2016. Her doctoral research was carried out on 1,238 individuals who visited hospitals in the Oxford region of the United Kingdom. In 2017 a sample of 71 was then selected for this project, they consist of 25 males, 20 nulliparous females and 26 parous females. They were selected randomly in their categories by Truesdell and any identifying information was removed before being given to the author.

As part of her then-doctoral research, Truesdell conducted extensive questionnaires with the subjects to gain information about their demographics (age, height, weight, body shape), lifestyles (smoking history, alcohol consumption, activity level and diet) and parity status (number of pregnancies, number of births and caesarean history). Truesdell's research was to improve techniques for the ageing of female individuals from the pubic symphysis and to better understand the effect the above information may have on them. Her results showed that sex, smoking and activity level all had a significant effect on the accuracy of pubic symphysis ageing. These variables were the main focus of this pilot study, to see if they also correlated with PAS morphology. However other variables were also included that will be detailed in the methodology section (6.2) of this chapter. It is important to note that the questionnaires and categories used were not designed for the present project but instead for Truesdell's research. As such some of the categories are perhaps too subjective for the purposes of this current study. This will be discussed further in section 6.4.1.

As previously discussed in Chapters 2 and 5, research by Maass (2012) investigated other potential causes of scars of parturition than obstetric events. One of these factors was body mass and size. The author suggested that a better explanation for scarring was weight-strain on the ligament and theorised that both pelvic dimensions (Chapter 5) and body mass are responsible for this. This follows the research on dorsal pubic pitting by Adams Holt (1976) who found that in nulliparous females' higher levels of scarring was found in obese individuals. Snodgrass and Galloway (2003) also found evidence of a correlation between pubic pitting and

BMI, especially in older females. For this reason, BMI was included in the present study to assess its relationship to PAS morphology.

The data for this study were collected using CT Scans, the provenance of these scans was detailed in section 3.5. The use of CT (Computed Tomography) Scans has been slowly growing in the forensic and bioarchaeology fields. Projects such as "The Virtopsy Project" (Bollinger *et* al., 2008) at the University of Zurich aimed to expand the medical imaging techniques used and provide a non-destructive method of body examination. Studies such as Truesdell (2016) and Decker *et al.* (2011) showed that medical imaging can be used to examine traits linked to both age and sex assessment. Decker *et al.* (2011) found that their method using a combination of obstetrical measurements and "traditionally nonmetric Phenice-derived Traits" (p. 1107) provided an accuracy of 100% correct sex estimation of 3D pelvic models from CT Scans. The use of CT Scans in the fields of forensic anthropology and bioarchaeology allows for the inclusion of living patient's data to broaden our understanding of the human skeleton and past populations. The aim of this side project is to use the CT Scans to assess the PAS of living subjects and study the effects that different variables may be having upon the presence and morphology of the PAS.

6.2- Methodology

The CT Scans were performed by staff in the radiography department of The Churchill Hospital, Oxford who were professionally trained and followed the standard NHS procedure. The CT Scans are stored in the form of DICOM (Digital Image and Communication of Medicine) data. In order to view this data software, OsiriX (Pixmeo, Geneva, Switzerland) was used. This is an open-sourced software (available at www.osirix-viewer.com) that is designed to display and be used in the interpretation of DICOM images (Rosset *et al.*, 2004). The software allows the researcher to view the images in multiple planes and enables a large amount of data provided to be narrowed down to focussing on specific traits. In the case of this study, the CT Scans were of the living patient's entire abdomen region. It was possible to narrow the area to only the PAS and for the soft tissue to be 'removed' in order for it to be graded. The volume rendering function of the software was used to create three-dimensional (3D) renderings of the scans (Figure 6.1). The bone is segmented from the surrounding soft tissue in a method called "thresholding" (Tuesdell, 2016). The pre-set "low-contrast" was found to be the most useful method of highlighting the bone, the software contains a 'bone-removal function' to isolate the bone from the surrounding tissue which was used. The 'scissor function' was then used to remove any excess bone or tissue leftover (Wink, 2014).

Figure 6.1- 3D CT image of the pelvic girdle as created in OsiriX

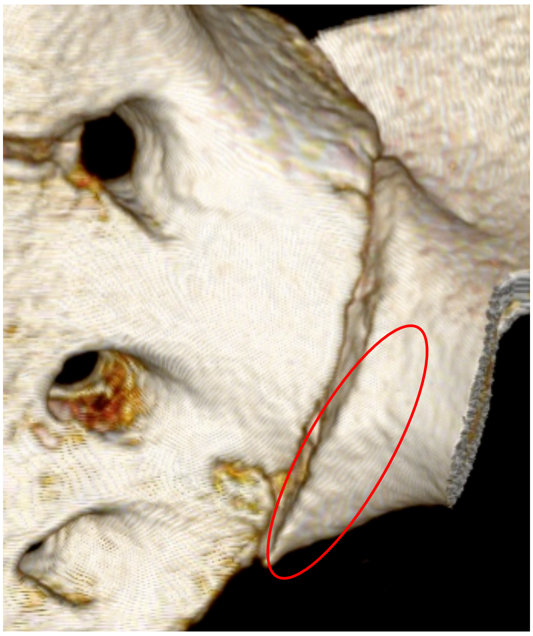


Figure 6.2- 3D CT image of a grade 0 (left *os coxae*) Figure 6.3- 3D CT image of a grade 1 (right *os coxae*)

Figure 6.4- 3D image of a grade 2 (right *os coxae*)

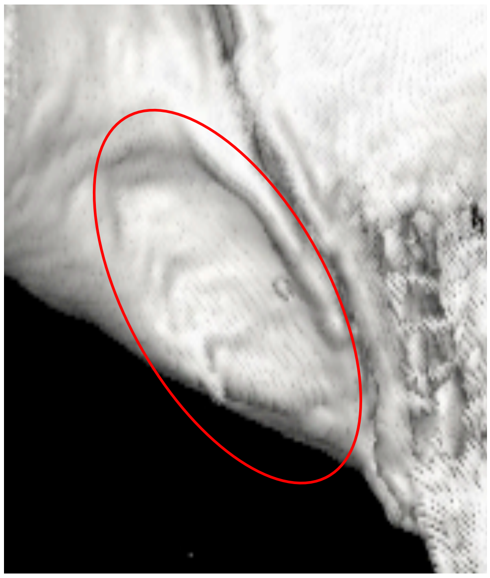


Figure 6.5- 3D CT image of a grade 3 (right *os coxae*)

Figure 6.6- 3D image of a grade 4 (left *os coxae*)

Once the CT Scans were rendered then an assessment of the PAS was graded using the main grading system of this study. As described in Chapter 4, Grade 0 is for when the sulcus is not present through to a Grade 4 for a deeply pitted expression of the trait. The method involves observing the PAS area and using the photographs and descriptions provided to classify the trait. The method proposed suggests that touch can additionally be used where possible although is not essential. However, with digital samples, only description and visual examination were used to classify the PAS. The 'rendering process' created a 3D model of the pelvic region that could be viewed (Figure 6.1). The area of the PAS was then focussed on and assessment of the PAS grade could be made. As it was a 3D image it could be rotated to give a view of the morphology of the sulcus floor and show any changes to the depth. Figures 6.2-6.6

show a series of images of close-ups of different PAS grades. However, it should be noted that as these are 2D images they do not fully show the range of depth that could be observed on the 3D models. The assessment of grade was made from the 3D models rather than the 2D images shown in this thesis.

Only after an assessment of the PAS was made was any biographical information examined by the researcher. The grades were entered in an Excel spreadsheet along with the data from the other variables. There were ten variables about the lifestyle habits of the subjects that were examined, they are detailed below

- **Body Mass Index (BMI)-** For each of the individuals, height (cm) and weight (kg) were recorded by Truesdell's questionnaires. This was then converted into BMI by the author and categorised into four groups:
  - Underweight (< 18.5kg/m2)
  - Healthy Weight (18.5 to 24.5kg/m2)
  - Overweight (25 to 29.9kg/m2)
  - Obese (30 to 39.9kg/m2)

  The NHS BMI Calculator was used to determine BMI (available at www.nhs.uk/live-well/healthy-weight/bmi-calculator/). These classifications were used as they are the official NHS guidelines for BMI. As stated above this variable was included as previous studies have found links between body mass and scars of parturition.
- **Body Shape-** This variable was included in Truesdell's 2016 study to examine the potential effects of weight distribution. It was hypothesised that differences in gait and shock absorption due to body type could have morphological effects on the pelvic bones. It is to further test this theory that it was included in the present research. The different body shapes were:
  - Rectangle (an even distribution of adipose)
  - Hourglass (a waist that is narrower than the chest and hips)
  - Apple (a concentration of adipose around the waist)
  - Triangle (where the shoulder is broader than the hips)
  - Pear (where the hips are broader than the shoulder and chest).

  The participants were asked to give their own assessment of their body shape but if unsure Truesdell would visually assess them herself.
- **Tobacco Consumption–** This variable was divided simply into whether the individual had a history of smoking or has no history of smoking. This question was included as Truesdell found smoking to have a significant effect on the ageing of the pubic symphysis. Studies (Ward and Klesges 2001) have shown that individuals with a history

of smoking have significantly reduced bone mass. It was included to examine whether smoking also affected bone remodelling of the PAS.

- **Alcohol Consumption-** The subjects were asked to give the number of alcohol units they usually consumed in a week:
    - 0 units a week
    - Less than 4 units
    - 5-9 units
    - 10-14 units
    - 15-19 units
    - 20-25 units
    - 25-29 units
    - More than 30 units

  This question was included as alcohol consumption also has an effect on bone density. Studies have shown that individuals with increased alcohol consumption have a higher risk of osteoporosis and reduced bone mass (Chakkalakal, 2005).
- **Activity Level-** The subjects were asked which of the four activity levels they felt best described their normal routine. This question was included to examine the effect that activity level may have on the PAS. Ashworth (1976) suggested that high activity levels may cause strain to the ligaments of the pelvis. The description of the different activity levels was provided by Truesdell (2016):
    - Immobile (unable to move of their own)
    - Light (movement in and around the house, garden, light chores and errands)
    - Moderate (walking or standing (including commuting) for approximately hour per day, and/or an hour or two of dedicated cardiovascular exercise, dance, or sport per week)
    - Active (Activity that exceeds the moderate level).
- **Diet-** The subjects were asked which of the three diet descriptions they felt best described their normal diet:
    - Poor-1
    - Average- 2
    - Good- 3.

  This question has been included as nutrition plays a role in bone development and health. Although this has been more linked to bone loss and osteoporosis (Ilich *et al.*, 2000) than bone remodelling diet was still included here to see if diet was a factor in changes to bone morphology.

- **Number of Pregnancies-** The subjects were asked how many times they had been pregnant. As stated in previous chapters parity has long been suggested to have an effect on the PAS (Derry, 1909; Stewart, 1957; Putschar, 1976; Houghton, 1975; Ubelaker and De La Paz, 2012). In a large portion of these studies, there appears to be no distinction made between parturition and pregnancy. However, as high as 25% of known pregnancies end in miscarriage (Brann and Bute, 2017) and 16.7% of pregnancies (per 1,000 residents) in 2017 were terminated in UK (UK Office of National Statistics, 2018). In this sample, it is unknown whether the pregnancies that were not full-term were either miscarried or terminated.
- **Number of Births-** Number of Births was included as a separate category as there were individuals who had either had miscarriage or terminations to their pregnancies. For the purposes of the present study, the Number of Births includes both vaginal births and caesareans.
- **Age at 1st Birth-** For this variable, the age at which they first gave birth was split into three categories:
  - Gave birth at younger than 25
  - 25-40
  - Older than 40-3

  This variable was included to see whether Age at 1st Birth had an effect of PAS morphology.
- **Caesareans-** This variable was divided simply into whether the individual had ever had a caesarean or not. As of 2018 approximately 29% (NHS Digital, 2018) of births in the UK were from caesarean section (13% elective and 16% emergency). This variable was included as it has been suggested (MacArthur *et al.,* 2016) that the mechanical process of vaginal birth may cause changes to the scars of parturition. However, a caesarean section would take away most of this mechanical strain so individuals who have had one would theoretically not see as much scarring if vaginal birth is the cause.

6.3- Results

This section will describe the statistical tests that were carried out and detail the results across the variables. The first statistical test to be run was to check the normality of the data, a Shapiro-Wilk, this was selected as the sample size was smaller than 2000. The results showed that the data were not normally distributed as the p-value was smaller than 0.05 (either 0.000 or 0.001 for all variables). Meaning that non-parametric tests were used going forward. A Kruskal-Wallis test was used to test for a significant difference between grades and presence and the variables. Finally, a Spearman Rank order test was performed to examine correlation. The results for these two tests for each variable will be detailed below along with descriptive statistics. Appendix 5 shows tables with the biographical information data. The data recorded by the author for the grades can be found in Appendix 6. Appendix 7 shows the SPSS (IBM Corp. 2012) output tables for the statistical tests performed.

BMI

There were seven individuals in the sample where BMI could not be calculated, this was either due to no height or weight information being provided. The most commonly reported BMI category for both females and males in this sample was Healthy Weight (Figure 6.7).

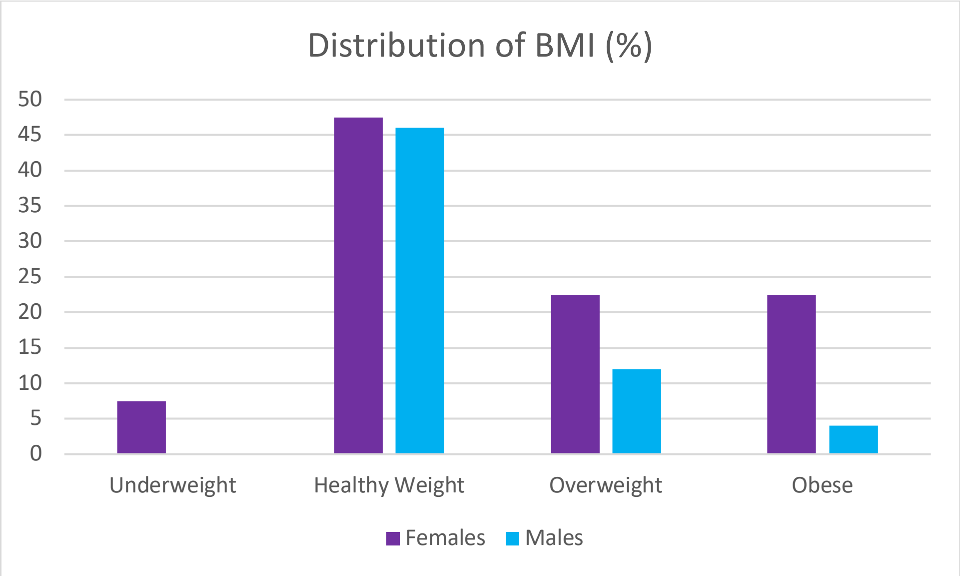


Figure 6.7- The distribution of BMI in % between males and females

The Kruskal-Wallis test showed that there was no significant difference in BMI between the grades (χ^2=3.180, df=4, p=0.365). It also showed that there was no significant difference in the occurrence levels of PAS between BMI (χ^2=3.155, df=3, p=0.368). The Spearman Rank test showed that there was also no correlation between this variable and grades (p=0.469, r_s=0.092) or occurrence levels of PAS (p=0.499, r_s=0.086).

Body Shape

There were two individuals where body shape was not provided. The most common Body Shape reported in females was Hourglass and in males Rectangle (Figure 6.8). The Kruskal-Wallis test showed that there was no significant difference in body shape between the grades (χ^2=5.258, df=4, p=0.262). It also showed that there was no significant difference in the occurrence levels of PAS between body shape (χ^2= 3.627, df=4, p=0.459). The Spearman Rank test showed that there was also no correlation between this variable and grades (p=0.288, r_s= 0.130) or occurrence levels of PAS (p=0.883, r_s=0.018).

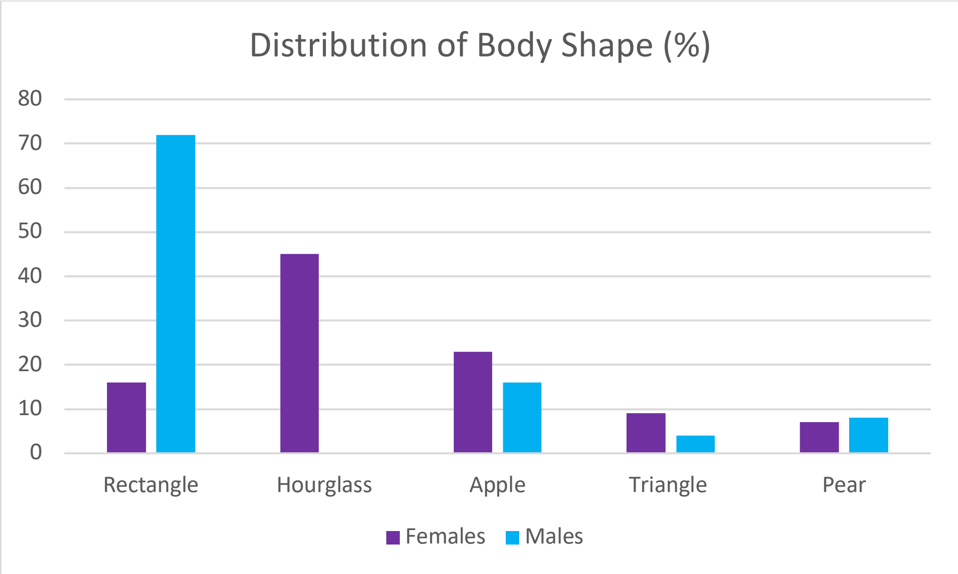


Figure 6.8- The distribution of body shape in % between males and females

Tobacco Consumption

There was one individual where no information on smoking habits was provided. The majority of the individuals in this sample reported no history of smoking in both females and males (Figure 6.9).

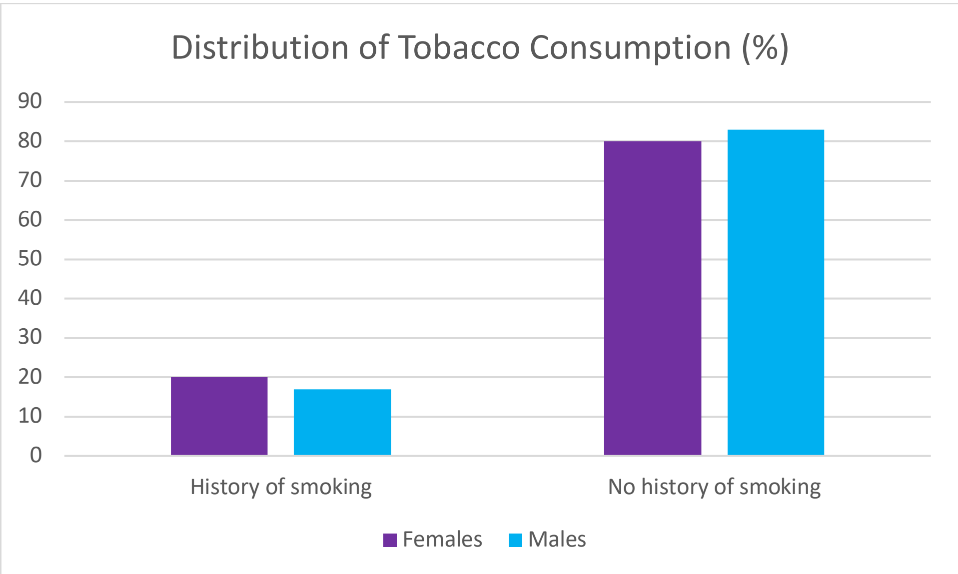


Figure 6.9- The distribution of tobacco consumption in % between males and females

The Kruskal-Wallis test showed that there was no significant difference in tobacco consumption between the grades (χ^2=0.116, df=1, p=0.733). It also showed that there was no significant difference in the occurrence levels of PAS between tobacco consumption (χ^2=0.000, df=1, p=0.993). The Spearman Rank test showed that there was also no correlation between this variable and grades (p=0.736, r_s= 0.041) or occurrence levels of PAS (p=0.993, r_s=-0.001).

Alcohol Consumption

There were two individuals where no information about alcohol consumption was provided. For females, the most commonly reported alcohol consumption was less than 4 units per week. For males, the most commonly reported consumption was between 5-9 units per week (Figure 6.10).

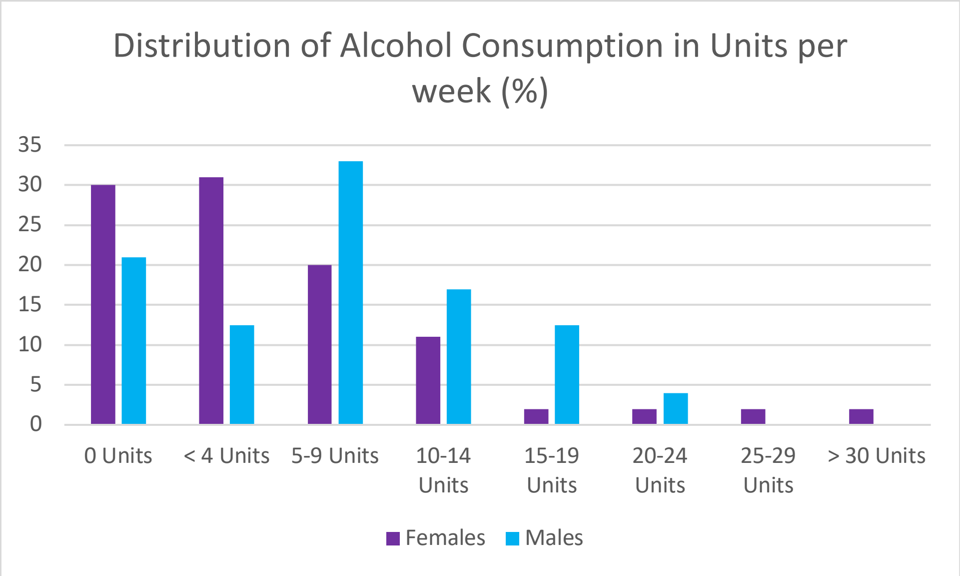


Figure 6.10- The distribution of alcohol consumption in % between males and females

The Kruskal-Wallis test showed that there was no significant difference in alcohol consumption between the grades (χ^2=5.644, df=7, p=0.582). It also showed that there was no significant difference in the occurrence levels of PAS between alcohol consumption (χ^2= 5.855, df=7, p=0.557). The Spearman Rank test showed that there was also no correlation between this variable and grades (p=0.505, r_s= -0.082) or occurrence levels of PAS (p=0.662, r_s=0.054).

Activity Level

All individuals provided information about their activity level. The most commonly reported activity level in both females and males was moderate (Figure 6.11). The Kruskal-Wallis test showed that there was no significant difference in activity level between the grades (χ^2=3.339, df=3, p=0.342). It also showed that there was no significant difference in the occurrence levels of PAS between activity level (χ^2= 2.426, df=3, p=0.489). The Spearman Rank test showed that there was also no correlation between this variable and grades (p=0.254, r_s= -0.137) or occurrence levels of PAS (p=0.563, r_s=-0.070).

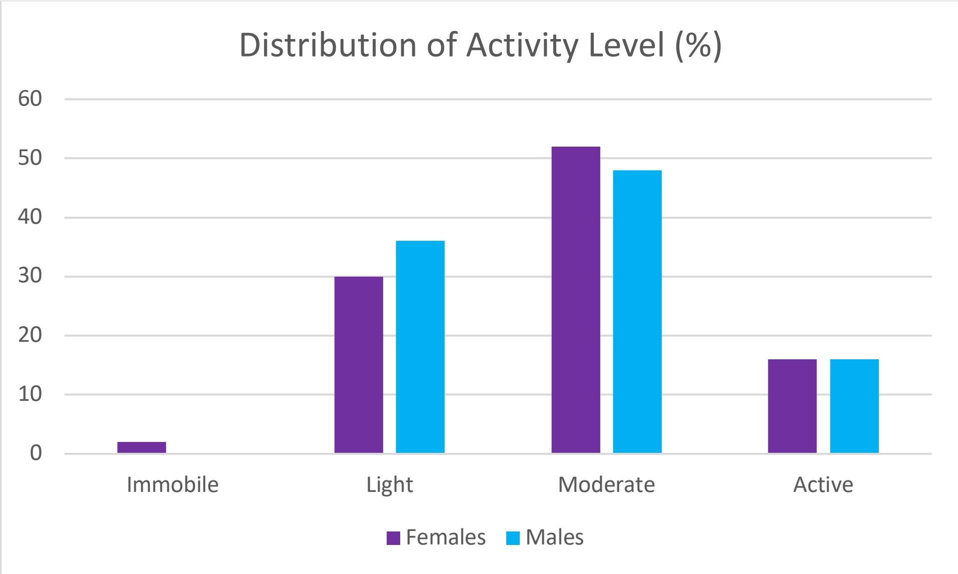


Figure 6.11- The distribution of activity level in % between males and females

Diet

There was one individual where no information about their diet was provided. The most commonly reported answer in both females and males for diet was average (Figure 6.12).

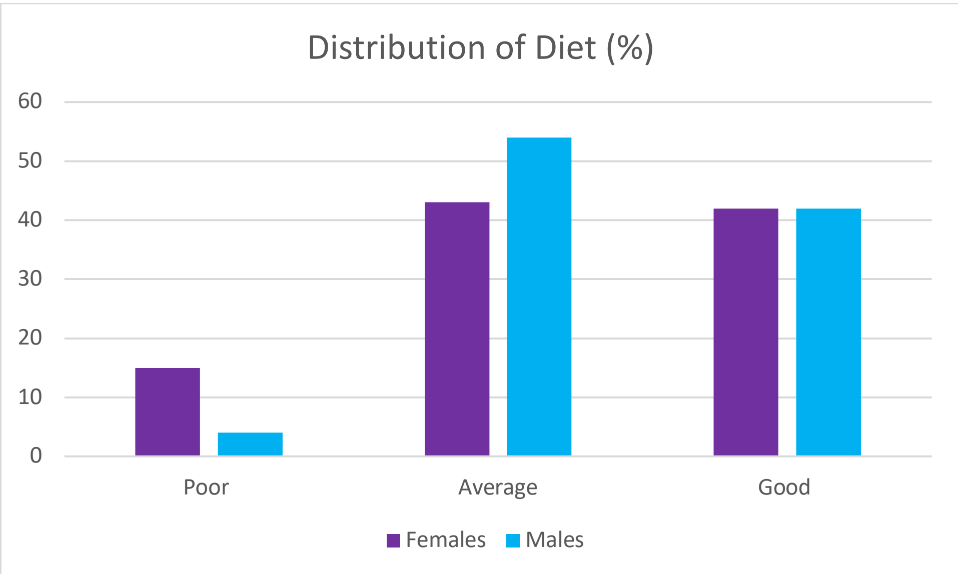


Figure 6.12- The distribution of diet in % between males and females

The Kruskal-Wallis test showed that there was no significant difference in diet between the grades (χ^2=0.574, df=2, p=0.751). It also showed that there was no significant difference in the occurrence levels of PAS between diet (χ^2= 0.409, df=2, p=0.815). The Spearman Rank test showed that there was also no correlation between this variable and grades (p=0.648, r_s= 0.055) or occurrence levels of PAS (p=0.782, r_s=0.033).

Number of Pregnancies

For this sample 18 of the females reported no history of pregnancy. Of the parous females, the most common number of pregnancies was 2 (Figure 6.13).

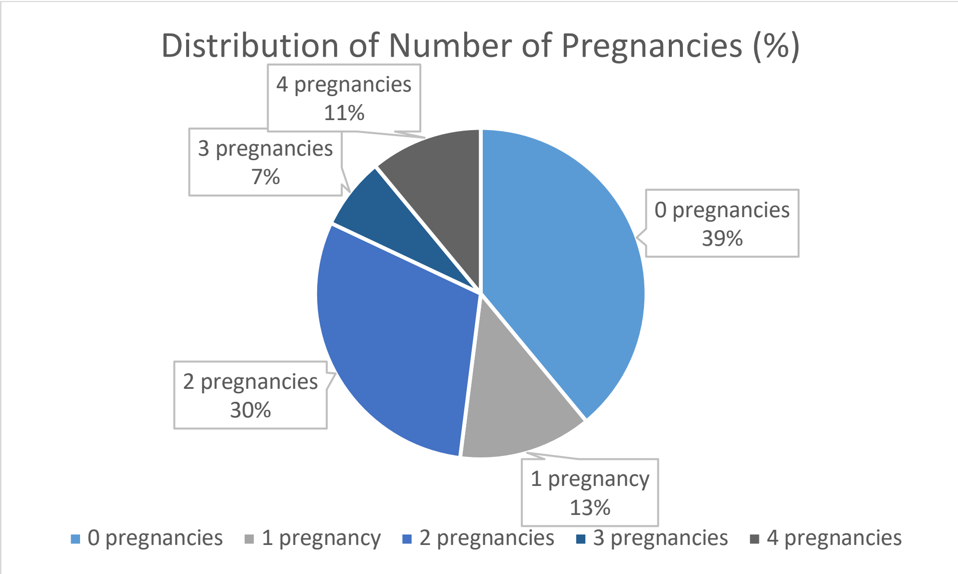


Figure 6.13- The distribution of the number of pregnancies in %

The Kruskal-Wallis test showed that there was a significant difference in the number of pregnancies between the grades (χ^2=10.698, df=4, p=0.030). However, it showed that there was no significant difference in the occurrence levels of PAS between the number of pregnancies (χ^2= 7.892, df=4, p=0.096). The Spearman Rank test showed however that there was a weak positive correlation between this variable and grades (p=0.008, r_s= 0.387) but not between occurrence levels of PAS (p=0.259, r_s=0.082).

Number of Births

For this sample 20 of the females reported no history of birth. Of the parous females, the most common number of births was 2 (Figure 6.14). The Kruskal-Wallis test showed that there was a significant difference in the number of births between the grades (χ^2=13.196, df=4, p=0.010). It also showed that there was a significant difference in the occurrence levels of PAS between the number of births (χ^2= 12.442, df=4, p=0.014). The Spearman Rank test showed however that there was a weak positive correlation between this variable and grades (p=0.032, r_s= 0.317) but not between occurrence levels of PAS (p=0.224, r_s=0.135).

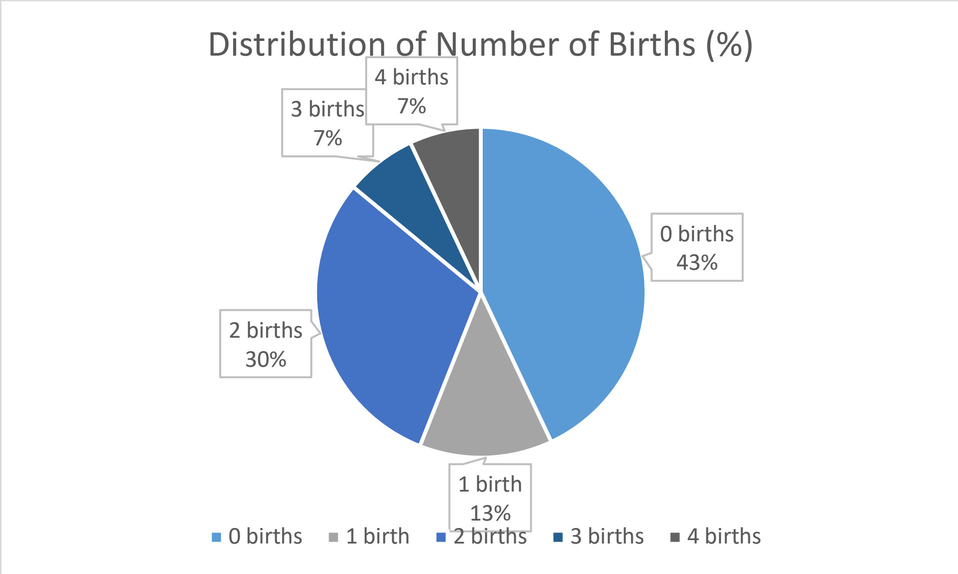


Figure 6.14- The distribution of the number of birth in %

Age at 1st Birth

All individuals who had given birth provided information on their age at 1st birth. The most common age category for the individuals in this sample for age at 1st birth was 2 (Figure 6.15).

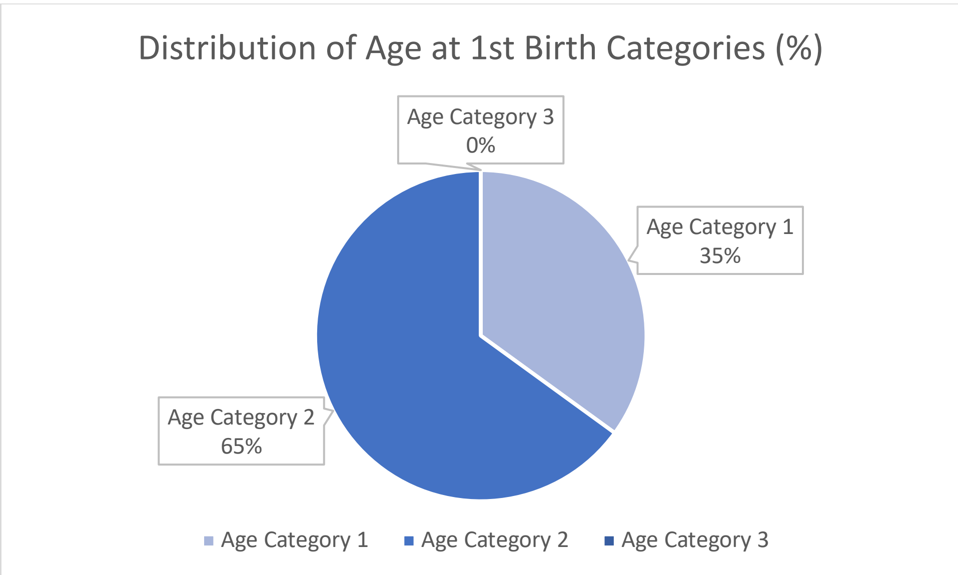


Figure 6.15- The distribution of age at 1st birth categories in %

The Kruskal-Wallis test showed that there was no significant difference in age at 1st birth between the grades (χ^2=0.601, df=1, p=0.438). It also showed that there was no significant difference in the occurrence levels of PAS between age at 1st birth (χ^2= 1.682, df=1, p=0.195). The Spearman Rank test showed that there was also no correlation between this variable and grades (p=0.064, r_s= 0.673) or occurrence levels of PAS (p=0.786, r_s=-0.041).

Caesareans

There was one individual that had previously had a child but did not provide information on whether they had had a caesarean. Of the parous females, the majority had no history of caesareans (Figure 6.16).

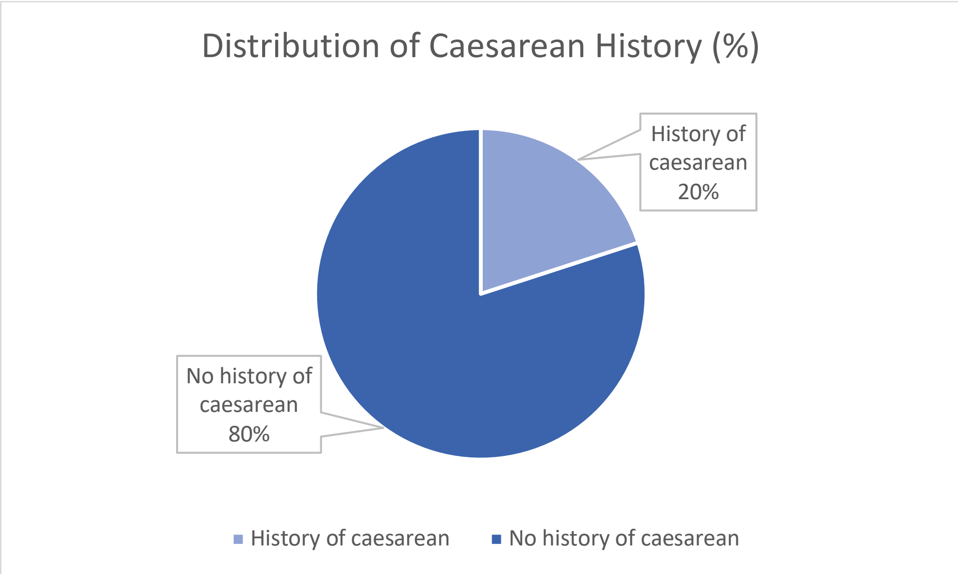


Figure 6.16- The distribution of caesarean history in %

The Kruskal-Wallis test showed that there was no significant difference in caesarean history between the grades (χ^2=3.164, df=1, p=0.075). It also showed that there was no significant difference in the occurrence levels of PAS between caesarean History (χ^2= 0.429, df=1, p=0.513). The Spearman Rank test showed that there was also no correlation between this variable and grades (p=0.131, r_s= 0.226) or occurrence levels of PAS (p=0.036, r_s=0.812).

6.4- Discussion

The study shows the viability of using CT Scans to examine PAS. All the scans were able to be rendered successfully and an assessment of the PAS grade was made. Suggesting that the grading system can be used on medical imaging and not solely skeletal samples. This is a valuable asset for a new method as there is a trend in forensic anthropology and bioarchaeology towards the use of virtual techniques. Although, as will be discussed in section 6.4.1, further research is needed to assess the accuracy of the method between physical and digital samples.

For the majority of the variables studied there was found to be no significant difference or correlation between them and the grades of the PAS. However, there were two exceptions to this: the number of pregnancies and the number of births. For both there was a weak positive correlation between the variables and grades, meaning that individuals with more pregnancies/births were more likely to have higher grades. However, there was no correlation between either of these variables and the presence of a PAS. The number of pregnancies (rs= 0.387) has a slightly higher correlation than the number of births (rs= 0.317) however the difference was minor. Although the correlation is weak and the sample size is relatively small, these results provided an interesting question about the relationship between parity and the preauricular sulcus. The results may suggest that giving birth multiple times has an effect on bone remodelling of the PAS. Chapter 7 (section 7.4.3) will also examine the effect of parity status on the trait. However, in that section parity will be treated as a binary answer (either has given birth or has not given birth). The differences between these two methods for categorising parity status will be discussed in section 8.7.

There were two females in this sample that had had a history of pregnancy but no births which is the reason for the slight difference in the two variables results. No information was provided about the details of these pregnancies, it is unknown to the author how far through the pregnancies they progressed and whether they were ended due to termination or miscarriage. In future studies, when looking at the differences between the number of pregnancies and the number of births, it may be beneficial to know these details. If the excess weight-bearing strain on the ligaments during pregnancy is a cause of changes to the PAS (Ashworth, 1976), then the further a pregnancy progressed before miscarriage the more bone remodelling it would cause.

Although the number of pregnancies/births appeared to have a significant effect on the morphology of the PAS, neither age at 1st birth or caesarean history did. These results are interesting as a positive result may have provided insight into the variation in PAS seen between parous females. However, the results suggest that neither the delivery method or age cause alteration to the trait. Although this could be due to a relatively small range of data concerning age and caesarean with the majority of females in this sample giving birth their first time aged 25-40 without a caesarean section.

Of the non-parity information variables that did not appear to have a significant effect on PAS grades or presence (BMI, body shape, tobacco consumption, alcohol consumption, activity level, diet), the most interesting results are BMI and body shape. The lack of relationship between PAS presence and grades and these variables seems to disagree with previous studies (Adams Holt, 1976; Snodgrass and Galloway, 2003 and Maass, 2012) that all found that body mass has a significant effect on the PAS. In the previous research, it was found that individuals with a higher body mass were more likely to have scarring than those with a lower BMI. However, the results of the present study did not find this, showing instead that body mass and size has no effect on the PAS. This difference in results could be due to different sample sizes and ranges of body mass examined.

6.4.1 Limitations

There are some limitations to this pilot study that could be improved upon with further research. Firstly the sample size (n=71) is relatively small. This was due to this sample being used as a pilot project to see if the assessment of PAS morphology could be carried out on CT Scans. In future research, this sample could be expanded on with either the 1,167 other individuals in this whole collection or other CT Scans collections. This could provide more information about the different variables relationships to the PAS. However, these results suggest that the majority of them do not have an effect.

This sample was the only one within the project that examined digital rather than physical specimens. No method error was carried out to see the differences in the accuracy of grading between these two types of specimens. This was due to the author not having access to any collections where a CT image of a specimen and the physical specimen itself could be examined. When studying the variation in physical and digital craniometrics Lee and Gerdau-Radonic (2020) found that there was an excellent statistical agreement between the two when compared to the reference value. However, they highlighted the range of inter-observer error that occurred and stated that different levels of data processing across digital techniques could drastically affect the results. Overall they concluded that digital methods were useful anthropological tools but highlighted the need for further research and examination into the variation between physical and digital techniques is needed. In future, it would be beneficial to the current research to test the grading system on the same specimens in both physical and digital formats. This additional testing could lead to a better understanding of the differences that may occur and test the accuracy of the method across different collections.

Many of the categories used in this study such as diet and body shape are very subjective. What one person may consider as a 'good' diet may not be when compared with professional/medical advice. Furthermore classifying it solely as 'good' 'average' and 'poor' gives no information about the nutritional value of the diets that are being eaten. For the definitions within the category of body shape, there is again a large amount of subjectivity as no actual measurements of fat distributions around the body were taken. However, the author had to use the categories and classification provided by Dr Truesdell. In future studies, it may be beneficial to use more scientifically quantifiable categories for both diet and body shape. For Tobacco Consumption the answers were narrowed by the author to make them binary (had a history of smoking or did not have a history of smoking). This was done as the original categories had a much broader set of answers, which included how many cigarettes people smoked and when they had smoked. However, with a small sample size (n=75) having such a wide range of categories meant that there were only a few specimens in each category, sometimes only one. Therefore to get meaningful statistical results the binary categories were created. Upon reflection, it is possible that this category was narrowed too much, in treating Tobacco Consumption as binary. Instead, a range of categories more similar to Alcohol Consumption would have been appropriate. Studies have shown that questionnaires are not always the most reliable indicator for some of the variables. Shepard (2003) found that data from questionnaires regarding physical activity had limited reliability when compared with laboratory measures of activity. Although, he recognised that the validity of questionnaires varied and that in some cases it was the best way to collect the data. The categories used in this pilot project were not designed for this research. As mentioned above, they were created specifically for a different Doctoral thesis (Truesdell, 2016). Although those categories may have fitted well for her thesis it is probable that they were not all accurate enough for the current study.

Finally, as stated in the Introduction (6.1) to this chapter and previous chapter 2 and 5, a study by Maass (2012) suggested that the most reliable predictor of PAS presence and morphology was both body mass and pelvic dimensions. This pilot study only looked at body mass, in the form of BMI, but no pelvic measurements. Despite BMI appearing to have no effect on PAS presence or morphology it may be beneficial in future studies to look at both these variables together.

7- Results for Preauricular Sulcus Grading System

7.1- Introduction

The following chapter shows the results for solely the preauricular sulcus grading system data, that is the main subject of this study. This results chapter will first show the inter-and-intra Observer error results (7.2). The order for the results of the main results will be; Results without parity information (7.3), Results with parity information (7.4), Results focussing on Age (7.5), Results focussing on Ancestry (7.6) and Results focussing on Location (7.7).

7.2- Inter-and-Intra-observer Error

For this study, the inter-and-intra-observer errors were examined using Cohen's Kappa Statistic. Table 7.1 shows the breakdown for the interpretation of Kappa as stated by Landis and Koch, 1977. The statistical programme SPSS (IBM Corp. 2012) was used to analyse all the data.

Table 7.1- Table showing the different levels of agreement represented by Cohen's Kappa Statistic (Landis and Koch, 1977)

Kappa Statistic	Strength of Agreement
<0.00	Poor
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost Perfect

The samples examined (n=30) were from St Owens housed at Liverpool John Moores University. No measurements were taken as part of the observer error, only the grades of the sulcus were included as the grading system is the main focus of this research. For this test *os coxae* from both sides of the skeleton were used.

For the Intra-observer error, the samples were re-examined three months after the first examination. The results showed an almost perfect agreement between the two sets of results, k= 0.917, p<.0001.

For the Inter-observer error, five independent observers were used, these observers were students attending a range of course at Liverpool John Moores University. All the students had some level of experience with human remains but not specifically with the *os coxae* or the preauricular sulcus. Each student was given the same 30 samples for one observation each, they were also given a description and photos of the grading system, similar to the ones in Chapter 4. Appendix 2 shows the information sheet given to the students and the data collection form.

The Forensic Anthropology BSc student showed a moderate level of agreement, k= 0.500, p<.0001.

The Forensic Science BSc student also showed a moderate level of agreement, k= 0.458, p<.0001.

The Bioarchaeology MSc student showed a fair level of agreement, k= 0.375, p<.0001.

The Forensic Science MSc student also showed a fair level of agreement, k= 0.292, p<.0001.

The Forensic Anthropology MSc student also showed a fair level of agreement, k= 0.375, p<.0001.

The data recorded by the observers can be found in Appendix 8. Appendix 9 shows the statistical output tables for the Intra-and-Inter-observer error. This chapter showed all the results for the research that made up the main body of this study. All the results from this chapter will be discussed in detail in the Discussion alongside the result from the pilot studies (Chapter 8).

7.3- Results without Parity Information

For this section of the chapter, two main hypotheses will be examined. The first hypothesis concerns the occurrence of the preauricular sulcus and the second the effect of sex of the grades of the PAS.

$1H_0$- There is no difference in the frequency of occurrence of preauricular sulcus in male and female human skeletons

$1H_1$- There is a difference in the frequency of occurrence of preauricular sulcus in male and female human skeletons

This hypothesis was tested using all the available and appropriate skeletons from all six samples with both male and female data.

The second hypothesis used the grading system that was developed for this project and looked at the effect of sex on the grades.

$2H_0$- Sex of the individual has no significant effect on the morphology of the preauricular sulcus in human skeletons.

$2H_1$- Sex of the individual has a significant effect on the morphology of the preauricular sulcus in human skeletons.

Appendix 10 shows tables with the grades within age categories and sex for all samples without parity information. The data recorded by the author for all samples without parity information can be found in Appendix 11. Appendix 12 shows the SPSS (IBM Corp. 2012) output tables for the statistical tests performed without parity information. Section 4.5 explains the age categories chosen for this research.

7.3.1- Poulton

For this sample, 94 specimens were examined. The majority (n=88) were left *os coxae* with the rest substituted for right. There was a 50% (n=47) split of female and male samples. Of the 94 specimens, 70 had a preauricular sulcus; 23 had grade 1, 20 had grade 2, 19 had grade 3 and eight had grade 4. The frequency of preauricular sulcus in males and females is presented in Figure 7.1, while Figure 7.2 shows the distribution of each grade of PAS for females and males. Table 7.2 shows the age categories of the samples.

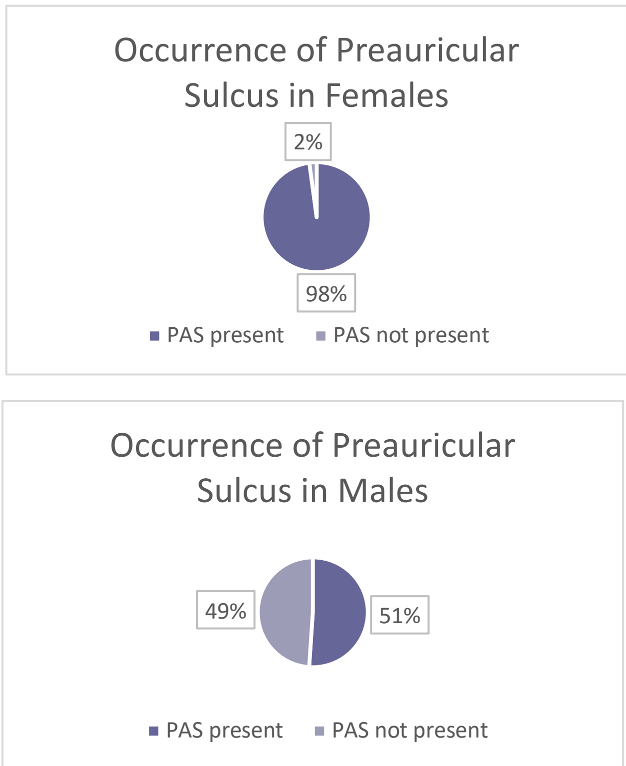


Figure 7.1- Frequency of occurrence rates of PAS in females and males in Poulton

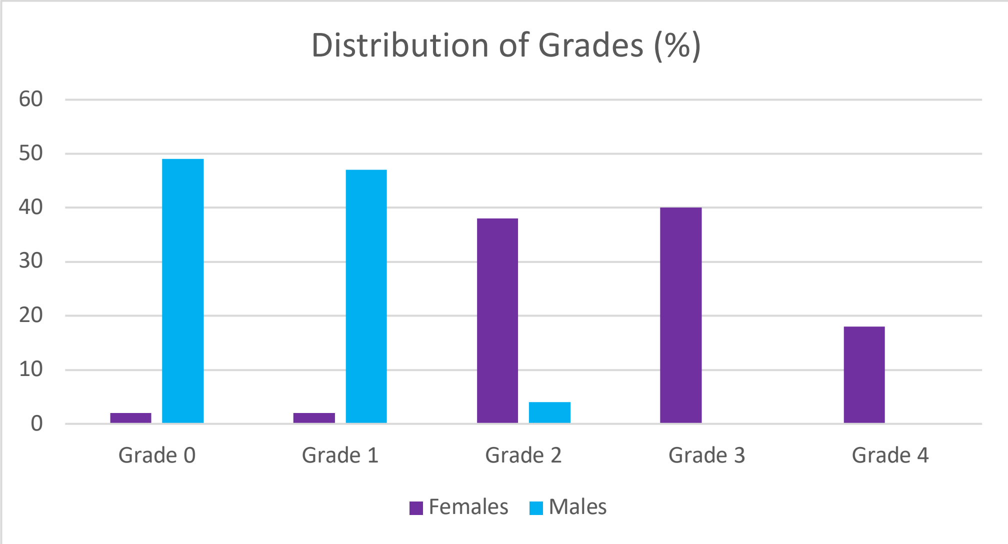


Figure 7.2- Distribution of grades between females and males in Poulton

Table 7.2- The Age categories for both male and females in Poulton

	Age Category 1 (18-25 yrs)	Age Category 2 (25-40 yrs)	Age Category 3 (40+ yrs)
Females	6	19	22
Males	4	22	21

The methods used to establish both the sex and age of the individuals were discussed in sections 4.4 and 4.5 respectively along with a description of the age categories. First, a Shapiro-Wilk test was carried out to analyse whether the data were normally distributed. The test showed that it was not as the p-value was smaller than 0.05 ($p<0.001$ for all variables) (Dytham, 2011). Next, a Mann Whitney U test was performed to examine whether there was a significant difference between sex and grade and presence of the sulcus. It was found that there was a significant difference for both grade ($U=66.5$, $p<0.001$) and presence ($U=587.5$, $p<0.001$). It showed that there was no significant difference between side ($U= 1104.5$, $p= 1.000$) and age ($U=587.5$, $p= 0.970$). A Kruskal-Wallis test was then run. It showed the same results for side, age, PAS presence and grade as the Mann Whitney U test. It also showed that for the variables of maximum length ($\chi^2= 22.434$, df= 1, $p<0.001$) and maximum width ($\chi^2=35.592$, df=1, $p<0.001$) there was a statistically significant difference between males and females.

A Spearman's rank test was run to examine the correlation between variables. The test showed that side and age has no significant correlation with any of the other variables. However, sex has a significant correlation between all the other variables: presence, maximum length, maximum width, and grade. Sex has a moderate negative correlation (Dytham, 2011) with presence ($p<0.001$, $r_s= -0.537$) showing that as the sex changed from female to male PAS presence decreased. There was also a strong negative correlation between sex and maximum width ($p<0.001$, $r_s= -0.625$) and a moderate negative correlation between sex and maximum length (p<0.001, r_s= -0.497) showing that as sex changed from female to male maximum width and length decreased. Finally, there was a strong negative correlation between sex and grade (p<0.001, r_s= -0.835) showing that as sex changed from female to male the grades decreased.

7.3.2- St Owens

For St Owens, 65 specimens were examined. The 60 were left *os coxae* and five were right. The sex distribution was 49% (n=32) female and 51% (n=33) male. Of the 65 samples, 42 had a preauricular sulcus; 13 had grade 1, 15 had grade 2, 12 had grade 3 and two had grade 4. The frequency of preauricular sulcus in males and females is presented in Figure 7.3, while Figure 7.4 shows the distribution of each grade of PAS for females and males. Table 7.3 shows the age categories of the samples.

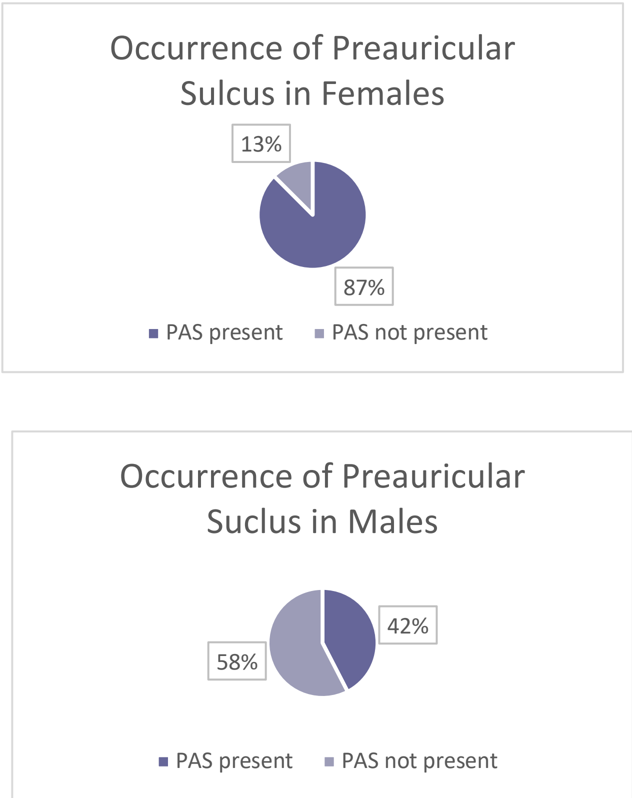


Figure 7.3- Frequency of occurrence rates of PAS in females and males in St Owens

That data was found to be not normally distributed with a Shapiro-Wilk test, as the p-value was smaller than 0.05 (p<0.001 for all variables) (Dytham, 2011). A Mann Whitney U test found that there was a significant difference for both grade (U=157, p<0.001) and presence (U=290, p<0.001) between the sexes. However, no significant difference was found between side (U= 497, p= 0.417) and age (U= 472, p= 0.394). A Kruskal-Wallis test showed the same outcome for side, age, PAS presence and grade as the Mann Whitney U test. For the additional variables of maximum length (χ^2= 12.46, df= 1, p<0.001) and maximum width (χ^2=16.648, df=1, p<0.001) there was a statistically significant difference between males and females.

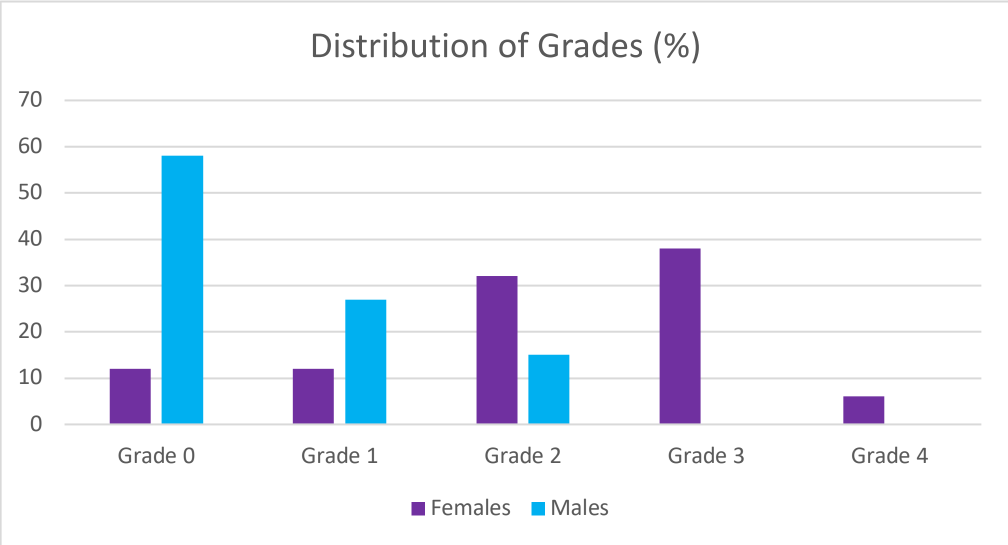


Figure 7.4- Distribution of grades between females and males in St Owens

Table 7.3 - The Age categories for both male and females in St Owens

	Age Category 1	Age Category 2	Age Category 3
Females	2	9	21
Males	5	9	19

A Spearman's rank test showed that side and age has no significant correlation with any of the other variables. For the variable of sex, there was a significant correlation with all the other variables: presence, maximum length, maximum width, and grade. Sex has a moderate negative correlation with presence (p<0.001, r_s= -0.471) showing that as the sex changed from female to male the PAS presence decreased. There was also a moderate negative correlation between sex and maximum width (p<0.001, r_s= -0.510) and a moderate negative correlation between sex and maximum length (p<0.001, r_s= -0.441) showing that maximum width and length decreased from male to female. Additionally, there was a strong negative correlation between sex and grade (p<0.001, r_s= -0.631) demonstrating that as sex changed from female to male the grades decreased.

7.3.3- Spitalfields

77 specimens were examined for this sample. Only two of the samples were right *os coxae* with the rest being left. Only females were examined in this collection. There was parity information available for all the individuals examined, and these will be discussed in section 7.4.2. This first section will focus on the data without the addition of parity. Of the 77 samples, 71 had a preauricular sulcus; nine had grade 1, 27 had grade 2, 22 had grade 3 and 13 had grade 4. The frequency of preauricular sulcus in the collection is presented in Figure 7.5, while Figure 7.6 shows the distribution of each grade of PAS. Table 7.4 shows the age categories of the samples.

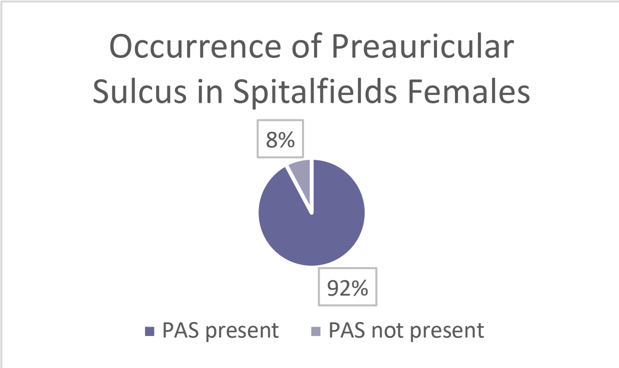


Figure 7.5- Frequency of occurrence rates of PAS in females in Spitalfields

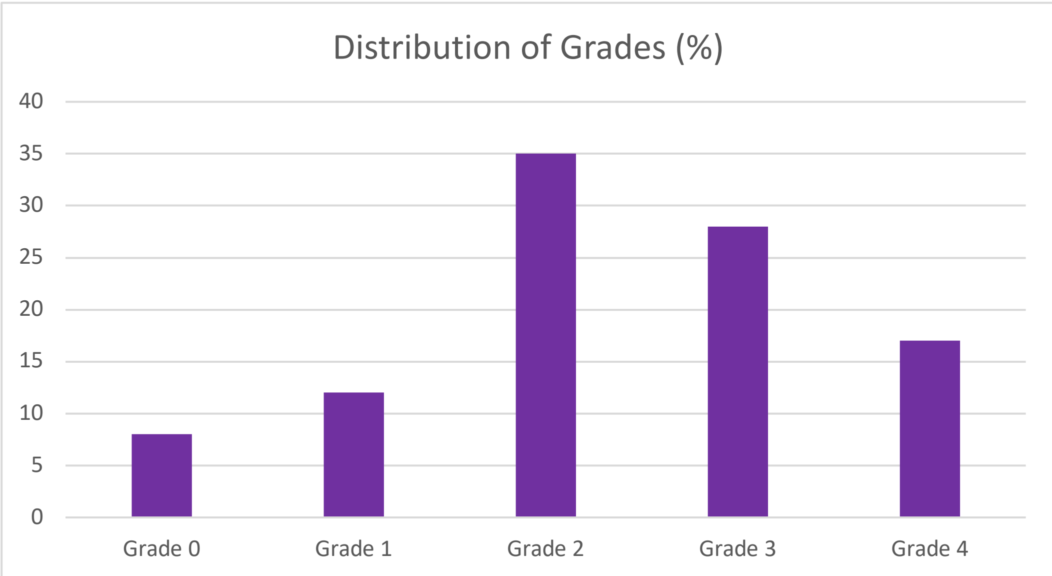


Figure 7.6- Distribution of grades in females in Spitalfields

Table 7.4- The Age categories for females in Spitalfields

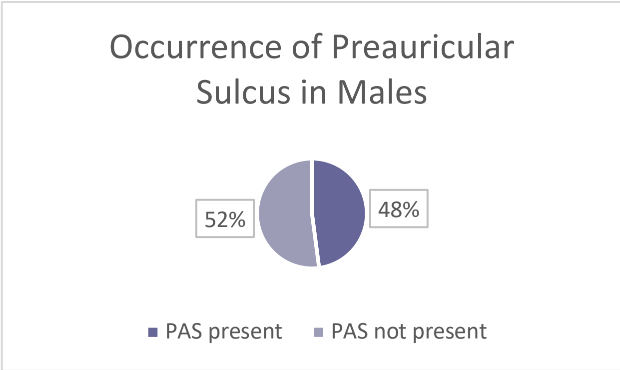
	Age Category 1	Age Category 2	Age Category 3
Females	5	13	59

For this sample, as there were only female individuals examined no statistical analysis between sex could be performed. This sample has been included here to show the levels of occurrence of preauricular sulcus and distributions of the grades in the females from this sample. Further results for parity will be shown in section 7.4.1.

7.3.4 - St Brides

For this sample, 190 specimens were examined. The majority (n=176) were left *os coxae* with the rest substituted for right. The majority, 52% (n=199) were male and 48% (n=91) were female. There were 70 female samples in the collection that parity information was available for, these will be discussed in section 7.5.2. Of the 190 samples, 136 had a preauricular sulcus; 46 had grade 1, 36 had grade 2, 40 had grade 3 and 17 had grade 4. The frequency of preauricular sulcus in males and females is presented in Figure 7.7, while Figure

7.8 shows the distribution of each grade of PAS for females and males. Table 7.5 shows the age categories of the samples.



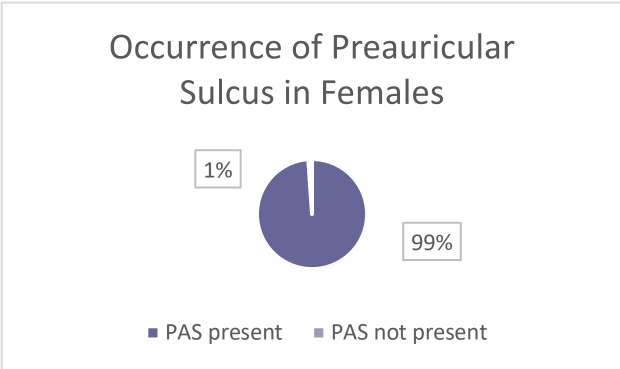


Figure 7.7- Frequency of occurrence rates of PAS in females and males in St Brides

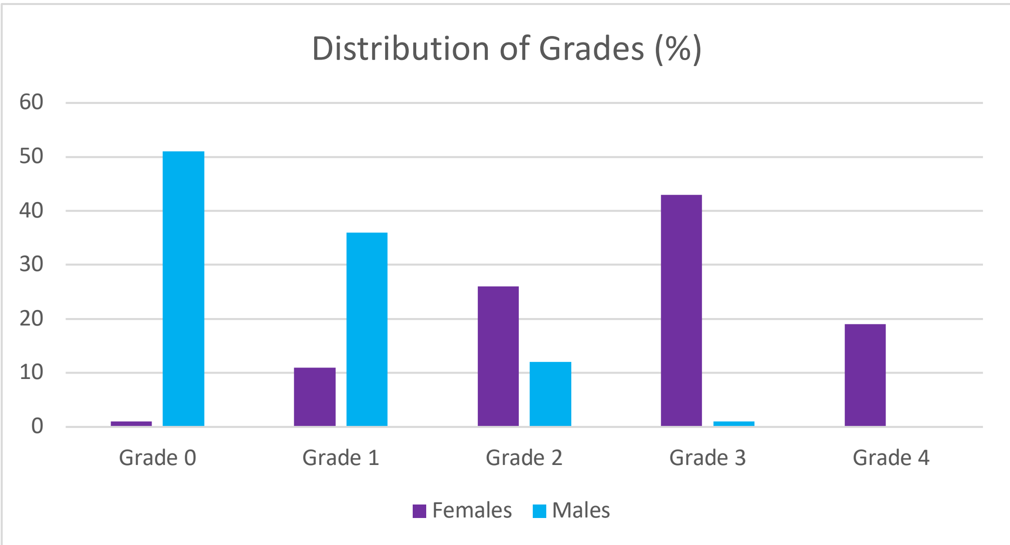


Figure 7.8- Distribution of grades between females and males in St Brides

Table 7.5- The Age categories for both male and females in St Brides

	Age Category 1	Age Category 2	Age Category 3
Females	6	21	64
Males	9	20	70

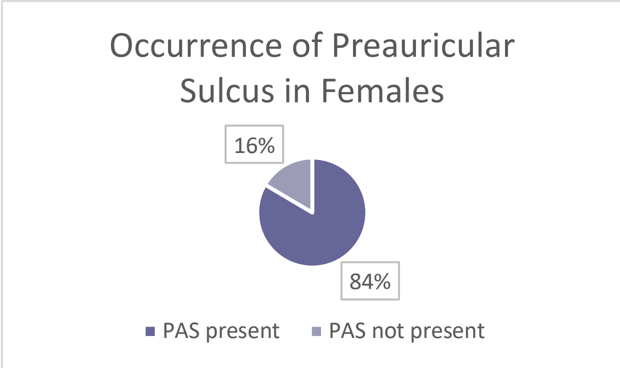
A Shapiro-Wilk test showed that the data was not normally distributed ($p<0.001$ for all variables) (Dytham, 2011). A Mann Whitney U test found that there was a significant difference between sexes for both grade (U=571.5, $p<0.001$) and presence (U=2279, $p<0.001$). There no significant difference between side (U= 4476.5, p= 0.870) and age (U= 4487, p= 0.954). A Kruskal-Wallis test agreed with the results for side, age, PAS presence and grade. It also showed that for the variables of maximum length (χ^2= 41.992, df= 1, $p<0.001$) and maximum width (χ^2=69.402, df=1, $p<0.001$) there was a statistically significant difference between sexes.

Side and age were found to have no significant correlation with any of the other variables with a Spearman ranks test. However, sex has a significant correlation between all the other variables: presence, maximum length, maximum width, and grade. Sex has a moderate negative correlation with presence ($p<0.001$, r_s= -0.557) showing PAS were more common in females. There was also a strong negative correlation between sex and maximum width ($p<0.001$, r_s= -0.606) and a moderate negative correlation between sex and maximum length ($p<0.001$, r_s= -0.471) showing that as sex changed from female to male maximum width and length decreased. There was also a strong negative correlation between sex and grade ($p<0.001$, r_s= -0.775) showing that grades higher grades were more common in females than males.

7.3.5- South African Blacks

No measurements of maximum length or width were taken for any of the sulci in this sample. As discussed in Section 3.4 the term South African Blacks was used in this thesis instead of Africa Ancestry as it is the official term used in the collection.
204 specimens were examined in this collection. All the specimens were left *os coxae.* The sex distribution was 48% (n=97) female and 52% (n=107) male. From samples, 115 had a preauricular sulcus; 38 had grade 1, 31 had grade 2, 25 had grade 3 and 21 had grade 4. The frequency of preauricular sulcus in males and females is presented in Figure 7.9, while Figure 7.10 shows the distribution of each grade of PAS for females and males. Table 7.6 shows the age categories of the samples.

The data for this sample was not normally distributed as a Shapiro-Wilk showed that the p-value was smaller than 0.05 ($p<0.001$ for all variables) (Dytham, 2011). To see whether there was a significant difference between sex and grade and presence of the sulcus a Mann Whitney U was used. As there was no maximum length and width taken for these samples, only the Mann Whitney U test was run, and not Kruskal Wallis, unlike the previous populations. It was found that there was a significant difference for both grade (U=1437.5, p<0.001) and presence (U=2505, p<0.001). It showed that there was no significant difference between age (U= 5112.5, p= 0.837).



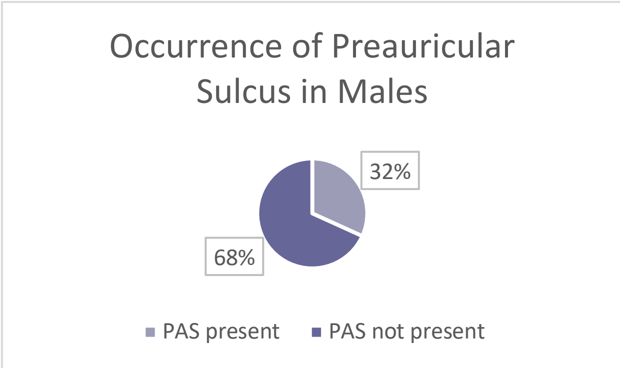


Figure 7.9- Frequency of occurrence rates of PAS in females and males in South African Blacks

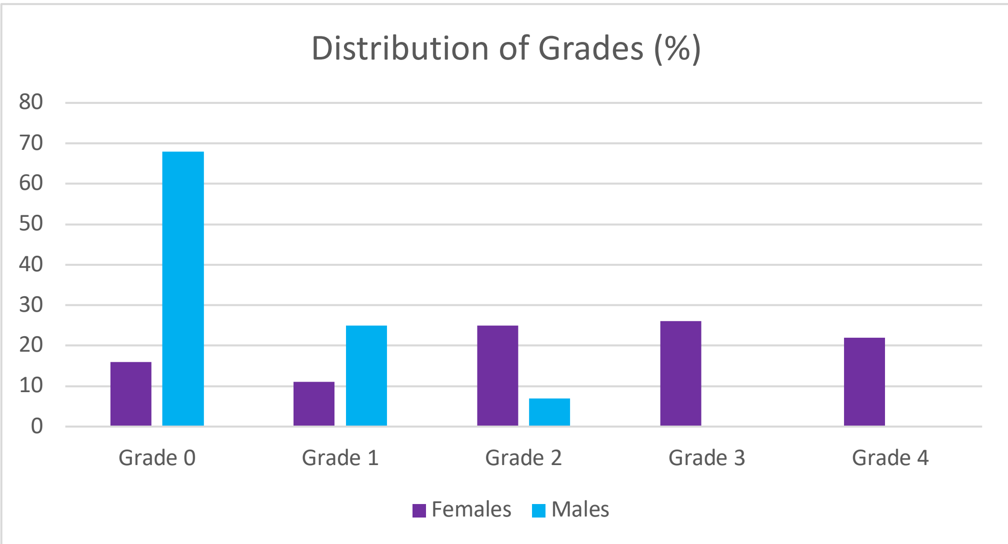


Figure 7.10- Distribution of grades between females and males in South African Blacks

Table 7.6- The Age categories for both male and females in South African Blacks

	Age Category 1	Age Category 2	Age Category 3
Females	9	37	51
Males	8	42	57

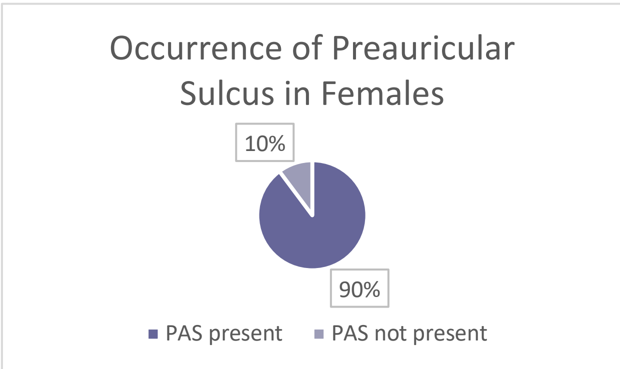
A Spearman's rank test showed that sex has a moderate negative correlation with presence (p<0.001, r_s= -0.521), showing that as the sex changed from female to male the PAS presence decreased. Sex additionally has a strong negative correlation with grade (p<0.001, r_s=

-0.658), showing that higher grades were more common in females. It also found that age has no significant correlation with any of the other variables.

7.3.6- South African Whites

No measurements of maximum length or width were taken for any of the sulci in this sample. As discussed in section 3.4 the term South African Whites was used in this thesis instead of Africa Ancestry as it is the official term used in the collection.

For this assemblage, 193 specimens were examined. They were all left *os coxae.* Of these individuals 51% (n=98) were females and 49% (n=95) were male. Of the 193 samples, 109 had a preauricular sulcus; 34 had grade 1, 31 had grade 2, 17 had grade 3 and 27 had grade 4. The frequency of preauricular sulcus in males and females is presented in Figure 7.11, while Figure 7.12 shows the distribution of each grade of PAS for females and males. Table 7.7 shows the age categories of the samples.



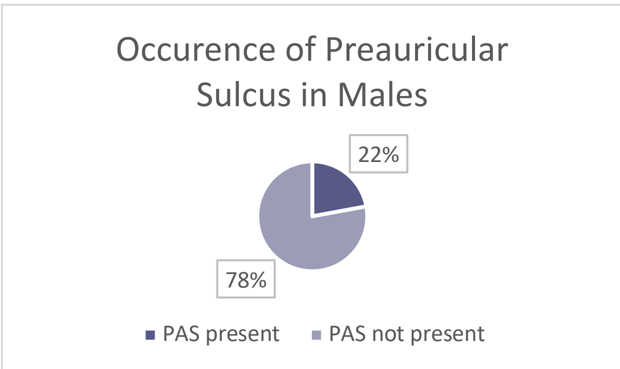


Figure 7.11- Frequency of occurrence rates of PAS in females and males in South African Whites

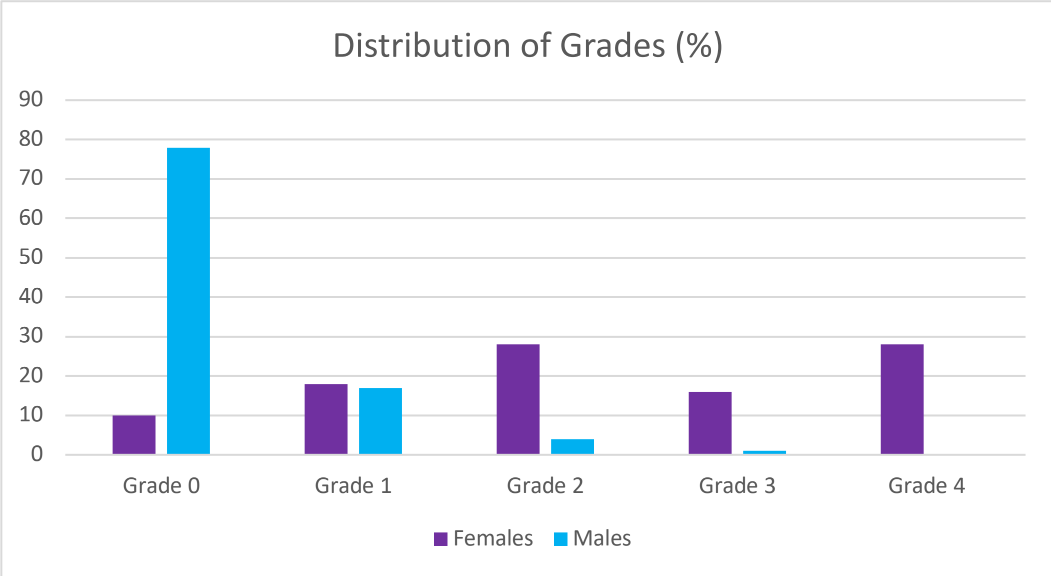


Figure 7.12- Distribution of grades between females and males in South African Whites

Table 7.7- The Age categories for both male and females in South African Whites

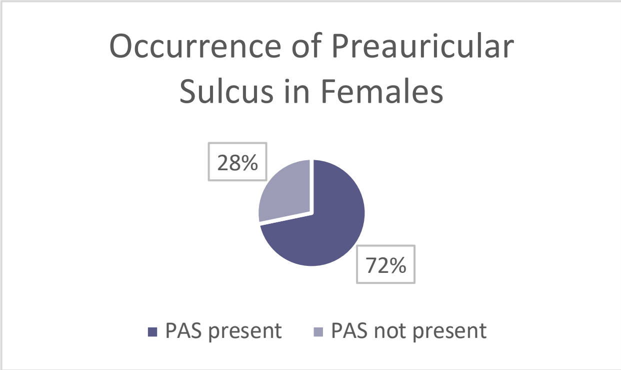
	Age Category 1	Age Category 2	Age Category 3
Females	1	0	97
Males	0	5	90

A Shapiro-Wilk test showed a p-value of <0.001 for all variables meaning that the data was not normally distributed (Dytham, 2011). A Mann Whitney U test found that there was a significant difference for both grade (U=903, p<0.001) and presence (U=1504, p<0.001) between sexes. However, there was no significant difference between age (U= 4460, p= 0.95).

A Spearman's rank test found none of the variables correlated with age. The variable of sex was found to be the most correlated with others. There was a strong negative correlation between sex and presence (p<0.001, r_s= -0.683) showing that PAS were more common in females than males. There was also a strong negative correlation between sex and grade (p<0.001, r_s= -0.734) showing that as sex changed from female to male the grades decreased.

7.3.7- CT Scans

For this collection, 71 specimens were examined. They were all left *os coxae.* Of these samples 65% (n=46) were female and 35% (n=25) were male. There were 92 females in the collection that parity information was available for, these will be discussed in section 7.3.3. Of the 71 samples, 44 had a preauricular sulcus; 23 had grade 1, 10 had grade 2, seven had grade 3 and four had grade 4. The frequency of preauricular sulcus in males and females is presented in Figure 7.13, while Figure 7.14 shows the distribution of each grade of PAS for females and males. Table 7.8 shows the age categories of the samples.



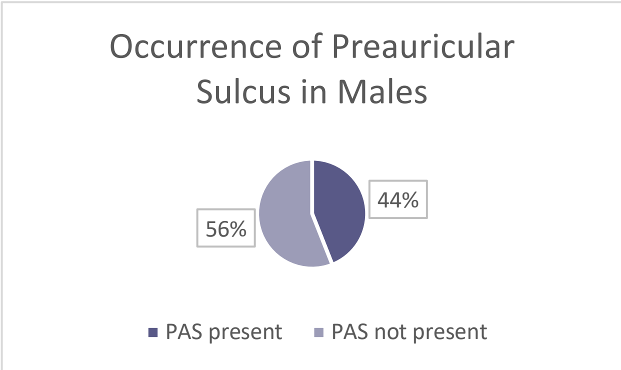


Figure 7.13- Frequency of occurrence rates of PAS in females and males in CT Scans

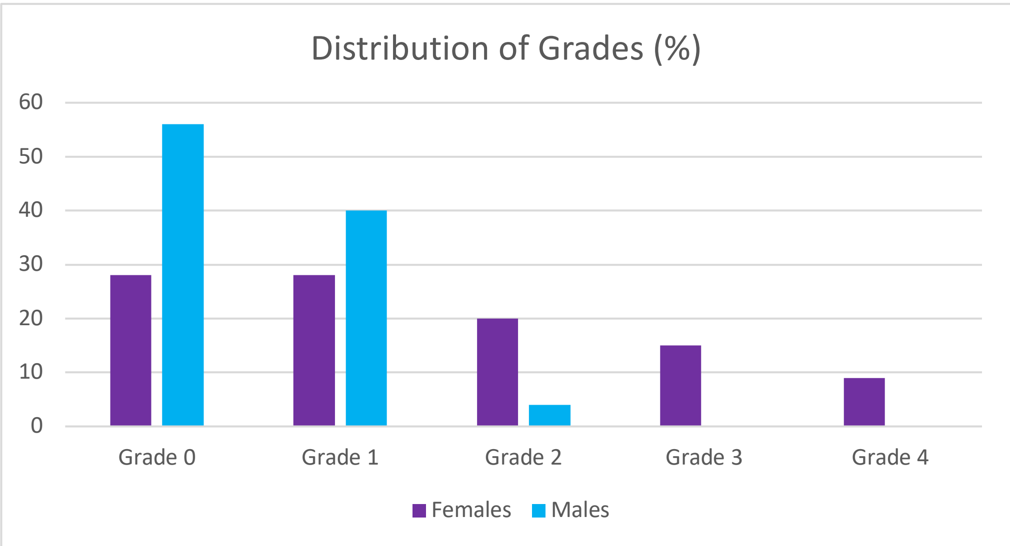


Figure 7.14- Distribution of grades between females and males in CT Scans

Table 7.8- The Age categories for both male and females in CT Scans

	Age Category 1	Age Category 2	Age Category 3
Females	5	9	32
Males	0	0	25

That data was found to be not normally distributed through the use of a Shapiro-Wilk test as the p values for all variables were <0.001 (Dytham, 2011). The relationship between sex and the other variables was then examined. There was found to be a significant difference between sex and grade (U=316.5, p= 0.001); presence (U=415.5, p= 0.022 and age (U= 400, p= 0.022).

A Spearman's rank showed that age has a moderate positive correlation with sex (p= 0.002, r_s= 0.363). Sex also has a significant correlation between both presence and grade. Sex has a weak negative correlation with presence (p<0.001, r_s= -0.273) showing that as the sex changed from female to male the PAS presence decreased. There was also a moderate negative correlation between sex and grade (p<0.001, r_s= -0.391) showing that males overall have lower grades than females.

7.4- Results with Parity Information

The next section will examine the samples where parity information was available. Out of the 7 collections, only 3 had either all or a portion with parity information. These were Spitalfields, St Brides and the CT scans. Section 3.6 details how the parity history of the individuals was established for each collection. There is a further hypothesis for this section, looking at the effect of the parity on the grading system.

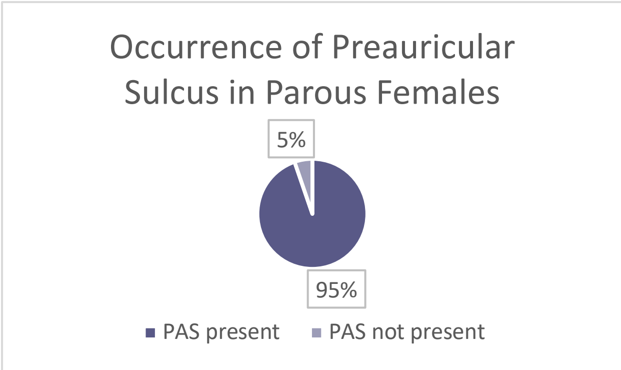
$3H_0$- Parity status has no significant effect of the occurrence and morphology of the preauricular sulcus in human skeletons.

$3H_1$- Parity status has a significant effect on the occurrence and morphology of the preauricular sulcus in human skeletons.

Appendix 13 shows tables with the grades within age categories and sex for all samples with parity information. The data recorded by the author for all samples with parity information can be found in Appendix 14. Appendix 15 shows the SPSS (IBM Corp. 2012) output tables for the statistical tests performed with parity information.

7.4.1- Spitalfields

For this collection, 77 individuals were examined. Of this sample 74% (n=57) were parous and 26% (n=20) were nulliparous. Of the 77 samples, 71 had a preauricular sulcus; nine had grade 1, 27 had grade 2, 22 had grade 3 and 13 had grade 4. The frequency of preauricular sulcus in parous and nulliparous females are presented in Figure 7.15, while Figure 7.16 shows the distribution of each grade of parous and nulliparous. Table 7.9 shows the age categories of the samples.



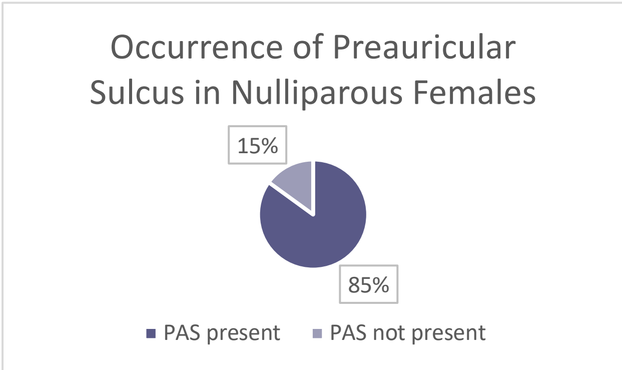


Figure 7.15- Frequency of occurrence rates of parous and nulliparous females in Spitalfields

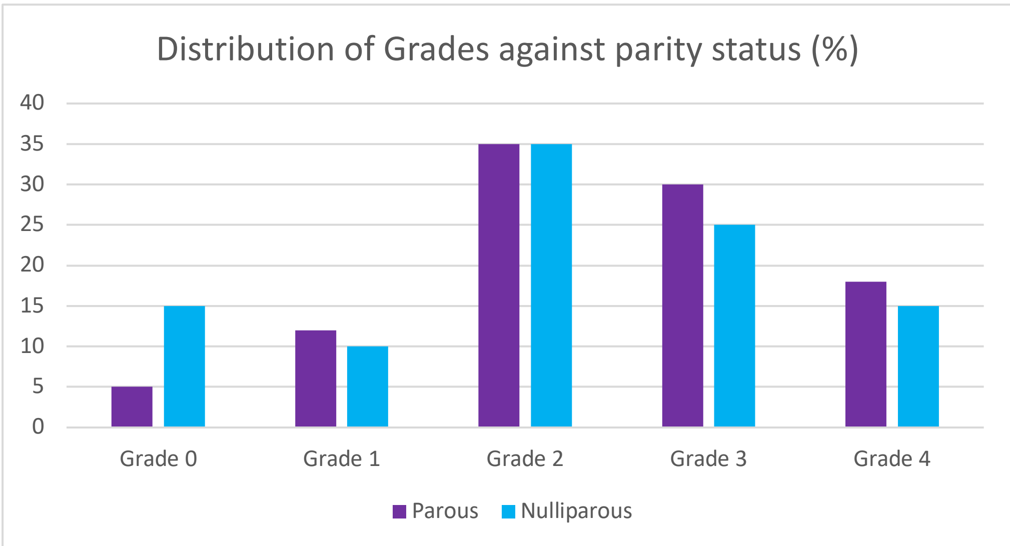


Figure 7.16- Distribution of grades between parous and nulliparous females in Spitalfields

Table 7.9- The Age categories for parous and nulliparous females in Spitalfields

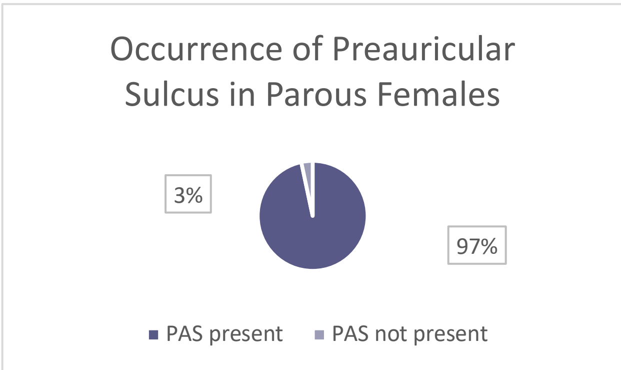
	Age Category 1	Age Category 2	Age Category 3
Parous	1	9	47
Nulliparous	4	4	12

A Shapiro-Wilk test showed that the data was not normally distributed (p<0.001 for all variables) (Dytham, 2011). Next, a Mann Whitney U test was performed to examine whether there was a significant difference between parity and grade and presence of the sulcus. It was found that there was no significant difference for grade (U=486, p=0.490), presence (U=484.5, p= 0.143), side (U= 522.5, p= 0.411) and age (U= 392.5, p= 0.016). A Kruskal-Wallis test demonstrated the same results for side, age, PAS presence and grade as the Mann Whitney U test. It additionally showed that for the variables of maximum length (χ^2= 0.696, df= 1, p= 0.404) and maximum width (χ^2=1.142, df=1, p= 0.485) there was no statistically significant difference between parous and nulliparous individuals.

A Spearman's rank test showed that side and age have no significant correlation with any of the other variables. Parity has no correlation with presence (p= 0.453, r_s= -0.87), grade (p= 0.585, r_s= -0.63), maximum length (p= 0.327, rs= -1.113) and maximum width (p= 0.471, r_s= -0.083).

7.4.2- St Brides

For this assemblage, 35 individuals were examined. All the specimens were left *os coxae.* Of these 86% (n=30) were parous and 14% (n=5) were nulliparous. Of the 35 samples, 34 had a preauricular sulcus; three had grade 1, 13 had grade 2, 15 had grade 3 and 3 had grade 4. The frequency of preauricular sulcus in parous and nulliparous females is presented in Figure 7.17, while Figure 7.18 shows the distribution of each grade of parous and nulliparous. Table 7.10 shows the age categories of the samples.



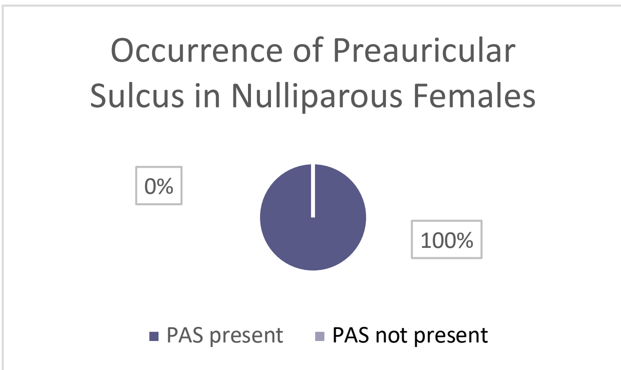


Figure 7.17- Frequency of occurrence rates of parous and nulliparous females in St Brides

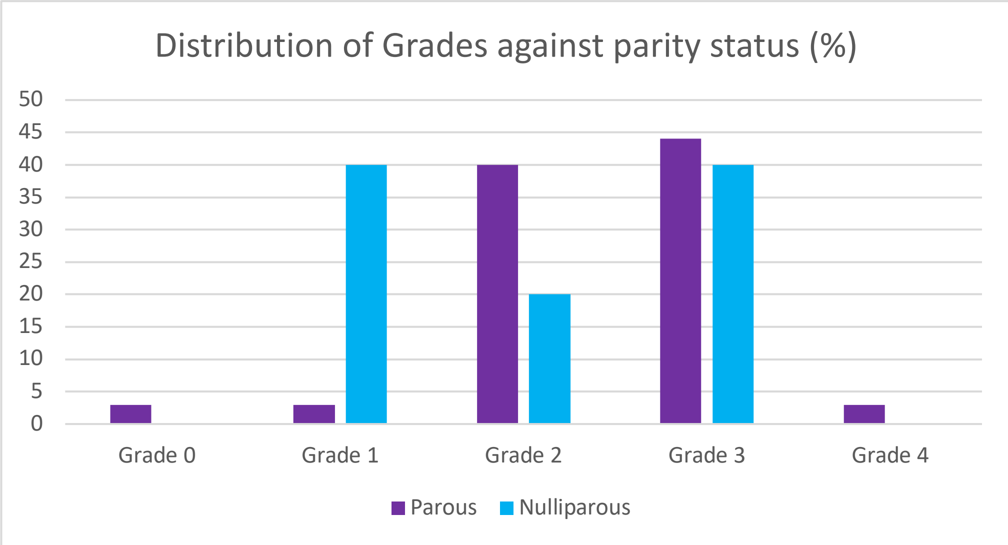


Figure 7.18- Distribution of grades between parous and nulliparous females in St Brides

Table 7.10- The Age categories for parous and nulliparous females in St Brides

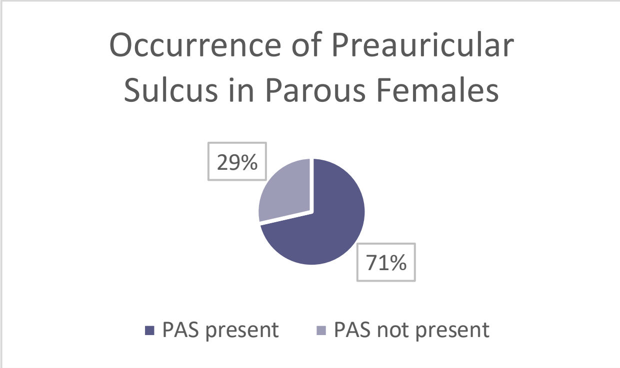
	Age Category 1	Age Category 2	Age Category 3
Parous	0	11	19
Nulliparous	4	1	0

According to a Shapiro-Wilk test, there was not a normal distribution to the data as the p-value was <0.001 for all variables (Dytham, 2011). A Mann Whitney U test found that there was no significant difference for grade (U=52, p=0.245) and presence (U=72.5, p= 0.683) between parity status. There was a statistical difference for age (U= 5.5, p<0.001). A Kruskal-Wallis test agreed with these results. It also showed that for the variables of maximum length (χ^2= 0.376, df= 1, p= 0.540) and maximum width (χ^2=0.376, df=1, p= 0.850) there was no statistically significant difference between parous and nulliparous individuals.

A Spearman's rank test was run to examine the correlation between variables. Parity has no correlation with presence (p= 0.689, r_s= 0.70), grade (p= 0.251, r_s= -0.199), maximum length (p= 0.548, r_s= 0.105) and maximum width (p= 0.854, r_s= 0.032).

7.4.3- CT Scans

For this assemblage, 46 specimens were examined. They were left *os coxae.* Of these 61% (n=28) were parous and 39% (n=18) were nulliparous. Of the 46 samples, 33 had a preauricular sulcus; 13 had grade 1, nine had grade 2, six had grade 3 and four had grade 4. The frequency of preauricular sulcus in parous and nulliparous females is presented in Figure 7.19, while Figure 7.20 shows the distribution of each grade of parous and nulliparous. Table 7.11 shows the age categories of the samples.



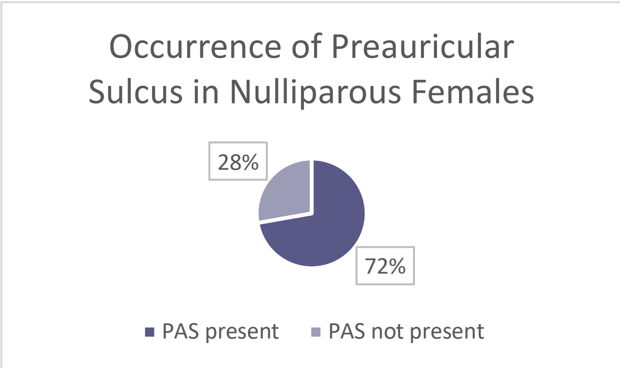


Figure 7.19- Frequency of occurrence rates of parous and nulliparous females in CT Scans

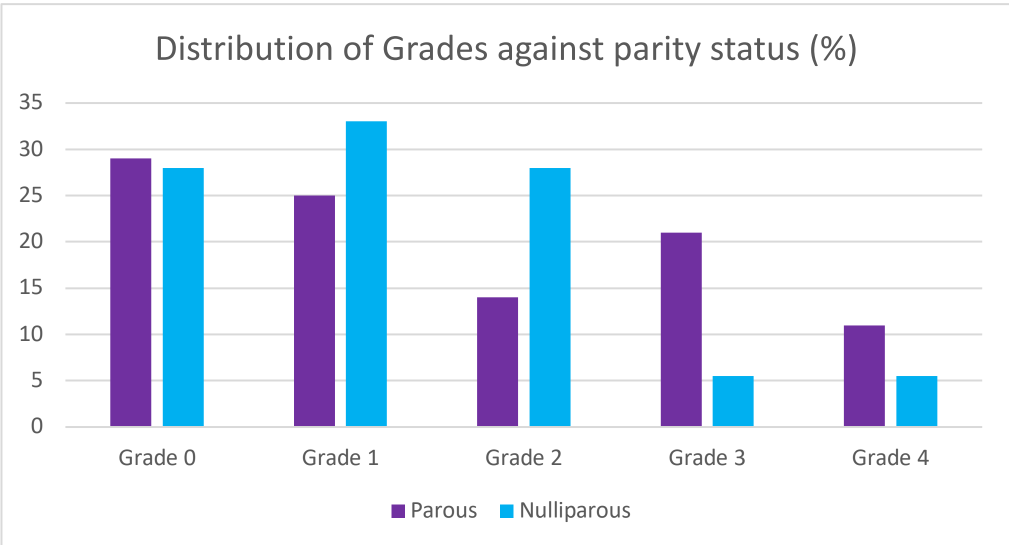


Figure 7.20- Distribution of grades between parous and nulliparous females in CT Scans

Table 7.11- The Age categories for parous and nulliparous females in CT Scans

	Age Category 1	Age Category 2	Age Category 3
Parous	0	5	23
Nulliparous	5	4	9

The data for this sample was also not normally distributed, this was again tested with a Shapiro-Wilk test and showed a result of $p<0.001$ for all variables (Dytham, 2011). A Mann Whitney U test found that there was no significant difference for grade (U=222.5, p=0.494) and presence (U=250, p= 1.000) between parous and nulliparous individuals. For the variable of age (U= 158.5, p= 0.009) there was also a significant difference. As there was no maximum length and width taken for these samples only the Mann Whitney U test was run. A Spearman's rank test was run to examine the correlation between variables. Parity has no correlation with presence ($p= 0.955$, $rs= 0.009$) and grade ($p= 0.500$, $rs= -0.102$).

7.5- Results Focusing on Age

For the previous samples it was mostly shown that there was no correlation between age and grades, however, this could be because there was a not a large distribution in the age range. Section 4.5 details the Age categories chosen to be used in this research. For all the samples the Age category 3 (40+ years) was the largest category by a big margin and Age category 1 (18-25 years) was the smallest with some samples having no Age category 1's for one of the sexes. This small range in the distribution of age could be a factor in why there is no significant correlation with grades. To test this theory all of the data from the British samples (Poulton, St Owens, St. Brides) were combined into one data set, Spitalfields was not included as only females were examined. This produced a sample of 349 preauricular sulci where the relationship between age and grade could be examined. There is a further hypothesis for this section, looking at the effect of the age on the grading system.

$4H_0$- Age has no significant effect on the occurrence and morphology of the preauricular sulcus in human skeletons.

$4H_1$- Age has a significant effect on the occurrence and morphology of the preauricular sulcus in human skeletons.

All the specimens for this sample were left *os coxae.* The distribution of the Age categories is shown in Figure 7.21, whilst Figure 7.22 shows the frequency of preauricular sulcus in the 3 different age categories. Finally, Figure 7.23 shows the distribution of the grades within the 3 categories.

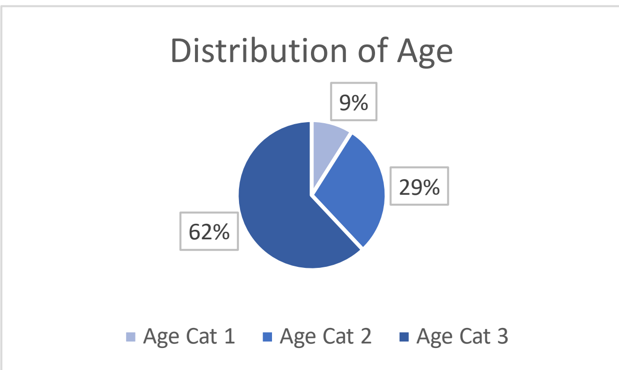
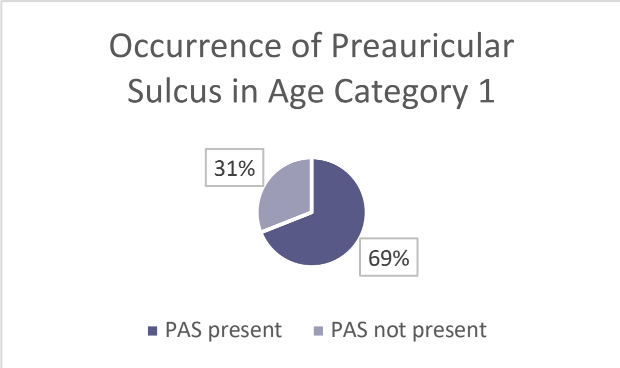
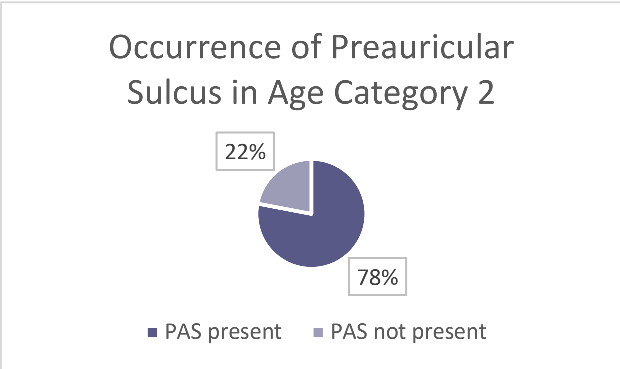


Figure 7.21- Distribution of the Age in the combined British sample





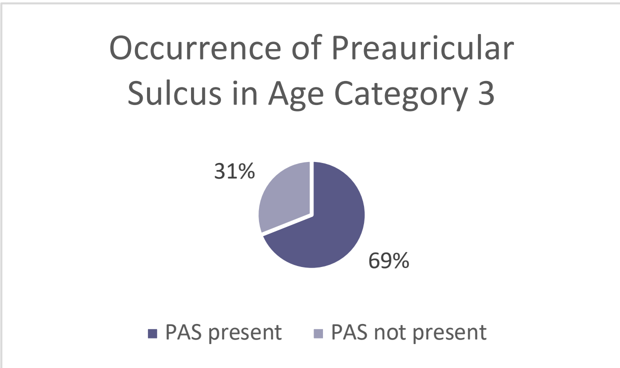


Figure 7.22- The frequency of occurrence rates in Age category 1, 2 and 3 in the combined British sample

A Shapiro-Wilk test was carried out to analyse whether the complied data were normally distributed. It was not as the p-value was smaller than 0.05 ($p<0.001$ for all variables) (Dytham, 2011). A Kruskal-Wallis showed that there was not a significant difference between the grades in the three Age categories ($\chi^2=2.226$, df=4, p= 0.694). Age showed no correlation with grades when a Spearman rank test was performed (p= 0.515, rs= -0.035). Appendix 16 shows the statistical output tables for the statistical tests performed.

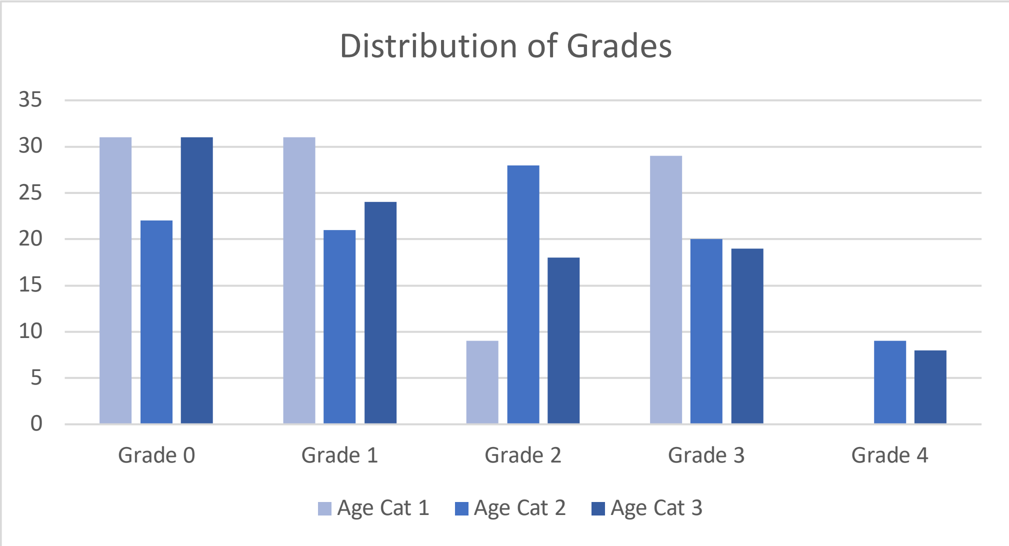


Figure 7.23- Distribution of grades between Age category 1, 2 and 3 in the combined British sample

7.6- Results Focusing on Ancestry

For the samples from South Africa, there was a split in ancestry between South African Blacks and South African Whites. Both samples showed that there was a strong negative correlation between sex and presence and sex and grade. The two samples were then compared with each other to examine whether ancestry has an effect on grade. The two were combined into one data set producing a sample of 397 preauricular sulci to be examined. There is a further hypothesis for this section, looking at the effect of the ancestry on the grading system.

$5H_0$- Ancestry has no significant effect on the occurrence and morphology of the preauricular sulcus in human skeletons.

$5H_1$-Ancestry has a significant effect on the occurrence and morphology of the preauricular sulcus in human skeletons.

All the specimens were left *os coxae.* The distribution of the ancestry is shown in Figure 5.24, whilst Figure 5.25 shows the frequency of preauricular sulcus in the sample. Finally, Figure 5.26 shows the distribution of the grades between the ancestries. The frequency of occurrence rates and distribution of grades for the separated South African Blacks and South African whites are shown in Figures 7.9- 7.12.

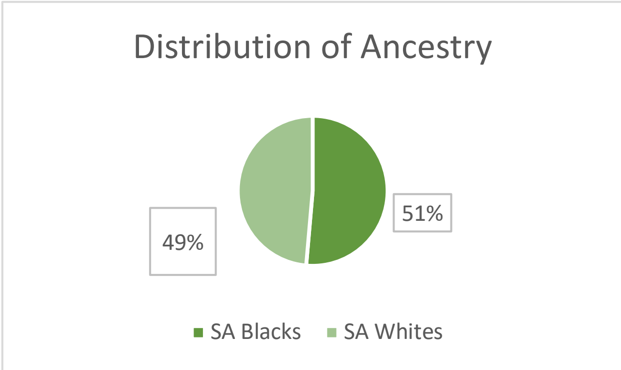


Figure 7.24- Distribution of the Ancestry in the combined South African sample

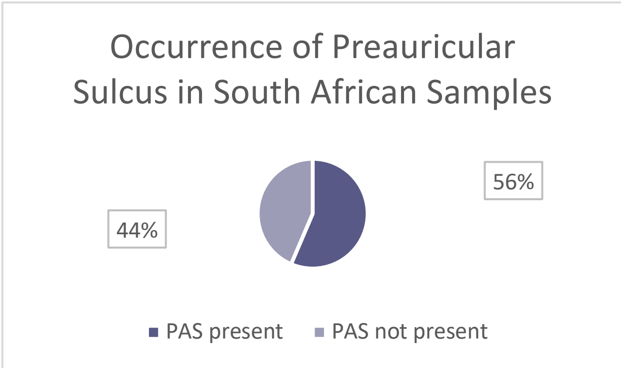


Figure 7.25- The frequency of occurrence rates in combined South African sample

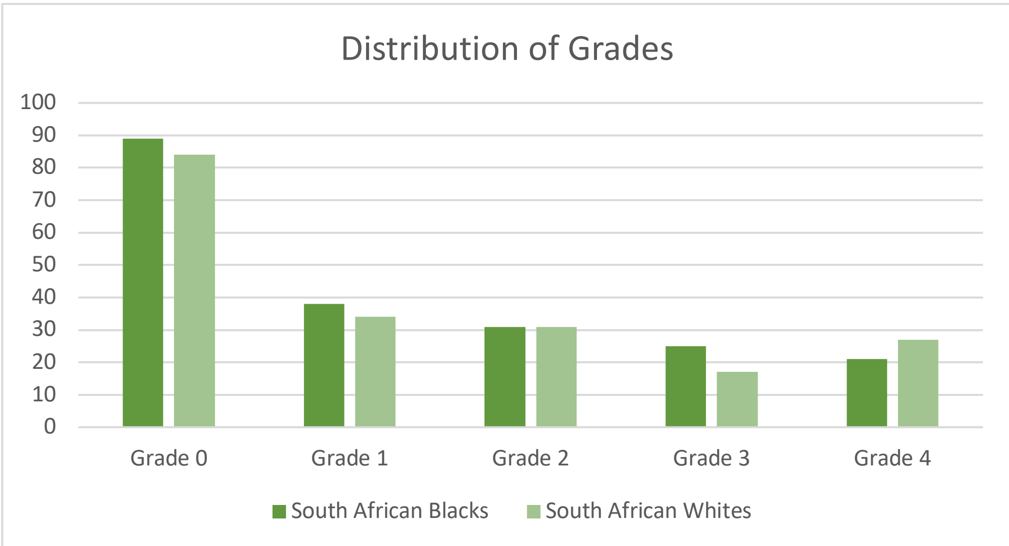


Figure 7.26- Distribution of grades between Ancestries in combined South African sample

The data was again not normally distributed when using a Shapiro-Wilk test ($p<0.001$ for all variables) (Dytham, 2011). A Kruskal-Wallis test was then run to examine if there was a significant difference between grades and the ancestry. It showed that there was not ($\chi^2=2.332$, df=4, p= 0.675). Appendix 17 shows the statistical output tables for the statistical tests performed.

7.7- Results Focusing on Location

The last comparison to be examined between samples was the effect of location on grade. This was performed by combining six of the samples into one set. The Spitalfields sample was not included as only females were examined, unlike the other samples where both sexes were. The maximum length and width measurements for the PAS were also not included as they were not taken for the South African samples. The samples were numbered as follows; Poulton-1, St Owens-2, St. Brides-3, South African Blacks-4, South African Whites-5 and CT Scans-6. This produced a sample of 816 preauricular sulci where the relationship between the location of the samples and grade could be examined. There is a further hypothesis for this section, looking at the effect of the location on the grading system.

$6H_0$- Sample location has no significant effect on the occurrence and morphology of the preauricular sulcus in human skeletons.

$6H_1$- Sample location has a significant effect on the occurrence and morphology of the preauricular sulcus in human skeletons.

The majority (n=791) were left *os coxae* with the rest substituted for right.

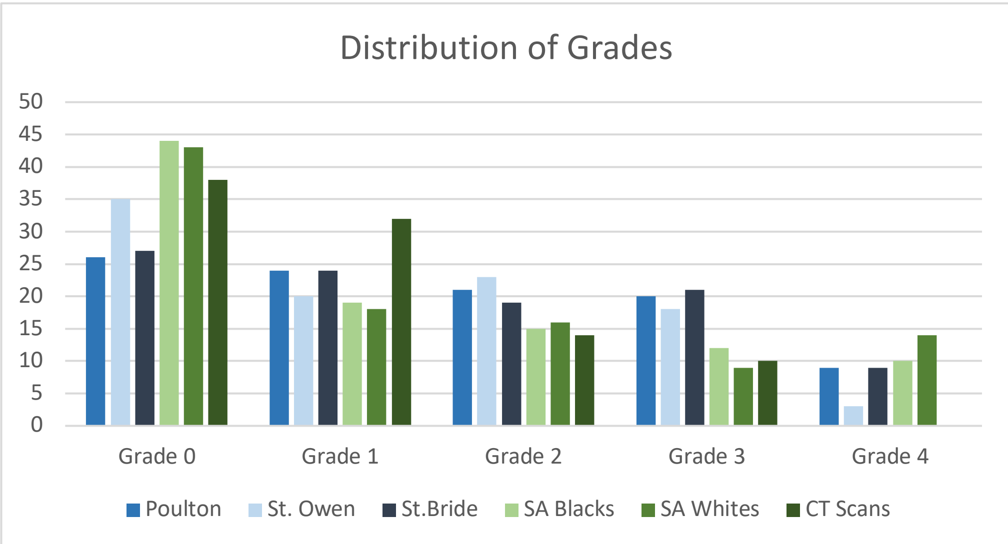


Figure 7.27- Distribution of grade percentages between the location of samples

A Shapiro-Wilk test demonstrated that there was not a normal distribution to the data ($p<0.001$ for all variables) (Dytham, 2011). A Kruskal-Wallis test showed that there was a significant difference for both presence ($\chi^2=21.190$, df=5, p=0.001) and grade ($\chi^2=15.575$, df=5, p=0.008) between the six locations. Appendix 18 shows the statistical output tables for the statistical tests performed.

7.8- Summary of Results

The results across the samples for PAS occurrence and grade distribution from section 7.3 and 7.4 have been summarised here. Section 7.3 for all samples showed that PAS occurs more in females than males (Tables 7.12 and 7.14). The correlation results for all six samples showed that there was a negative correlation between sex and the presence of a PAS, further demonstrating that PAS was more common in females than males (Table 7.13). Section 7.3 also demonstrated that PAS morphology was significantly different between the two sexes for all samples, this can be seen through the distribution of grades (Table 7.15). Section 7.3 further showed that for all the samples there was a correlation between sex and grades. The negative correlation demonstrates that higher grades are more common in females and that lower grades more common in males (Table 7.16). Section 7.4 demonstrates that there was no significant difference in PAS occurrence or distribution of grades between the three samples with parity information (Table 7.17, Table 7.18 and Table 7.19). All the results from this chapter will be discussed in Chapter 8.

Table 7.12- The PAS presence between sexes in the six samples

Samples	**PAS presence in females (%)**	**PAS presence in males (%)**
Poulton	98	51
St Owens	88	42
St Brides	99	48
South African Blacks	84	32
South African Whites	90	22
CT Scans	72	44

Table- 7.13- The correlation results for sex against PAS presence in the six samples

Samples	Poulton	St Owens	St Brides	South African Blacks	South African Whites	CT Scans
Correlation with presence	Moderate negative correlation (rs= -0.537)	Moderate negative correlation (rs= -0.471)	Moderate negative correlation (rs= -0.557)	Moderate negative correlation (rs= -0.521)	Strong negative correlation (rs= -0.683)	Weak negative correlation (rs= -0.273)

Table- 7.14- The PAS absence between sexes in the six samples

Samples	PAS absence in females (%)	PAS absence in males (%)
Poulton	2	49
St Owens	12	58
St Brides	1	52
South African Blacks	16	68
South African Whites	10	78
CT Scans	28	56

Table 7.15- The distribution of grades between sexes in the six samples

Samples	Grade 0 (%)	Grade 1 (%)	Grade 2 (%)	Grade 3 (%)	Grade 4 (%)
Poulton Females	2	2	38	40	18
Poulton Males	49	47	4	0	0
St Owens Females	12	12	32	38	6
St Owens Males	58	27	15	0	0
St Brides Females	1	11	26	43	19
St Brides Males	51	36	12	1	0
South African Black Females	16	11	25	26	22
South African Black Males	68	25	7	0	0
South African White Females	10	18	28	16	28
South African White Males	78	17	4	1	0
CT Scan Females	28	28	20	15	9
CT Scan Males	56	40	4	0	0

Table 7.16- The correlation results for sex against grades in all six samples

Samples	Poulton	St Owens	St Brides	South African Blacks	South African Whites	CT Scans
Correlation with grades	Strong negative correlation (rs= -0.835)	Strong negative correlation (rs= -0.631)	Strong negative correlation (rs= -0.775)	Strong negative correlation (rs= -0.658)	Strong negative correlation (rs= -0.734)	Moderate negative correlation (rs= -0.391)

Table 7.17- The PAS presence between parity in all three samples

Samples	**PAS presence in parous females (%)**	**PAS presence in nulliparous females (%)**
Spitalfields	95	85
St Brides	97	100
CT Scans	71	72

Table- 7.18- The PAS absence between parity in all three samples

Samples	**PAS absence in parous females (%)**	**PAS absence in nulliparous females (%)**
Spitalfields	5	15
St Brides	3	0
CT Scans	29	28

Table 7.19- The distribution of grades between parity in all three samples

Samples	**Grade 0 (%)**	**Grade 1 (%)**	**Grade 2 (%)**	**Grade 3 (%)**	**Grade 4 (%)**
Spitalfields Parous Females	5	12	35	30	18
Spitalfields Nulliparous Females	15	10	35	25	15
St Brides Parous Females	3	3	40	44	10
St Brides Nulliparous Females	0	40	20	40	0
CT Scan Parous Females	29	25	14	21	11
CT Scan Nulliparous Females	28	33	28	5.5	5.5

8- Discussion

8.1- Introduction

The overall aim of this project was to carry out a close examination of the preauricular sulcus and its relationship to sexual dimorphism and parity status. This was achieved through the creation and implementation of a new grading system to better describe the morphology of the preauricular sulcus. The new method was tested using skeletons from six collections: Poulton, St Owens, Christ Church Spitalfields, St Brides, Pretoria Bone Collection and Raymond A. Dart Collection. In addition, a sample of British CT Scans from living subjects was analysed (details of the collections can be found in Chapter 3).

Research Questions:

- Is there a difference in the frequency of occurrence of preauricular sulcus in males and females in human skeletons?
- Does the sex of an individual have a significant effect on the morphology of the preauricular sulcus?
- Does parity status have a significant effect on the occurrence and morphology of the preauricular sulcus?
- Does age, ancestry or location have a significant effect on the levels of occurrence and morphology of the preauricular sulcus?
- Do the dimensions of the pelvis have a significant effect on the levels of occurrence and morphology of the preauricular sulcus?
- Do certain lifestyle and biological variables have a significant effect on levels of occurrence and morphology of the preauricular sulcus observed using CT Scans?

8.2- Occurrence Levels of Preauricular Sulcus Between Sexes

Question 1: Is there a difference in the frequency of occurrence of preauricular sulcus in males and females in human skeletons?

The initial objective to be tested in this study was if there is a difference in the frequency of occurrence of preauricular sulcus in male and female human skeletons. This was tested by solely looking at the presence of the PAS, not by applying the grading system and instead simply using a binary system of absent or present. The results showed that the null hypothesis should be rejected. For all six of the samples where both males and females were analysed (Spitalfields was not included as only females were examined), there is a significant difference in the presence of a PAS between the sexes (sections 7.3). In all the samples, although PAS were found in both sexes they are more common in females than males. The levels of occurrence of the PAS for the females ranged from 72-98% across the samples and 22-51% for the males (Table 7.12).

The study shows that PAS are found in both females and males which was expected. Similar results have been reported by Derry (1909), Kelley (1979), Cox (1989) and Maass (2012) who all found preauricular sulci occurred more frequently in females than males. As mentioned in Chapter 2 one of the possible reasons for the high level of PAS in females has been suggested to be pregnancy and parturition (Angel, 1969; Houghton, 1975) which will be discussed further in section 8.4. However, the occurrence of PAS in males in both the present and previous studies shows that parturition and pregnancy can not be the only cause of PAS development. Houghton (1975) concluded that sulci developed in both males and females as a natural product of bone remodelling at the ligament attachment site but suggested that the morphology was different between the sexes, this will be discussed further in section 8.3. Angel (1969) suggested that scars of parturition occurred in males as a result of either disease or trauma. Although this could be possible in some individuals, the relatively high levels of occurrence in males in the present study suggest this is unlikely to be the cause. If this was the reason for PAS in males, that would mean that in the Poulton sample the majority (51%) had some kind of trauma/disease affecting the *os coxae*. This seems improbable especially considering that all the skeletal remains used in this study were screened for observable signs of trauma or disease to the pelvis and only healthy specimens were included. Although in all the samples PAS are more common in females than males, there is variation in the frequency. The difference in levels of occurrence between samples suggests that other factors may affect the development of the trait, including parity status, age, ancestry, location of the samples, pelvic shape and other biographical differences. These possible variables will be discussed in sections 8.4-8.7. The findings confirm that any factor that does cause the development of a PAS must occur more frequently in females, considering that there is consistently a significant difference between sexes in all samples. The results for all samples showed that there is a negative correlation between presence and sex, meaning that PAS are more common in females than males (Table 7.14).

In agreement with previous studies (Derry, 1909; Dunlap, 1981; Maass and Friedling, 2016), this research found that some females did not have a PAS, ranging from 2-28% (Table 7.13). The absence of PAS in a significant portion of females further demonstrates that sex can not be the only factor in PAS development. The above factors (parity status, age etc.) may also explain the absence in some females. Consequently, if one of those variables is the cause of sulcus development, then the absence of the factor may be the reason some females do not show the trait. As discussed in Chapter 5, a possible explanation for PAS development is the size of the pelvic girdle. This will be discussed further in section 8.6, however, it is possible that some female's pelves do not exhibit the pelvic dimension that leads to scarring.

8.3- The Effect of Sexual Dimorphism on the Morphology of the PAS

Question 2: Does the sex of an individual have a significant effect on the morphology of the preauricular sulcus?

The second question in this research was if sex has a significant effect on the morphology of the PAS. The results showed for this research question that the null hypothesis should be rejected. In all six of the samples where both males and females were examined, there is a significant correlation between PAS grades and sex (sections 7.3). No male was found in any of the six samples that had a grade 4. In four of the samples, there were also no male individuals with a grade 3 sulcus, in two (St. Brides and South African Whites) only 1% of men had grade 3 sulci. For males that had a PAS the most common grade in all samples was a grade 1, ranging from 17-47% of individuals depending on the sample. For females, the most common grade within a sample was either 2 (ranging from 20-28%) or 3 (26-43%) (Table 7.15).

The results of this study suggest that although the presence of a PAS is not exclusive to females; the morphology is a reliable indicator of sex. There is a significant difference in the distribution of grades between sexes. The deep pitted grooves characteristic of a grade 4 sulcus are only found in females and not in males. This is consistent with Houghton (1975) who observed deeper sulci only in females. Several other studies (Kelley, 1979; Cox, 1989; Spring *et al.*, 1998; Schemmer *et al.,* 1995; Maass and Fielding, 2016) also reported similar findings, supporting the idea that scarring is often more severe in female individuals than males. Although both Hoshi (1961) and Bruzek (2002) concluded that the presence of a PAS is not a reliable indicator of sex, they both suggested that the morphology is, which is further supported by the present research. Although the presence of a PAS may give an indication of the sex of an individual, the most accurate method for sex assessment from the sulci is an examination of the morphological changes. This is further supported when analysing the strength of the correlation relationships found in this study. For all six of the samples where sexes were compared against each other, the results demonstrate a stronger correlation between sex and grades than sex and presence of the trait (Tables 7.14 and 7.16). This finding indicates that although sex affects the presence of the trait, the dimorphism is more evident when the morphology of the sulcus is analysed.

Similarly, in consistence with the above studies, the present research found that large portions of the female individuals did have lower grade PAS's as well. As stated above Angel (1969), Hougton (1975) and Kelley (1979) attributed this to parity status. They hypothesised that the females with more severe scarring, or in the case of this study higher grades, were parous and those with less scarring, lower grades, were nulliparous. This theory was tested in this research and will be discussed in section 8.4. Regardless, the results show that extensive bone remodelling at the ligament attachment site is more common in females than males although the cause is unclear.

Another area to be examined was the effect that the sex of an individual had on the maximum width and maximum length of the sulci. Only three of the samples (Poulton, St Owens, St Brides) had measurements of the sulcus taken. For all the samples there is a negative correlation between the measurements and sex, meaning that females typically had wider and longer PAS than males. For all three samples, the correlation with the maximum width was stronger than the maximum length. This demonstrates that sex is a factor in the development of the PAS length and width. Although the focus of this project was on the change in depths of the sulcus, these results provide an interesting insight into the effect of sex on the overall size and shape of the PAS, not solely the depth.

There are a limited number of theories as to the reason for the difference seen in sulcus morphology between sexes (Houghton, 1975; Cox, 1989). The cause of the differences between sexes may be explained by either: pregnancy and parturition (section 8.4) or the different shape requirements of the pelvic girdle between males and females (section 8.6).

8.4- The Effect of Parity Status on the PAS

Question 3: Does parity status have a significant effect on the occurrence and morphology preauricular?

A common theory for the development of a PAS is the role of pregnancy and parturition. As detailed in Chapter 2 several studies have examined its relationship to parity status, suggesting an obstetric event as a possible explanation of the development (Angel, 1969; Houghton, 1975; Schemmer *et al.,* 1995). The previous studies suggest that a shallow PAS can develop in either sex, however, a deeper more pitted one is caused by parity. The idea is so prevalent that the term scars of parturition is used to describe traits such as the PAS, despite the fact that there is uncertainty as to the cause of these traits (Ubelaker and De La Paz, 2012).

The present study was designed to further examine this relationship between PAS and parity status. Parity information about the individuals was obtained for three of the samples (Spitalfields, St Brides and CT Scans) (section 3.6). For this research question, the results showed insufficient evidence to reject the null hypothesis. Suggesting that parity status has no significant effect on the sulcus. The results (section 7.4) show that for all three of the samples there is no statistical difference between the level of occurrence in parous and nulliparous individuals (Tables 7.17 and 7.18).

The results also showed that there is no significant difference between the grades of the parous and nulliparous individuals. In the Spitalfields sample, the most common grade was 2 for both parous and nulliparous females. For St Bride's the most common grade was 3 for both groups. Finally, for the CT Scans, of the individuals with sulci the most common grade was grade 1 regardless of parity. For all three of the samples, where parity status was examined, there was also found to be no correlation between parity and presence, grade, maximum length and maximum width (section 7.4).

Previous studies (Ambranson *et al.,* 1934 and Putschar, 1976) have demonstrated that pregnancy and the release of hormones such as relaxin cause a loosening of the ligaments. This occurs in order to allow for the widening of the birth canal, to ensure successful parturition. It has been hypothesised that excess weight-bearing and strain on these softened ligaments during pregnancy leads to the development of bone remodelling at the attachment sites (Ashworth, 1976). Houghton (1975) further suggested that it was not only the excess weight on the ligament during pregnancy that leads to the development of a PAS. He concluded that, during parturition, the strain on the ligament leads to a rupturing of fibres and haemorrhaging which eventually result in bone remodelling at the attachment site. Houghton (1975) suggested that this strain on the ligament is the cause of the difference in sulcus morphology. He categorised sulci into GLs (groove of ligaments) for smoother, shallow PAS and GPs (groove of pregnancies) for deeply pitted sulci. He concluded that males and nulliparous females exhibited GLs and parous females exhibited GPs.

However, this theory does not appear to have been developed using skeletal remains where the parity status was known. Houghton's research (1974) that presented the theory for the first time, states that parity was established by examination of the posterior of the pubic bone for pitting (dorsal pubic pitting). Several studies have found this method of parity estimation to be inaccurate (Adams Holt, 1976; Suchey *et al.,* 1979; Cox, 1989). Due to the fact that the sample was not documented and parity status was ascertained using an unreliable method, the parity information for the sample may not have been correct. Other techniques for establishing parity information in previous research include autopsies of the soft tissue which Adams Holt himself described as an "imperfect" method (Adams Holt, 1976, p.92). The information available for collection is a common problem in the research of scars of parturition: studies have often been performed on skeletal remains where the parity information may not have been accurate. This may explain the often confusing and contradicting results that have been found over the last century. The author of the present study has instead analysed samples where the information on parity status has been confirmed to be accurate.

The present study found that grade 3 or 4 PAS (similar to Houghtons GPs) occurred in both nulliparous and parous females. The present study appears to disagree with the parity status theory (Houghton, 1975) indicating that pregnancy and parturition are not the cause of differences between PAS morphology. Although these results do not indicate the cause of sulcus development, it is clear that parity does not have a significant effect. If the weight-bearing strain on the ligament is the cause of changes to the PAS, pregnancy does not appear a long enough period of time for this to occur. Previous research (Todd, 1921; Gilbert and Mckern, 1973; Bergfelder and Hermann, 1980; Spring *et al.,* 1989; Cox and Scott; 1992; Mcfadden and Oxenham, 2018) appears to confirm that parity has no significant effect on the sulcus. Although the grading results of this study contradict Houghton (1975) who concluded deep pitted sulci were related to parity, they agree about size and shape. The results of this study showed that parity does not have a significant effect on the maximum width and length of the PAS which Houghton also observed.

As the results show that parturition is not the cause of the development of a PAS, other variables in both this present study and further research need to be considered. The vast majority of studies examining the PAS and other pelvic scarring focus on parity status as the primary factor. Angel (1969) suggested that parity has such an effect on pitting of the pelvis that it could be used to calculate the number of births a female had undergone. According to this theory, the number of pits on the pelvis increased with the number of obstetrical events. However, there were specimens in his own sample that appeared to disprove this hypothesis: for example, there was a female with multiple deep pits that had only given birth twice. Angel explained this inconsistency, suggesting that the individual was either pathological or had more children than was reported. Although this could be a possible explanation for this particular individual, the same approach can not be adopted for the present study. It seems unlikely in the samples analysed for this PhD research that the parity information would be incorrect in so many cases to affect the results. Although Angel was not the first researcher to suggest a link between parity and pelvic scarring, his paper, despite being disproved, raised interest in the relationship between these factors. Several subsequent studies (Houghton, 1975; Ashworth, 1976 Adams Holt, 1976; Kelley, 1979) focused on the same factors rather than other variables.

8.5- The Effect of Additional Variables on the PAS

Question 4: Does age, ancestry or location have a significant effect on the levels of occurrence and morphology of the preauricular sulcus?

The variable age (section 7.5) was tested by combining three of the British samples (Poulton, St. Owen and St. Brides) to create a larger age range. Figure 7.22 showed the occurrence level of PAS in each of the three age categories. For this variable, the results fail to reject the null hypothesis, that age has no significant effect on the sulcus. The results showed that there is no significant difference and correlation between age and grades. This indicates that age is not a factor in the appearance of scarring of the sulcus. That occurrence and distribution of grades do not change as individuals age. Kelley (1979) proposed that age may be related to the occurrence of scarring finding that the scars of parturition were obliterated over time, occurring less frequently in older individuals. This theory was further supported by Bergfelder and Herrmann (1980) who concluded that a long time-lapse after birth and scar formation would allow for bone remodelling and concealment of the trait. This means that older individuals would exhibit less PAS than those who were younger. However, contradicting this Suchey *et al.* (1979) found fewer instances of pubic pitting in younger nulliparous females than older and suggested that age was an important factor in the presence of dorsal pubic pitting. The findings of this present study are consistent with Maass (2012) who observed no significant difference in the PAS when compared with age. The outcome of this study suggests that age is not responsible for the difference in occurrence levels and morphology of the PAS. This suggests that any factor that affects the development and morphology of the PAS stays consistent throughout the years. Which further validates the lack of parity status results. If pregnancy is the cause of sulci development, then it would be expected to see more scarring in older females who are likely to have had more pregnancies and birth.

However, an important limitation in this research is that the majority of the individuals studied were towards the older end of the age range. Of the 349 individuals in the pooled sample, only 9% were young adults (25 or younger), 29% were age middle adults (25-40) and 62% old adults (40+). To accurately assess the effect of age on the sulcus it would be beneficial to examine a more even distribution of ages.

The next variable to be analysed was ancestry (section 7.6). This was performed on the two South African skeletal collections where both Black and White South African individuals were studied. The samples were compared against each other to see whether the occurrence of PAS and the distribution of grades was significantly different between them. For this variable, there was insufficient evidence to reject the null hypothesis. The results showed that ancestry does not have a significant effect on the occurrence and morphology of the PAS as there are no significant differences found between the Black and White individuals. These results agree with Adams Holt (1978) and Kelley (1979) who also found that ancestry did not appear to alter the PAS. Based on previous research, this result was expected; however, the variable was included in the present study to broaden the geographic diversity of the populations analysed.

The final variable to be tested in the main results chapter (7) was the geographical location of the samples (section 7.7). Six of the samples; Poulton, St. Owens, St. Brides, South African Blacks, South African Whites and Ct Scans (Spitalfields was not included as only female individuals were examined) were combined to see if there were significant differences in PAS presence and morphology between samples. For this variable that location has a significant effect on PAS, the null hypothesis was rejected. The results showed that there is a significant difference in both presence and grades between the locations of the samples. The reason for these differences is unclear from the results and further analysis would need to be carried out to understand them. However, a possible explanation might be due to the different format of the specimens. The majority of individuals were from skeletal remains. However, a selection of was examined digitally (CT Scans). It is possible that the morphology of the sulcus was analysed differently between the two formats.

Another source of uncertainty is the researcher's unfamiliarity with the rendering of CT Scans. It is possible that when "thresholding" (isolating the bone from the surrounding tissue) more/or less of an effect on the bone was created than is actually present. This could additionally be due to software accuracy, especially when removing soft tissue, in the form of ligaments, in such close proximity to the bone. Experts trained in the use of imaging software would be needed to fully assess variability to the bone surface between scans. The significant difference in location is likely between the skeletal and digital specimens. These findings disagree with Maass (2012) who found no significant differences in scarring between the different samples that she studied. Her samples ranged from Later Stone Age individuals to modern cadaver collections but were all skeletal and not digital. However, the results agree with Stewart (1957) who when comparing skeletal remains from Eskimo individuals against modern samples from the Robert J. Terry Anatomical Skeletal Collection found the earlier specimens had a greater number of scars. Stewart attributed these differences to the differing levels of obstetric care between the two populations. However, the lack of parity correlation in this present study would indicate that that is not the cause.

8.6- The Effect of Pelvic Shape on the PAS

Question 5: Do the dimensions of the pelvis have a significant effect on levels of occurrence and morphology of preauricular sulcus?

As discussed earlier in this PhD thesis, there were two side pilot projects carried out that related to the study but analysed additional aspects. The first of these projects was to examine the effect of pelvic shape on the PAS (Chapter 5). Measurements from the pelvis were taken to describe the size and shape and then tested to see whether there was a significant difference between sex and the grades. The result for this project is discussed in full detail in section 5.4 therefore only a summary will be given here.

The results further corroborate previous studies (Tague, 1992; Arsuaga, J.L. and Carretero, 1994; Kurki, 2007) that demonstrate many of the dimensions of the female pelves are larger than males (section 5.4.1). Despite males having on average larger dimensions than females in the majority of skeletal elements, it was found across the following measurement they were smaller: Maximum Sacral Width, Sacral Width Inferior, Transverse Diameter, Conjugate Diameter and Bispinious. This is due to male pelves not having the same evolutionary constraints acting upon them that females do. As mentioned in Chapters 2 and 5 female pelves are required to be wider than males in order for safe parturition to occur (Gruss and Schmitt, 2015).

The present study also found that for four of the five (excluding Conjugate Diameter) measurements that were larger in females there is also a correlation with grades (section 5.4.2). Demonstrating that deeper pitted sulci were more likely to occur in individuals with larger pelvic dimensions. The findings agree with studies by Cox (1989) and Maass (2012) that show more severe scars of parturition are prevalent in individuals with wider pelves. In the four pelvic measurements, the dimensions increased concurrently alongside the grades. It has been suggested (Cox, 1989) that this occurs due to larger pelves requiring more ligament stabilisation leading to more bone remodelling at the attachment sites. Cox concluded that pelves with greater dimensions were more flexible and less stable in the transmission of weight between the torso and lower limbs during walking or other movements. To compensate for this mobility, there is more strain on the ligament to stabilise the pelvic girdle, which can lead to the formation of a well defined PAS. This means that females, whose pelves are on average wider than males, typically have more scarring than the other sex in the form of a PAS. This theory agrees with suggestions by authors, such as Houghton (1975) and Ashworth (1976), that ligament strain is the cause of bone remodelling at the attachment site. However, instead of this strain being caused by pregnancy or parturition as they suggested, it is the result of wide pelvic dimensions. The author of the present PhD thesis agrees with Cox (1989) and Maass (2012) that pelvic size is a better explanation for the variation in PAS morphology than parity status.

The present research indicates that the occurrence of deeply pitted sulci are not caused by the acts of pregnancy and parturition themselves but instead result from evolutionary differences in the pelves between males and females. These differences occur because in order for females to successfully give birth their pelvis need to be wider allowing for safe passage of the foetus. This leads to more ligament strain and thus more scarring at the attachment site regardless of obstetric events. The variation in pelvic size across the sexes explains why some males have PAS and some females do not. It is probable that females without a PAS have narrower pelvic dimensions than typical, and thus have less ligament strain that causes this trait. In contrast, males with PAS likely have wider pelvic dimensions than a typical male, similar to an average female; consequently, there would be more ligament strain across the pelves that leads to more scarring. The positive relationship between certain pelvic diameters and grades offer perhaps the strongest explanation for the differences in the presence and morphology of the PAS across individuals.

The results also showed that pitting on the dorsal pubic symphysis are more common in females than males (section 5.4.3) but is not exclusively a sexually dimorphic trait agreeing with studies by (Stewart, 1975; Putschar, 1976; Suchey *et al.,*1979). It was also found that there is a correlation between the occurrence of this pitting and PAS grades. The correlation is weak but it is positive indicating that grades and levels of pitting increase simultaneously. These results agree with Maass (2012) who found in some of her samples there appeared to be a relationship between the two traits. If the strain on the pelvic ligaments to stabilise the pelvis is the cause of scarring then it is logical there would be a correlation between these two features as they are both ligament attachment sites.

8.7- The CT Scans with Biographical Information

Question 6: Do certain lifestyle and biological variables have a significant effect of levels of occurrence and morphology on the preauricular sulcus observed using CT Scans?

As previously discussed, the second pilot study carried out was on a collection of CT Scans from living subjects. The aim of this pilot study (Chapter 6) was to first test if the grading system could be applied to CT Scans and examine the effect that additional variables may have on the PAS. A full discussion of the results can be found it section 6.4 therefore only an overview will be given here.

For this sample additional information regarding demographics (age, height, weight, body shape), lifestyles (smoking history, alcohol consumption, activity level and diet) and parity status (number of pregnancies, number of births and caesarean history) were available. These different variables were examined to see their potential relationship to the presence and morphology of the PAS. Studies (Wilczak, 1998; Maass, 2012) have shown that factors such as age, body mass and mechanical stress can affect some ligament and muscle insertion sites (e.g. *pronator teres, pectoralis major* etc.). However, this does not appear to be the case for the PAS.

For the majority of the variables, there was found to be no significant difference or correlation with the PAS. The two exceptions to this were the number of pregnancies and the number of births, both of which have a weak positive correlation with grades. This means that the grades increase concurrently with the number of pregnancies/births individuals had. As discussed previously Angel (1969) concluded that it was possible to assess the number of births a female had previously had by counting the number of pits on the dorsal aspect of the pubic surface. This theory has been disproved (Ubelaker and De La Paz, 2012) and although there is a correlation in the present study between PAS grades and the number of pregnancies/births this finding should be viewed with caution as the correlations were weak (section 6.3). However, the findings are especially interesting when compared against the CT Scan results from Chapter 7 (section 7.4.3). In that section when parity was assessed as only a binary answer (either: had given birth or had never given birth), there was found to be no significant difference in grades. The results from this pilot study suggest that multiple pregnancies/births may have a relationship to the morphology of the PAS. This may be linked to the suggestion that it is wider pelvic dimensions that lead to more scarring (section 8.6). A wider pelvis would lead to a more successful birth allowing for multiple births to occur. It may not be that more pregnancies are causing the scarring, rather the optimal (wider) pelvic dimensions needed for multiple successful parturitions. The positive correlation between the number of pregnancies/births and grades is unlikely to indicate that the obstetric events themselves are causing this relationship.

Previous research (Boland, 1933; Thorp and Fray, 1938 and Kowalk *et al.,* 1996) found that pregnancy and parturition could lead to a widening of the pelvis in the form of separation of the pubic symphysis. However, this widening when it did occur began to reduce back to normal almost immediately after birth, indicating that parturition does not lead to a permanent widening of the pelvis that would cause scar development. Although the results from this pilot study are not conclusive they suggest that future research into the effects of parity status on the PAS would benefit from including data about the number of pregnancies and births.

8.8- Conclusions

8.8.1- Overall Conclusions

For this project as a whole, the main conclusion is that the PAS is a sexually dimorphic trait and that sex has a significant effect on the occurrence and morphology of the sulcus. Furthermore, it was found that parity status is not the cause of the range of variation that is found across the trait. The results instead suggested that pelvis shape is the best predictor of a PAS, with wider pelves generally having more severe scarring. Evolutionary selection pressures mean that females typically have wider pelvic dimensions than males to allow for successful reproduction. The results of this project also indicate that the trait can be a reliable tool in the use of biological profiling.

The PAS can be an often overlooked but important trait to use, especially in the education of new bioarcheologists and forensic anthropologists. This is one of the reasons that the new grading system is proposed, to provide clarity in the use of the trait. Throughout the course of developing this new system, many undergraduate students at LJMU (during practical demonstrations) stated that they found the existing grading systems difficult to understand, as they rely on drawings and diagrams only. These diagrams can be hard to use for early-stage researchers/bioarcheologists who do not have much familiarity with the trait. Variations in depth and surface texture are difficult to depict in a drawing. The grading system in this project instead uses photographs and detailed descriptions to present clearer images of the variation in the sulcus. The results of the Cohen's Kappa Tests show that the new grading system can be used by non-experts in human osteology with a fair level of agreement (section 7.2) and experts with an almost perfect level of agreement (section 3.4). The inter-observer error analysis suggests that familiarity with osteology improves the accuracy of grading system application but does not indicate it cannot be used by individuals less experienced with skeletal remains. This demonstrates the potential of the method as both a teaching tool and to be used in forensic and bioarchaeological contexts.

The area where the PAS is located is often recovered in forensic and bioarchaeological remains, especially compared to other sexing traits. One of the most common methods taught to undergraduate students is the Phenice Method (1969) due to its high accuracy rate. However, all three traits used are on the pubis which Waldron (1987) found was only present and undamaged in approximately 30% archaeological remains. Walker (2005) found that the area of the Greater Sciatic Notch, which is next to the PAS, is recovered undamaged more often that the pubis.

When establishing the identity/ biological profile of an individual one of the most important components is the determination of sex (Meindl *et al.*, 1985). The results of the present project highlight the use of the PAS as one of these morphological features. As discussed in section 8.3 the observed difference in levels of occurrence and morphology demonstrates that it can be a reliable tool to use for sex assessment for both forensic and bioarcheological purposes when used alongside other features. The study determined that an individual with a PAS, no matter the grade of expression, is more likely to be female. This finding corroborates Rogers and Sanders (1994) who found that the presence of a PAS was an accurate indicator of sex 91% of the time. However, the presence of PAS in males highlights that this feature should be used in conjunction with other sexing traits. Previous studies (Meindl *et al.,* 1985 and Bruzek, 2002) have demonstrated that sex assessment is most accurate when a combination of features is used.

This project and the new grading system highlights that although the presence of a PAS may give an indication of the sex of an individual, the most accurate method for sex assessment from the sulci is an examination of the morphological changes. One of the main conclusions of this project was that instead of looking at the PAS in a binary way (either present or not) the trait should be viewed considering the wide range of variation. This is why four grades were created to describe the morphology of the trait. A grade 1 sulcus has very different morphology to a grade 4 and classing them both in the same group (as simply present) does not sufficiently describe the expression. This conclusion is in agreement with Klales (2012) who found, in regards to the Phenice Method, that using five categories for each trait rather than simply present or absent increased the consistency and accuracy of the method. This is further validated by the unanticipated finding of the presence of a grade 3 PAS in one of the St Brides males and South African White males. None of the samples examined exhibited any observable pathologies to the *os coxae,* therefore it is unlikely this was the cause. This inconsistency may be due to either human error in grade determination or sexing. However, it also shows that multiple grades are necessary to describe PAS morphology across the sexes. This is additionally supported when analysing the strength of the correlation relationships found in this study. For all six of the samples where sexes were compared against each other, the results demonstrate a stronger correlation between sex and grades than sex and presence. This finding indicates that although sex affects the presence of a PAS, the differences are more evident when the morphology of the sulcus is analysed. It is for this reason that multiple grades are proposed for the new grading system rather than simply binary (absent and present).

In conclusion, this study shows that the morphology of the PAS is significantly different between sexes demonstrating that sexual dimorphism plays a role in the development of PAS morphology. The research indicates that the morphology of the PAS can be used to assess sex. Grade 4 sulci were only found in female individuals, showing that a deeply pitted sulcus is a reliable indicator of the female sex.

A common theory for the variation in sulci between females is parity status. Houghton (1975) stated that nulliparous females had less severe expressions of the trait and parous females more serve. However, in the present study, it was found that grade 3 or 4 PAS occurred in both nulliparous and parous females. The present study appears to disagree with the parity status theory (Houghton, 1975) indicating that pregnancy and parturition are not the cause of differences between PAS morphology. Although these results do not indicate the cause of sulcus development, it is clear from the results of the present study that parity does not have a significant effect.

Previous studies into the effect of pregnancy and parturition on the trait have provided conflicting and contrasting results. Despite this, it is still used by many bioarcheologists as a method of determining parity status (Ubelaker and De La Paz, 2012; Maass and Friedling, 2014). As stated previously the results of this study indicate that pregnancy and parturition is not the cause of the variation in the sulcus, which corroborates with multiple other studies (Cox and Scott, 1992; Spring *et al*, 1989; Maass, 2012) These findings highlight the need to educate and train members in this field about the inaccuracies of using scars of parturition as a method of determining the parity history of an individual. The emphasis on pregnancy and parturition as a cause of pelvic scarring is understandable considering the frequency of PAS in females over males. However, the term scars of parturition itself may also influence researchers. Parity status is often one of the first variables considered when studying the reason for scarring (Angel, 1969; Cox, 1989; MacArthur *et al.,* 2016) possibly at the expense of other causes. The present study is not exempt from this bias, parity was the first variable examined. The present research, as well as recent studies by Decrausaz (2012), Maass (2012) and Mcfadden and Oxenham (2018), demonstrate that parity is not the primary cause of PAS development. This research reinforces the possibility that new terminology may be required for the discussion of these traits.

During the main research and pilot studies, other variables were examined to determine their relationship to the trait. Age and Ancestry were both found to have no significant correlation. In contrast, the location of the specimens studied was found to affect the PAS. However, as discussed in section 8.6 this is likely due to the differing nature of the specimens used (digital and physical). For the CT Scan pilot study, the majority of the additional biological and lifestyle variables examined were found to have no significant effect on the PAS. However, the implementation of the new system on CT Scans provides interesting results into the use of such techniques on digital collections.

The present research found that alongside sex, the most significant factor for the occurrence and morphology of the PAS was the size of the pelvis. The four pelvic measurements (Maximum Sacral Width, Sacral Width Inferior, Transverse Diameter, and Bispinous Diameter) were all found to be significantly larger in the female individuals from St Brides than the males. They additionally all correlated positively with grades, demonstrating that individuals with wider pelves were more likely to have severe expressions of the trait. Transverse Diameter was found to be the best predictor of sulcus grades with the strongest correlation. The reason for this relationship is likely because pelves with wider dimensions require more ligament stabilisation, which in turn leads to excess strain at the ligament insertion site causing bone remodelling. The reason females typically present with more severe PAS is because their pelves are on average wider than males. This further explains why some females present without a sulcus, those with smaller pelves, and some males present with one, those with wider pelves more similar to a typical female. As stated previously, the larger size of the female pelves is due to the evolutionary changes required in order to give birth. Therefore, PAS occurrence and morphology is linked to pregnancy and parturition. However, not the process itself but rather the evolutionary selection pressures acting on the pelvic girdle to create the optimal conditions for birth.

8.8.2- Limitations

It is important to recognise the limitations of this research. For the two pilot studies these can be found in detail in their respective chapters (5 and 6). However, given that perhaps the most significant results of the study were regarding pelvic shape dimensions one of the limitations is that it was only tested on one sample. This was due to either constraints when having access to the collections or poor preservation not allowing for articulation of the pelvic girdle. Betti and Manica (2018) found that pelvis size differed across populations, therefore, suggesting that testing the relationship between pelvic diameters and the PAS across a more diverse geographic distribution may provide interesting results.

The majority of the samples studied did not have parity information documented. For the samples where parity status was available, two of them (Spitalfields and St Brides) were archaeological populations. The parity information in these samples may not have been completely accurate as they were based off parish records. For St Brides especially, the information on parity was difficult to assess. As detailed in Chapter 4, the parish records have been digitised. It was difficult to establish for certain, that some of the females had never given birth. It was not always possible to know whether birth records could not be found because they did not exist or because they had just been lost. This meant that females were discounted from use because sufficient records could not be found, who may have been nulliparous. It would be beneficial for future studies to use samples where there were a greater number of nulliparous individuals. Furthermore, miscarriages and stillbirths would not have been recorded in the parish records.

Another limitation to this project was the lack of range in ancestry. The majority of samples were from White British individuals. Although the results (sections 7.6 and 8.5) suggest that ancestry is not a factor in the occurrence and morphology of a PAS this was only tested on a small range of possible ancestries. Despite the fact that it appears that there are no differences between the PAS of White and Black South Africans this may not be accurate for all ancestries.

Finally, an area of improvement would be represented by testing the new grading system against existing methods such as Houghton (1975) and Buikstra and Ubelaker (1994). Although the focus of the study was on the relationship of the new grades against the variables tested, it may have provided interesting results to examine if and how they differed from the existing methods.

8.9- Future Research

The results of this research highlight the importance of expanding the variables analysed when examining the cause of PAS occurrence and morphology. Historically the emphasis has often been on the effect of pregnancy and parturition on this trait, however, the study suggests that they are not the direct cause. Additional analysis may benefit from not focusing on these factors and instead examining other causes. That being said, if parity is studied it should be investigated on collections with a wider range than was included in this study. The author of the present PhD thesis encountered difficulty in finding nulliparous samples to include. The use of skeletal collections where only parish records are available can limit the reliability of the parity information used. Furthermore, the correlation found between the number of pregnancies/births and the PAS suggests that additional studies should include this variable when evaluating parity status, rather than treating it as a binary answer. Marking the females as only either parous or nulliparous does not describe the full range of parity variables that may be affecting morphological changes to the bone.

This research suggests that the most reliable indicator of PAS occurrence and morphology is the size of the pelvic girdle, especially the Transverse Diameter, however, this was only measured on a small number of skeletons. The analysis of additional samples, including a greater number of individuals, would provide a better insight into the nature of the relationship between PAS and the dimensions of the pelvis. Furthermore, in regards to pelvic shape, the author only examined a single British post-medieval collection; it would be important to include other populations to broaden the geographical and temporal diversity. Pelvic shape varies across different populations and this should be reflected in further studies into the topic.

Widening the ancestry of the data included would be beneficial in all areas of this topic, not just the analysis of pelvic shape. The study found that there was no difference in the frequency and morphology of the PAS between South African Blacks and South African Whites. However, only two ancestry groups were examined. Even though no differences were found between these two samples, this does not exclude the fact that other ancestries could vary from each other. This study could be improved by looking at a wider range of samples from across the world.

Additionally, although this research found no link between body size and the PAS previous studies have, especially when combined with pelvic shape. In this thesis, the two variables were not examined on the same collections due to the different natures of them (skeletal remains and CT Scans). It may prove beneficial in further studies to examine both factors at the same time.

The use of CT Scan data in this research demonstrates that morphological analysis can be conducted on clinical imaging. The use of more data of this nature broadens the field for Biological Anthropology and widens our understanding of human bodies. Future studies would benefit from using this virtual approach to skeletal examination as the biographical information from medical imaging is often more detailed and accurate than that provided from historical collections. In addition, the methods traditionally developed on known documented collections could be tested and even validated on data sets from living and known individuals (after anonymising them). Furthermore, future research may benefit from testing the grading system on the same specimens in digital and physical formats to assess the agreement of grades across the two. It is possible this could be done using cadaver collections; first CT Scanning the bodies, 3D rendering the images and then grading them after which the bodies could be macerated and then grading carried out again on the skeletal remains. The two grades could be then compared to see if there were differences in the results.

The main conclusion of this research is the high variability across the preauricular sulcus. The thesis highlights the importance of not viewing the trait in a binary way (present or absent) but instead describing the full range of variation through the use of the five grades. Through the use of the new grading system, a better understanding of the traits relationship to sex, parity status and pelvic shape was achieved. The new method is also proposed as a more accessible educational tool for students that struggle to use the existing grading systems. The author hopes that the newly proposed grading system for the description of the preauricular sulcus can be applied by other researchers to broaden our understanding of this trait.

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Appendix 1

Data Collection Sheet

Skeleton Number-		
Collection-		
Age (Methods used)-		
Sex (Methods used)-		
Preauricular Sulcus Presence	Left-	Right-
Grade-	Left-	Right-
Maximum Length-		
Maximum Width-		
Additional Information		

Appendix 2

Information and Data Sheet Given to Observers

Grading System

The preauricular sulcus or groove is located on the *os coxae* between the auricular surface and the greater sciatic notch. The preauricular sulcus is the site of the attachment for the anterior sacroiliac ligament. During pregnancy this ligament is loosened in order to widen the birth canal in preparation for parturition (giving birth), it is these changes that are suggested to cause remodelling of the bone that can observed.

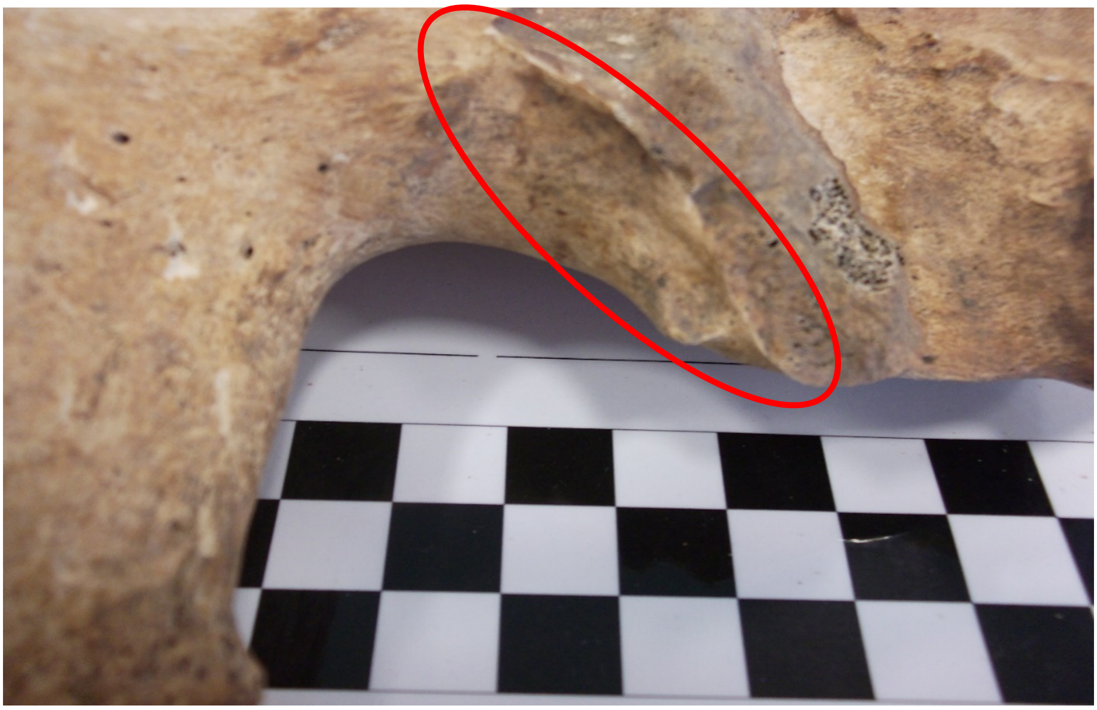
A new grading was created to assess the preauricular sulcus, for this practical you will be testing out the grading system.

Grade 0- This is where there is no preauricular sulcus present.

Grade 1- This is for a preauricular sulcus that is shallow and the floor of the sulcus is all one consistent depth, there are no pits or grooves and the edges are often undefined. This grade of preauricular sulcus is often scarcely visible which can make the measurements difficult, as

there are usually no definite edges.

Grade 2- Grade 2 is for preauricular sulcus whose floor has a slightly uneven depth and is not completely smooth. There should only be a small change in depth, however, and preauricular sulcus with more than one pit of different depths would be classified as a grade 3 instead.



Grade 3- Grade 3 preauricular sulcus, although similar to Grade 2, differ as the floor of the sulcus has multiple varying depths and will have more than one pit. Grade 3s typically have a

more defined edge than Grades 1 and 2.

Grade 4- Grade 4 preauricular sulcus are for those that have a very inconsistent depth; they will have multiple deep pits or channels through the sulcus. The surface of the sulcus will appear rough and these sulcus are very easy to observe on the bone. Unlike Grade 1

preauricular sulcus, it would be difficult to overlook them. Grade 4 typically look like a deep channel in the bone.

Data collection for Grading System Project- Students

Course-

Skeleton Number	Collection	Grade

Appendix 3

Data Recorded by Author for Pelvic Shape

Skeleton	Presence	Sex	Age Category	Grade	Max. Sacral Width	Sacral Width Inferior	Sacral Length
105	0	M	3	0	100.39	88.80	108.00
181	1	M	3	1	100.68	83.99	111.00
11	0	M	2	0	101.01	82.04	122.00
180	1	M	3	1	101.85	81.18	106.00
20	1	M	3	1	103.32	86.80	106.00
68	1	M	2	1	103.83	92.33	116.00
124	0	M	3	0	104.67	81.31	139.00
59	0	M	3	0	104.70	82.54	109.00
107	1	M	3	1	105.09	87.88	N/A
198	1	M	3	1	107.75	89.16	108.00
14	1	M	2	1	107.91	88.41	115.00
135	1	F	3	3	107.91	88.78	103.00
69	1	F	2	1	110.33	89.54	111.00
64	0	M	3	0	110.48	83.34	129.00
206	0	M	3	0	110.48	93.58	121.00
29	0	M	3	0	111.39	90.02	116.00
84	0	M	3	0	112.03	88.87	136.00
119	1	M	2	2	112.80	83.00	118.00
29	1	M	3	1	113.43	90.02	116.00
152	1	F	2	1	114.22	97.68	105.00
112	0	M	3	0	114.77	95.89	121.00
203	1	F	1	3	114.99	96.23	101.00
171	0	M	2	0	116.35	94.96	128.00
215	1	F	3	4	116.64	93.44	112.00
33	1	F	3	3	116.74	94.09	116.00
143	1	M	3	1	116.82	89.22	141.00
104	1	F	3	2	116.93	94.47	128.00
101	1	F	3	4	117.11	97.20	132.00
106	1	F	2	3	117.17	91.62	110.00
134	1	F	3	4	117.18	98.52	N/A
224	0	M	3	0	117.52	94.41	126.00
177	1	F	2	2	117.70	91.34	116.00
77	1	F	1	3	119.26	98.39	128.00
128	1	F	3	3	119.49	90.73	111.00
183	1	M	3	2	124.79	97.43	119.00

Skeleton	Sacral Depth	Transverse Diameter	Conjugate Diameter	Bispinous Diameter	Pubo-Sacro Diameter	Ischial Spine Pubic Symphysis Diameter	Dorsal Pubic Pitting
105	19.00	103.00	94.00	91.00	106.39	107.59	0
181	30.00	120.00	101.00	81.00	104.65	98.80	0
11	26.00	120.00	111.00	96.00	97.63	93.51	0

180	27.00	113.00	90.00	91.00	102.86	96.92	0
20	34.00	118.00	94.00	97.00	103.21	98.43	0
68	16.00	122.00	113.00	110.00	108.47	97.50	0
124	32.00	110.00	96.00	91.00	102.91	97.71	0
59	28.00	118.00	114.00	79.00	108.16	101.08	0
107	N/A	101.00	107.00	91.00	102.13	100.96	0
198	27.00	123.00	88.00	100.00	102.59	96.83	0
14	33.00	119.00	106.00	80.00	111.17	113.00	0
135	22.00	120.00	99.00	109.00	113.57	92.32	0
69	26.00	123.00	107.00	119.00	100.11	94.96	1
64	29.00	98.00	108.00	80.00	119.58	106.19	0
206	21.00	116.00	103.00	98.00	110.93	103.04	0
29	16.00	121.00	103.00	95.00	106.62	101.01	0
84	19.00	110.00	95.00	109.00	105.66	99.86	0
119	35.00	115.00	99.00	91.00	103.60	100.25	0
29	16.00	121.00	103.00	95.00	112.71	107.60	0
152	N/A	119.00	109.00	101.00	106.87	97.35	1
112	23.00	129.00	110.00	117.00	111.05	112.33	0
203	20.00	133.00	195.00	106.00	94.07	91.95	0
171	23.00	121.00	111.00	95.00	115.86	100.22	0
215	30.00	138.00	112.00	118.00	111.11	101.19	0
33	25.00	131.00	124.00	110.00	119.82	105.95	0
143	48.00	128.00	104.00	86.00	120.14	109.22	0
104	29.00	119.00	110.00	111.00	115.27	106.99	1
101	22.00	135.00	114.00	106.00	112.53	89.58	1
106	18.00	139.00	115.00	111.00	110.09	91.77	0
134	N/A	151.00	101.00	128.00	115.09	108.68	1
224	13.00	132.00	111.00	106.00	119.17	109.93	0
177	17.00	141.00	125.00	95.00	122.58	106.97	1
77	16.00	140.00	134.00	128.00	121.29	108.47	0
128	31.00	140.00	98.00	121.00	108.03	105.15	0
183	8.00	139.00	102.00	104.00	N/A	N/A	N/A

Appendix 4

Statistical Output for Results Focusing on Pelvic Shape

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Side	.539	31	.000	.176	31	.000
Presence	.412	31	.000	.607	31	.000
Sex	.412	31	.000	.607	31	.000
AgeCat	.413	31	.000	.647	31	.000
MaxLengthPS	.254	31	.000	.782	31	.000
MaxWidthPS	.229	31	.000	.872	31	.002
Grade	.241	31	.000	.841	31	.000
MaxSacralWidth	.155	31	.055	.911	31	.013
SacralWidthInferior	.126	31	.200*	.950	31	.152
SacralLength	.158	31	.047	.954	31	.195
SacralDepeth	.086	31	.200*	.943	31	.101
TransDia	.149	31	.079	.957	31	.249
ConjDia	.252	31	.000	.690	31	.000
BisDia	.108	31	.200*	.965	31	.391
PuboSacroDia	.097	31	.200*	.976	31	.688
IscPubicDia	.111	31	.200*	.968	31	.470
PubicPitting	.518	31	.000	.397	31	.000

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Test Statistics[a,b]

	Side	Presence	Sex	AgeCat	MaxLengthPS	MaxWidthPS	MaxSacralWidth	SacralWidthInferior	SacralLength	SacralDepeth	TransDia	ConjDia	BisDia	PuboSacroDia	IscPubicDia	PubicPitting
Chi-Square	2.182	34.000	23.031	4.590	23.280	25.718	15.813	8.622	9.167	3.000	14.695	5.119	13.188	4.699	2.452	13.167
df	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Asymp. Sig.	.702	.000	.000	.332	.000	.000	.003	.071	.057	.558	.005	.275	.010	.320	.653	.010

a. Kruskal Wallis Test

b. Grouping Variable: Grade

Test Statistics[a]

	MaxLengthPS	MaxWidthPS	Grade	MaxSacralWidth	SacralWidthInferior	SacralLength	SacralDepeth	TransDia	ConjDia	BisDia	PuboSacroDia	IscPubicDia	PubicPitting
Mann-Whitney U	61.000	35.000	15.000	48.500	52.000	90.000	103.000	43.000	67.500	28.500	93.000	109.000	73.500
Wilcoxon W	314.000	288.000	268.000	301.500	305.000	168.000	169.000	296.000	320.500	281.500	324.000	200.000	304.500
Z	-2.844	-3.745	-4.528	-3.227	-3.107	-1.351	-.497	-3.418	-2.580	-3.920	-1.542	-.975	-3.380
Asymp. Sig. (2-tailed)	.004	.000	.000	.001	.002	.177	.619	.001	.010	.000	.123	.330	.001
Exact Sig. [2*(1-tailed Sig.)]	.004	.000	.000	.001	.001	.187	.639	.000	.009	.000	.129	.344	.024

a. Grouping Variable: Sex

Correlations

			Side	Presence	Sex	AgeCat	MaxLengthPS	MaxWidthPS	Grade	MaxSacralWidth	SacralWidthInferior	SacralLength	SacralDepeth	TransDia	ConjDia	BisDia	PuboSacroDia	IscPubicDia	PubicPitting
Spearman's rho	Side		1.000	.116	.132	.115	.207	-.069	-.018	.017	-.008	.000	-.234	.000	-.068	-.094	.115	.186	-.081
			.	.507	.450	.511	.233	.694	.920	.923	.961	1.000	.198	1.000	.698	.593	.516	.291	.651
			35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
	Presence		.116	1.000	-.520	-.206	.817	.817	.833	.256	.204	-.389	.150	.406	.052	.275	.035	-.170	.320
			.507	.	.001	.235	.000	.000	.000	.138	.239	.025	.413	.016	.767	.110	.843	.337	.065
			35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
	Sex		.132	-.520	1.000	.277	-.488	-.642	-.776	-.553	-.533	.239	.089	-.586	-.442	-.672	-.268	.170	-.588
			.450	.001	.	.107	.003	.000	.000	.001	.001	.181	.627	.000	.008	.000	.125	.337	.000
			35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
	AgeCat		.115	-.206	.277	1.000	-.346	-.298	-.160	-.107	-.190	.120	.158	-.224	-.506	-.124	.071	.236	-.144
			.511	.235	.107	.	.041	.082	.358	.540	.276	.505	.387	.196	.002	.476	.691	.180	.417
			35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
	MaxLengthPS		.207	.817	-.488	-.346	1.000	.689	.718	.333	.328	-.337	.042	.434	.195	.318	-.026	-.099	.232
			.233	.000	.003	.041	.	.000	.000	.051	.055	.055	.820	.009	.262	.063	.886	.579	.187
			35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
	MaxWidthPS		-.069	.817	-.642	-.298	.689	1.000	.841	.271	.328	-.311	.000	.497	.225	.466	.028	-.264	.400
			.694	.000	.000	.082	.000	.	.000	.115	.055	.078	.998	.002	.195	.005	.876	.131	.019

		35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
Grade		-.018	.833	-.776	-.160	.718	.841	1.000	.528	.422	-.265	.028	.623	.244	.525	.213	-.148	.351
		.920	.000	.000	.358	.000	.000	.	.001	.012	.137	.880	.000	.159	.001	.227	.403	.042
		35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
MaxSacralWidth		.017	.256	-.553	-.107	.333	.271	.528	1.000	.750	.328	-.304	.750	.427	.540	.640	.337	.354
		.923	.138	.001	.540	.051	.115	.001	.	.000	.062	.091	.000	.011	.001	.000	.051	.040
		35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
SacralWidthInferior		-.008	.204	-.533	-.190	.328	.328	.422	.750	1.000	.136	-.548	.684	.477	.673	.471	.196	.433
		.961	.239	.001	.276	.055	.055	.012	.000	.	.449	.001	.000	.004	.000	.005	.266	.011
		35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
SacralLength		.000	-.389	.239	.120	-.337	-.311	-.265	.328	.136	1.000	-.033	-.009	.154	-.027	.439	.371	.033
		1.000	.025	.181	.505	.055	.078	.137	.062	.449	.	.857	.959	.393	.881	.012	.037	.859
		33	33	33	33	33	33	33	33	33	33	32	33	33	33	32	32	32
SacralDepeth		-.234	.150	.089	.158	.042	.000	.028	-.304	-.548	-.033	1.000	-.362	-.321	-.324	-.221	.009	-.059
		.198	.413	.627	.387	.820	.998	.880	.091	.001	.857	.	.042	.073	.070	.233	.960	.751
		32	32	32	32	32	32	32	32	32	32	32	32	32	32	31	31	31
TransDia		.000	.406	-.586	-.224	.434	.497	.623	.750	.684	-.009	-.362	1.000	.460	.637	.397	.095	.280
		1.000	.016	.000	.196	.009	.002	.000	.000	.000	.959	.042	.	.005	.000	.020	.594	.109
		35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
ConjDia		-.068	.052	-.442	-.506	.195	.225	.244	.427	.477	.154	-.321	.460	1.000	.252	.407	.026	.197

		.698	.767	.008	.002	.262	.195	.159	.011	.004	.393	.073	.005	.	.144	.017	.883	.265
		35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
BisDia		-.094	.275	-.672	-.124	.318	.466	.525	.540	.673	-.027	-.324	.637	.252	1.000	.151	-.061	.312
		.593	.110	.000	.476	.063	.005	.001	.001	.000	.881	.070	.000	.144	.	.395	.731	.073
		35	35	35	35	35	35	35	35	35	33	32	35	35	35	34	34	34
PuboSacroDia		.115	.035	-.268	.071	-.026	.028	.213	.640	.471	.439	-.221	.397	.407	.151	1.000	.605	.173
		.516	.843	.125	.691	.886	.876	.227	.000	.005	.012	.233	.020	.017	.395	.	.000	.328
		34	34	34	34	34	34	34	34	34	32	31	34	34	34	34	34	34
IscPubicDia		.186	-.170	.170	.236	-.099	-.264	-.148	.337	.196	.371	.009	.095	.026	-.061	.605	1.000	-.063
		.291	.337	.337	.180	.579	.131	.403	.051	.266	.037	.960	.594	.883	.731	.000	.	.724
		34	34	34	34	34	34	34	34	34	32	31	34	34	34	34	34	34
PubicPitting		-.081	.320	-.588	-.144	.232	.400	.351	.354	.433	.033	-.059	.280	.197	.312	.173	-.063	1.000
		.651	.065	.000	.417	.187	.019	.042	.040	.011	.859	.751	.109	.265	.073	.328	.724	.
		34	34	34	34	34	34	34	34	34	32	31	34	34	34	34	34	34

Appendix 5

CT Scans with All Biographical information

BMI

Females

Underweight	Healthy Weight	Overweight	Obese
3 7.5%	19 47.5%	9 22.5%	9 22.5%

Males

Underweight	Healthy Weight	Overweight	Obese
0 0%	11 46%	12 50%	1 4%

Body Shape

Females

Rectangle	Hourglass	Apple	Triangle	Pear
7 16%	20 45%	10 23%	4 9%	3 7%

Males- 24

Rectangle	Hourglass	Apple	Triangle	Pear
18 72%	0 0%	4 16%	1 4%	2 8%

Tobacco Consumption

Females

History of smoking	No history of smoking
9 20%	37 80%

Males

History of smoking	No history of smoking
4	20

17%	83%

Alcohol Consumption

Females

0 Units	<4 Units	5-9 Units	10-14 Units	15-19 Units	20-24 Units	25-29 Units	>30 Units
13 30%	14 31%	9 20%	5 11%	1 2%	1 2%	1 2%	1 2%

Males

0 Units	<4 Units	5-9 Units	10-14 Units	15-19 Units	20-24 Units	25-29	>30 Units
5 21%	3 12.5%	8 33%	4 17%	3 12.5%	1 4%	0 0%	0 0%

Activity Level

Females

Immobile	Light	Moderate	Active
1 2%	14 30%	24 52%	7 16%

Males

Immobile	Light	Moderate	Active
0 0%	9 36%	12 48%	4 16%

Diet

Females

Poor	Average	Good
7 15%	20 43%	19 42%

Males

Poor	Average	Good
1	13	10

4%	54%	42%

Number of pregnancies

0	**1**	**2**	**3**	**4**
18 39%	6 13%	14 30%	3 7%	5 11%

Number of births

0	**1**	**2**	**3**	**4**
20 43%	6 13%	14 30%	3 7%	3 7%

Age at 1st birth

Gave birth at younger than 25	**25-40**	**Older than 40**
9 35%	17 65%	0 0%

Caesarean

History of caesarean	**No history of caesarean**
5 20%	20 80%

Appendix 6

Data Recorded by Author of CT Scans with All Biographical Information

BMI Codes

1- Underweight
2- Healthy Weight
3- Overweight
4- Obese

Body Shape Codes

1- Rectangle
2- Hourglass
3- Apple
4- Triangle
5- Pear

Tobacco Consumption Codes

1- History of smoking
2- No history of smoking

Alcohol Consumption Codes

0- 0 Units
1- <4 Units
2- 5-9 Units
3- 10-14 Units
4- 15-19 Units
5- 20-24 Units
6- 25-29 Units
7- >30 Units

Activity Level Codes

1- Immobile
2- Light
3- Moderate
4- Active

Diet

0- Unknown
1- Poor
2- Average
3- Good

Caesarean Codes

0- Nulliparous
1- History of caesarean

2- No history of caesarean

Skelton	Side	Presence	Sex	Age	Grade	BMI	Body Shape
51	L	0	M	3	0	3	1
52	L	1	M	3	1	4	3
53	L	0	M	3	0	2	1
54	L	0	M	3	0	2	1
55	L	0	M	3	0	2	1
56	L	1	M	3	1	2	1
57	L	1	M	3	1	2	1
58	L	0	M	3	0	2	1
59	L	1	M	3	1	3	1
60	L	0	M	3	0	3	3
61	L	0	M	3	0	2	1
62	L	1	M	3	1	2	1
63	L	0	M	3	0	2	1
64	L	1	M	3	1	3	4
65	L	1	M	3	1	N/A	1
66	L	0	M	3	0	3	5
67	L	0	M	3	0	3	1
68	L	1	M	3	1	2	5
69	L	0	M	3	0	2	1
70	L	0	M	3	0	3	3
71	L	1	M	3	1	3	1
72	L	1	M	3	1	3	1
73	L	1	M	3	2	3	1
74	L	0	M	3	0	3	1
75	L	0	M	3	0	3	3
5	L	1	F	3	2	3	3
7	L	1	F	2	2	2	4
8	L	1	F	1	1	2	2
12	L	1	F	1	1	N/A	2
15	L	1	F	3	1	2	1
16	L	1	F	3	2	3	2
18	L	0	F	3	0	3	2
21	L	0	F	1	0	1	2
24	L	1	F	2	1	2	2
30	L	1	F	2	3	2	1
32	L	0	F	1	0	2	2
34	L	1	F	3	2	2	3
35	L	0	F	2	0	2	4
38	L	1	F	3	1	2	2
40	L	0	F	1	0	2	2
43	L	0	F	3	0	N/A	5
44	L	1	F	3	4	4	2
46	L	1	F	3	2	2	2
48	L	1	F	3	2	4	1
50	L	1	F	3	1	3	2
2	L	0	F	3	0	1	1
3	L	0	F	3	0	2	2

11	L	0	F	3	0	3	3
17	L	1	F	2	1	2	1
33	L	0	F	3	0	N/A	N/A
36	L	0	F	2	0	4	5
4	L	1	F	2	1	N/A	2
6	L	1	F	3	3	N/A	2
9	L	1	F	3	2	N/A	3
10	L	1	F	3	4	2	2
13	L	1	F	3	3	2	1
14	L	1	F	3	1	4	3
23	L	0	F	3	0	4	3
26	L	1	F	2	1	1	2
27	L	0	F	3	0	3	3
28	L	1	F	3	4	2	4
29	L	1	F	3	3	2	2
31	L	1	F	3	4	3	4
41	L	1	F	3	1	4	1
47	L	1	F	3	1	2	2
19	L	1	F	3	3	3	3
45	L	1	F	3	2	4	3
49	L	1	F	3	1	4	2
25	L	1	F	3	2	3	3
39	L	1	F	3	3	2	N/A
42	L	1	F	2	3	4	5

Skeleton	Tobacco	Alcohol	Activity	Diet	Num. Preg.	Num. Births	Age 1st Birth	Caesarean
51	2	2	3	2	N/A	N/A	N/A	N/A
52	1	5	2	1	N/A	N/A	N/A	N/A
53	2	2	3	2	N/A	N/A	N/A	N/A
54	2	0	2	2	N/A	N/A	N/A	N/A
55	2	3	4	2	N/A	N/A	N/A	N/A
56	2	0	3	3	N/A	N/A	N/A	N/A
57	2	1	3	3	N/A	N/A	N/A	N/A
58	1	3	3	3	N/A	N/A	N/A	N/A
59	1	N/A	2	2	N/A	N/A	N/A	N/A
60	2	2	3	3	N/A	N/A	N/A	N/A
61	2	2	4	2	N/A	N/A	N/A	N/A
62	2	3	3	2	N/A	N/A	N/A	N/A
63	2	1	2	3	N/A	N/A	N/A	N/A
64	2	4	4	3	N/A	N/A	N/A	N/A
65	N/A	2	2	0	N/A	N/A	N/A	N/A
66	2	2	3	3	N/A	N/A	N/A	N/A
67	2	2	3	2	N/A	N/A	N/A	N/A
68	2	0	3	2	N/A	N/A	N/A	N/A
69	2	0	3	3	N/A	N/A	N/A	N/A
70	2	2	3	2	N/A	N/A	N/A	N/A
71	2	2	2	2	N/A	N/A	N/A	N/A
72	2	1	2	3	N/A	N/A	N/A	N/A
73	1	3	4	2	N/A	N/A	N/A	N/A
74	2	1	2	2	N/A	N/A	N/A	N/A

75	2	0	2	3	N/A	N/A	N/A	N/A
5	2	1	4	2	0	0	0	0
7	2	1	3	3	1	0	0	0
8	2	1	3	2	0	0	0	0
12	1	0	3	2	0	0	0	0
15	2	2	3	3	0	0	0	0
16	2	0	2	2	0	0	0	0
18	2	2	2	2	0	0	0	0
21	2	5	4	3	0	0	0	0
24	2	1	3	3	0	0	0	0
30	2	0	3	2	0	0	0	0
32	2	1	4	2	0	0	0	0
34	2	2	3	3	0	0	0	0
35	1	6	3	2	0	0	0	0
38	2	1	3	3	0	0	0	0
40	2	7	4	2	0	0	0	0
43	2	2	2	2	0	0	0	0
44	2	2	2	2	2	0	0	0
46	2	0	3	3	0	0	0	0
48	2	0	2	1	0	0	0	0
50	1	1	3	2	0	0	0	0
2	1	1	3	1	1	1	2	2
3	2	1	3	2	2	1	2	1
11	1	0	2	1	1	1	2	2
17	2	1	4	2	1	1	2	1
33	1	3	3	1	1	1	2	1
36	2	3	3	3	1	1	2	2
4	2	1	3	2	2	2	2	2
6	2	4	2	1	2	2	2	2
9	1	0	2	1	2	2	1	2
10	1	2	3	3	3	2	2	2
13	2	0	3	3	2	2	1	2
14	2	0	3	3	2	2	2	1
23	2	3	3	3	2	2	1	2
26	2	1	4	1	2	2	1	0
27	2	0	1	3	2	2	2	2
28	2	0	2	3	2	2	2	2
29	2	N/A	2	3	2	2	2	2
31	2	2	3	3	2	2	2	2
41	2	0	2	3	4	2	2	1
47	1	3	2	2	2	2	2	2
19	2	2	2	2	3	3	1	2
45	2	5	3	2	4	3	1	2
49	2	2	4	3	3	3	1	2
25	2	0	3	2	4	4	1	2
39	2	3	3	2	4	4	1	2
42	2	0	2	3	4	4	2	2

Appendix 7

Statistical Output for Results of CT Scans with All Biographical Information

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Skelton	.073	38	.200*	.964	38	.253
Side	.	38	.	.	38	.
Presence	.446	38	.000	.570	38	.000
Sex	.	38	.	.	38	.
Age	.415	38	.000	.639	38	.000
Grade	.199	38	.001	.877	38	.001
BMICat	.288	38	.000	.843	38	.000
BodyShape	.257	38	.000	.882	38	.001
TocaccoCat	.508	38	.000	.439	38	.000
AlcoholCat	.214	38	.000	.832	38	.000
NumPreg	.251	38	.000	.823	38	.000
NumBirths	.286	38	.000	.802	38	.000
Age1stBirth	.307	38	.000	.724	38	.000
CaesareanCat	.326	38	.000	.696	38	.000
Activity	.284	38	.000	.840	38	.000
Diet	.299	38	.000	.762	38	.000

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

BMI

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	3.155	3.180
df	3	3
Asymp. Sig.	.368	.365

a. Kruskal Wallis Test

b. Grouping Variable: BMICat

Body Shape

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	3.627	5.258
df	4	4

Asymp. Sig.	.459	.262

a. Kruskal Wallis Test

b. Grouping Variable: BodyShape

Tobacco Consumption

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	.000	.116
df	1	1
Asymp. Sig.	.993	.733

a. Kruskal Wallis Test

b. Grouping Variable: TocaccoCat

Alcohol Consumption

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	5.855	5.644
df	7	7
Asymp. Sig.	.557	.582

a. Kruskal Wallis Test

b. Grouping Variable: AlcoholCat

Activity Level

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	2.426	3.339
df	3	3
Asymp. Sig.	.489	.342

a. Kruskal Wallis Test

b. Grouping Variable: Activity

Diet

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	.409	.574
df	2	2
Asymp. Sig.	.815	.751

a. Kruskal Wallis Test

b. Grouping Variable: Diet

Number of pregnancies

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	7.892	10.698
df	4	4
Asymp. Sig.	.096	.030

a. Kruskal Wallis Test

b. Grouping Variable: NumPreg

Number of Births

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	12.442	13.196
df	4	4
Asymp. Sig.	.014	.010

a. Kruskal Wallis Test

b. Grouping Variable: NumBirths

Age 1st Birth

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	1.682	.601
df	1	1
Asymp. Sig.	.195	.438

a. Kruskal Wallis Test

b. Grouping Variable: Age1stBirth

Caesareans

Test Statistics[a,b]

	Presence	Grade
Kruskal-Wallis H	.429	3.164
df	1	1
Asymp. Sig.	.513	.075

a. Kruskal Wallis Test

b. Grouping Variable: CaesareanCat

			Presence	Sex	Age	Grade	BMICat	BodyShape	TocaccoCat	AlcoholCat	NumPreg	NumBirths	Age1stBirth	CaesareanCat	Activity	Diet
Spearman's rho	Presence	Correlation Coefficient	1.000	-.273*	-.006	.883**	.086	.018	-.001	.054	.259	.224	-.041	.036	-.070	.033
		Sig. (2-tailed)	.	.021	.960	.000	.499	.883	.993	.662	.082	.135	.786	.812	.563	.782
		N	71	71	71	71	64	69	70	69	46	46	46	46	71	71
	Sex	Correlation Coefficient	-.273*	1.000	.363**	-.391**	.021	-.371**	.035	.197	.	.	.	.	-.014	.023
		Sig. (2-tailed)	.021	.	.002	.001	.871	.002	.771	.105	.	.	.	.	.906	.850
		N	71	71	71	71	64	69	70	69	46	46	46	46	71	71
	Age	Correlation Coefficient	-.006	.363**	1.000	.049	.291*	-.137	-.050	-.003	.346*	.324*	.268	.368*	-.352**	.017
		Sig. (2-tailed)	.960	.002	.	.685	.019	.263	.684	.977	.019	.028	.071	.012	.003	.890
		N	71	71	71	71	64	69	70	69	46	46	46	46	71	71
	Grade	Correlation Coefficient	.883**	-.391**	.049	1.000	.092	.130	.041	-.082	.387**	.317*	.064	.226	-.137	.055
		Sig. (2-tailed)	.000	.001	.685	.	.469	.288	.736	.505	.008	.032	.673	.131	.254	.648
		N	71	71	71	71	64	69	70	69	46	46	46	46	71	71
	BMICat	Correlation Coefficient	.086	.021	.291*	.092	1.000	.303*	.034	-.057	.349*	.290	.167	.269	-.343**	-.001
		Sig. (2-tailed)	.499	.871	.019	.469	.	.016	.790	.655	.027	.069	.303	.093	.006	.993
		N	64	64	64	64	64	63	64	63	40	40	40	40	64	64
	BodyShape	Correlation Coefficient	.018	-.371**	-.137	.130	.303*	1.000	.022	-.121	.201	.236	.131	.244	-.048	.160
		Sig. (2-tailed)	.883	.002	.263	.288	.016	.	.862	.329	.190	.123	.398	.110	.694	.188
		N	69	69	69	69	63	69	68	67	44	44	44	44	69	69
	TocaccoCat	Correlation Coefficient	-.001	.035	-.050	.041	.034	.022	1.000	-.135	.067	.039	-.156	-.127	.087	.355**
		Sig. (2-tailed)	.993	.771	.684	.736	.790	.862	.	.270	.658	.795	.301	.398	.475	.003
		N	70	70	70	70	64	68	70	69	46	46	46	46	70	70
	AlcoholCat	Correlation Coefficient	.054	.197	-.003	-.082	-.057	-.121	-.135	1.000	-.051	-.092	-.029	-.155	.205	-.009
		Sig. (2-tailed)	.662	.105	.977	.505	.655	.329	.270	.	.742	.550	.851	.309	.091	.944
		N	69	69	69	69	63	67	69	69	45	45	45	45	69	69
	NumPreg	Correlation Coefficient	.259	.	.346*	.387**	.349*	.201	.067	-.051	1.000	.940**	.714**	.808**	-.233	.108
		Sig. (2-tailed)	.082	.	.019	.008	.027	.190	.658	.742	.	.000	.000	.000	.120	.476
		N	46	46	46	46	40	44	46	45	46	46	46	46	46	46
	NumBirths	Correlation Coefficient	.224	.	.324*	.317*	.290	.236	.039	-.092	.940**	1.000	.755**	.885**	-.186	.076
		Sig. (2-tailed)	.135	.	.028	.032	.069	.123	.795	.550	.000	.	.000	.000	.215	.617
		N	46	46	46	46	40	44	46	45	46	46	46	46	46	46
	Age1stBirth	Correlation Coefficient	-.041	.	.268	.064	.167	.131	-.156	-.029	.714**	.755**	1.000	.834**	-.244	.030
		Sig. (2-tailed)	.786	.	.071	.673	.303	.398	.301	.851	.000	.000	.	.000	.102	.841
		N	46	46	46	46	40	44	46	45	46	46	46	46	46	46
	CaesareanCat	Correlation Coefficient	.036	.	.368*	.226	.269	.244	-.127	-.155	.808**	.885**	.834**	1.000	-.285	.071
		Sig. (2-tailed)	.812	.	.012	.131	.093	.110	.398	.309	.000	.000	.000	.	.055	.641

		N	46	46	46	46	40	44	46	45	46	46	46	46	46	46
	Activity	Correlation Coefficient	-.070	-.014	-.352**	-.137	-.343**	-.048	.087	.205	-.233	-.186	-.244	-.285	1.000	.097
		Sig. (2-tailed)	.563	.906	.003	.254	.006	.694	.475	.091	.120	.215	.102	.055	.	.423
		N	71	71	71	71	64	69	70	69	46	46	46	46	71	71
	Diet	Correlation Coefficient	.033	.023	.017	.055	-.001	.160	.355**	-.009	.108	.076	.030	.071	.097	1.000
		Sig. (2-tailed)	.782	.850	.890	.648	.993	.188	.003	.944	.476	.617	.841	.641	.423	.
		N	71	71	71	71	64	69	70	69	46	46	46	46	71	71

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 8

Data Recorded by Observers

Skelton	Side	Correct Grades	Intra-observer grades	Sam Rennie	Student 1	Student 2	Student 3	Student 4	Student 5
42	L	1	1	1	1	1	1	1	1
42	R	1	1	2	2	2	1	1	0
372	L	0	0	0	0	0	0	2	0
372	R	0	0	0	1	1	1	1	0
460	L	0	0	0	1	1	0	0	0
460	R	0	0	0	0	0	0	1	0
497	L	0	0	0	0	0	1	1	1
497	R	0	0	0	1	1	0	1	0
288	L	1	1	1	1	1	2	1	1
288	R	1	1	1	1	1	1	1	0
336	L	1	2	1	2	2	1	1	1
336	R	1	1	1	2	2	3	3	0
90	L	2	3	1	3	3	2	2	1
90	R	2	2	2	3	3	2	2	3
110	L	2	2	2	2	2	1	2	1
110	R	2	2	2	2	2	1	1	2
293	L	2	2	2	1	1	1	1	1
293	R	2	2	2	2	2	2	1	2
380	L	3	3	3	3	3	2	1	2
380	R	3	3	3	3	3	3	3	3
392	L	3	3	3	1	1	2	1	2
392	R	3	3	3	4	4	2	2	2
448	L	3	3	2	3	3	2	3	4
448	R	3	3	3	2	2	1	3	2
340	L	4	4	4	4	4	4	4	4
340	R	4	4	4	4	4	4	3	4
485	L	4	4	4	4	4	3	3	4
203	R	4	4	4	4	3	3	3	3
313	R	4	4	4	4	4	2	3	3
331	L	4	4	4	4	4	4	3	4

Appendix 9

Statistical Output for Intra-and-Inter-Observer Error

CorrectGrades * SamRennie

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.875	.068	9.598	.000
N of Valid Cases		30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

CorrectGrades * IntraobserverGrade

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.917	.057	10.056	.000
N of Valid Cases		30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

CorrectGrades * Student1- The Forensic Anthropology BSc student

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.500	.111	5.539	.000
N of Valid Cases		30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

CorrectGrades * Student2- The Forensic Science BSc student

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.458	.113	5.070	.000
N of Valid Cases		30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

CorrectGrades * Student3- The Bioarchaeology MSc student

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.375	.113	4.233	.000
N of Valid Cases		30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

CorrectGrades * Student4- The Forensic Science MSc student

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.292	.103	3.512	.000

N of Valid Cases	30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

CorrectGrades * Student5- The Forensic Anthropology MSc student

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.375	.112	4.137	.000
N of Valid Cases		30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

<u>Appendix 10</u>

Grade/Age within Sex

Poulton

Females

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 0 0%	N= 2 33%	N= 4 67%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 0 0%	N= 8 42%	N= 8 42%	N= 3 16%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 1 **4.5%**	N= 1 4.5%	N= 8 36%	N= 7 32%	N= 5 23%

Males

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 1 **25%**	N= 3 75%	N= 0 0%	N= 0 0%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 10 **45%**	N= 10 45%	N= 2 10%	N= 0 0%	N= 0 0%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 12 **57%**	N= 9 43%	N= 0 0%	N= 0 0%	N= 0 0%

St Owens

Females

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 0 0%	N= 0 0%	N= 2 100%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 0 0%	N= 4 44%	N= 4 44%	N= 1 12%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 4 **19%**	N= 4 19%	N= 6 29%	N= 6 29%	N= 1 4%

Males

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 2 **40%**	N= 2 40%	N= 1 20%	N= 0 0%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 4 **45%**	N= 3 33%	N= 2 22%	N= 0 0%	N= 0 0%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 13 **68%**	N= 4 21%	N= 2 11%	N= 0 0%	N= 0 0%

Spitalfields

Females

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 3 **60%**	N= 0 0%	N= 1 20%	N= 1 20%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 1 **8%**	N= 2 15%	N= 38%	N= 4 31%	N= 1 78%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 2 **3%**	N= 7 12%	N= 21 36%	N= 17 29%	N= 12 20%

St Brides

Females

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 3 50%	N= 0 0%	N= 3 50%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 2 10%	N= 7 33%	N= 7 33%	N= 5 24%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 1 **2%**	N= 5 8%	N= 17 27%	N= 29 45%	N= 12 18%

Males

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 7 **78%**	N= 2 22%	N= 0 0%	N= 0 0%	N= 0 0%

Age category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 8 **40%**	N= 6 30%	N= 5 25%	N= 1 5%	N= 0 0%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 35 **50%**	N= 28 40%	N= 7 10%	N= 0 0%	N= 0 0%

South African Blacks

Females

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 1 11%	N= 2 23%	N= 3 33%	N= 3 33%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 10 **27%**	N= 1 3%	N= 11 29%	N= 10 27%	N= 5 14%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 6 **11%**	N= 9 18%	N= 11 22%	N= 12 23%	N= 13 24%

Males

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 5 **63%**	N= 3 37%	N= 0 0%	N= 0 0%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 29 **69%**	N= 7 17%	N= 6 14%	N= 0 0%	N= 0 0%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 39 **68%**	N=17 30%	N= 1 2%	N= 0 0%	N= 0 0%

<u>South African Whites</u>

Females

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 0 0%	N= 1 100%	N= 0 0%	N= 0 0%

For this sample there were no females in Age Category 2

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 10 **10%**	N= 18 19%	N= 26 27%	N= 16 16%	N= 27 28%

Males

For this sample there were no males in Age Category 1

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 4 **80%**	N=1 20%	N= 0 0%	N= 0 0%	N= 0 0%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 70 **78%**	N=15 17%	N= 4 4%	N= 1 1%	N= 0 0%

CT Scans

Females

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 3 **60%**	N= 2 40%	N= 0 0%	N= 0 0%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 2 **22%**	N= 4 45%	N= 1 11%	N= 2 22%	N= 0 0%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 8 **25%**	N= 7 22%	N= 8 25%	N= 5 16%	N= 4 12%

For this sample all the males were Age Category 3

Appendix 11

Data Recorded by Author without Parity information

Poulton

Skelton	Side	Presence	Sex	Age Category	Max. Length	Max. Width	Grade
41	L	1	M	1	23.31	26.24	1
358	L	1	F	2	40.62	14.05	2
372	L	0	M	3	.00	.00	0
375	L	0	M	3	.00	.00	0
380	L	1	F	1	30.68	16.66	3
386	L	1	M	2	39.90	6.20	1
392	L	1	F	3	29.38	14.62	3
395	L	1	F	2	33.47	15.08	3
369	L	1	F	2	39.20	8.96	3
416	L	1	M	2	37.93	10.86	1
419	L	0	M	3	.00	.00	0
420	L	1	F	3	24.19	36.76	2
425	L	1	M	3	32.83	7.64	1
428	L	1	F	3	28.96	9.37	3
436	L	1	M	3	34.34	9.16	1
448	L	1	F	1	26.42	7.19	3
457	L	1	F	2	40.29	15.74	3
458	L	1	F	2	37.50	7.84	3
460	L	0	M	3	.00	.00	0
481	L	1	M	2	32.56	7.83	1
482	L	1	F	3	32.46	9.15	2
485	L	1	F	2	35.74	10.23	4
487	L	1	M	1	26.83	7.18	1
490	L	1	F	3	36.51	6.99	3
496	L	0	M	2	.00	.00	0
497	L	0	M	3	.00	.00	0
507	L	0	M	2	.00	.00	0
508	L	1	M	2	27.56	8.75	1
513	L	1	M	2	44.65	9.23	1
515	L	1	M	2	40.11	11.08	1
519	L	1	F	2	37.95	17.12	4
526	R	1	F	3	45.33	8.24	3
531	L	0	M	3	.00	.00	0
536	L	1	F	2	32.95	10.16	3
553	L	1	M	3	34.85	6.03	1
555	L	1	F	2	33.02	6.46	3
564	L	0	M	3	.00	.00	0
537	L	1	M	2	33.36	10.65	2
538	L	1	M	2	48.89	6.86	1
539	L	0	M	2	.00	.00	0
546	L	1	F	1	40.94	10.23	2
548	L	1	F	3	34.22	8.74	4

576	L	1	F	3	44.19	12.19	4
578	L	0	M	2	.00	.00	0
580	L	1	F	3	39.00	11.98	2
585	R	0	M	2	.00	.00	0
586	L	1	M	3	25.67	3.12	1
587	L	1	F	3	25.56	6.60	2
589	L	0	M	2	.00	.00	0
601	L	1	M	2	42.17	6.76	2
609	L	1	F	3	35.79	5.76	2
611	L	1	F	1	51.63	9.14	3
617	L	0	M	1	.00	.00	0
621	L	1	M	2	47.36	6.00	1
622	L	1	F	1	34.52	8.00	3
627	R	1	M	3	25.55	4.62	1
641	L	0	M	2	.00	.00	0
45	L	1	F	3	31.48	6.06	2
50	L	1	M	3	37.73	6.36	1
67	L	1	F	2	31.60	7.09	2
85	L	1	M	1	27.32	5.40	1
86	L	1	F	3	N/A	N/A	3
90	L	1	F	2	35.54	7.38	2
93	L	1	F	2	27.85	10.16	2
95	L	1	F	2	41.70	11.25	2
96	L	1	F	3	32.59	9.72	2
103	L	0	F	3	.00	.00	0
110	L	1	F	2	33.21	7.01	2
112	L	1	F	3	30.34	6.30	1
113	L	1	F	3	30.98	13.42	2
131	L	0	M	3	.00	.00	0
155	L	1	F	3	44.70	11.12	3
180	R	1	F	2	32.23	7.32	2
202	R	1	F	1	34.12	10.36	2
203	L	1	F	2	41.37	9.11	3
207	L	0	M	2	.00	.00	0
274	L	1	F	3	41.87	10.76	4
286	L	0	M	3	.00	.00	0
288	L	1	M	3	34.64	3.84	1
292	L	1	M	3	19.85	4.34	1
293	L	1	F	2	N/A	N/A	2
295	L	1	M	2	28.31	5.78	1
298	L	0	M	2	.00	.00	0
306	L	1	F	2	50.88	14.84	3
310	L	0	M	3	.00	.00	0
313	L	1	F	3	51.48	9.99	3
318	L	0	M	2	.00	.00	0
328	L	0	M	3	.00	.00	0
330	L	1	F	3	39.38	15.04	4
331	L	1	F	2	34.93	13.87	4
334	L	0	M	3	.00	.00	0
336	L	1	M	3	29.52	10.50	1
339	R	1	M	2	34.13	7.79	1
340	L	1	F	3	42.53	15.31	4

St Owens

Skeleton	Side	Presence	Sex	Age category	Max. Length	Max. Width	Grade
1354	L	1	F	2	21.89	7.92	2
1062	L	0	M	3	.00	.00	0
1035	L	1	F	3	38.48	13.64	3
1330	L	0	M	3	.00	.00	0
1068	L	1	F	3	40.47	33.02	2
1711	L	0	F	3	.00	.00	0
1312	L	0	M	3	.00	.00	0
1259	L	1	M	2	23.69	6.09	1
1544	L	1	F	3	39.67	9.53	2
1714	L	0	M	3	.00	.00	0
1724	L	1	F	3	16.97	6.30	1
1698	L	1	F	2	45.20	14.84	3
1623	L	1	F	3	22.17	6.65	1
1214	L	0	M	1	.00	.00	0
1142	L	1	F	3	36.37	36.74	3
1235	L	0	M	3	.00	.00	0
1742	L	1	M	3	27.62	7.90	2
1065	L	1	F	3	32.31	28.63	1
1133	L	0	F	3	.00	.00	0
1160	L	0	M	2	.00	.00	0
1529	R	1	M	1	35.78	10.63	1
1443	L	0	M	3	.00	.00	0
1072	L	1	F	3	37.56	8.02	3
1513	R	0	M	3	.00	.00	0
1704	L	1	M	3	24.63	7.05	1
1721	L	1	F	2	35.84	29.78	4
1369	L	1	F	3	31.64	8.37	2
1321	L	1	F	3	36.56	5.23	4
1282	L	1	M	3	30.26	8.13	1
1761	L	0	F	3	.00	.00	0
1538	L	1	F	2	26.26	5.89	2
1241	L	0	M	3	.00	.00	0
1541	L	1	M	3	31.84	14.14	2
1279	L	0	F	3	.00	.00	0
1306	R	1	M	2	19.42	5.98	1
1157	L	1	F	2	31.39	6.16	2
1387	L	0	M	3	.00	.00	0
1144	R	1	F	3	35.58	6.81	1
1532	L	1	F	2	29.42	7.44	2
1357	L	1	M	1	39.42	30.57	1
1149	L	1	M	2	33.38	6.56	2
1333	L	0	M	3	.00	.00	0
1611	L	0	M	2	.00	.00	0
1079	L	0	M	2	.00	.00	0
1755	L	1	F	3	19.18	5.80	2
1228	L	1	M	3	41.45	12.36	1

1173	L	0	M	3	.00	.00	0
1336	R	1	M	2	33.43	7.38	1
1468	L	0	M	1	.00	.00	0
1500	L	1	F	3	29.52	33.88	3
1506	L	1	F	2	41.57	32.79	3
1629	L	1	F	3	36.51	32.65	3
1453	L	1	F	2	39.54	40.73	3
1551	L	1	F	1	33.21	13.06	3
1605	L	1	F	2	29.54	12.73	3
1572	L	0	M	3	.00	.00	0
1459	L	0	M	3	.00	.00	0
1584	L	0	M	2	.00	.00	0
1471	L	1	M	1	33.57	8.05	2
1662	L	1	F	3	26.70	14.34	2
1456	L	1	M	2	32.55	5.22	2
1560	R	1	F	3	46.25	17.83	3
1602	L	1	F	3	32.39	13.12	2
1688	L	1	M	3	30.92	8.98	1
1557	L	1	F	1	27.18	8.36	3

Spitalfields

Skeleton	Side	Presence	Sex	Age Category	Max. Length	Max. Width	Grade
2142	L	1	F	2	33.40	7.10	2
2152	L	1	F	3	19.80	7.10	3
2169	L	1	F	3	42.50	8.30	2
2175	L	0	F	1	.00	.00	0
2189	L	1	F	3	31.80	12.70	3
2205	L	1	F	3	40.10	15.20	4
2281	L	1	F	2	44.10	9.60	1
2335	L	1	F	3	37.10	6.20	2
2382	L	1	F	3	43.80	14.90	4
2477	L	1	F	2	34.10	9.60	2
2521	L	1	F	3	36.40	11.50	3
2557	L	1	F	3	41.70	9.60	4
2605	L	0	F	1	.00	.00	0
2609	L	1	F	3	26.90	6.30	3
2667	L	1	F	2	35.40	10.40	2
2698	L	0	F	1	.00	.00	0
2747	L	1	F	3	21.80	6.30	1
2752	L	1	F	1	25.10	11.30	3
2867	L	1	F	3	33.60	11.60	2
2918	L	1	F	3	27.80	10.50	2
2004	L	1	F	3	36.60	11.80	2
2070	L	1	F	2	47.20	14.70	4
2098	R	1	F	3	42.60	9.00	3
2099	L	1	F	3	33.80	6.00	2
2111	L	1	F	3	34.70	9.90	4
2166	L	1	F	3	22.60	13.30	3
2184	L	1	F	3	36.50	11.00	2

2192	L	1	F	3	.00	.00	1
2204	L	1	F	3	35.50	10.50	3
2243	L	1	F	3	38.40	11.00	1
2259	L	1	F	3	38.50	11.50	2
2263	L	1	F	3	33.80	9.40	2
2298	L	1	F	3	41.60	22.50	3
2301	L	1	F	2	29.20	8.60	2
2327	L	1	F	1	27.90	12.40	2
2368	L	1	F	3	30.40	7.20	2
2371	L	1	F	3	31.20	15.10	4
2399	L	1	F	2	33.80	11.80	3
2407	L	1	F	3	23.50	4.50	1
2432	L	1	F	3	33.30	17.50	4
2465	L	1	F	2	29.10	7.10	3
2467	L	1	F	3	32.50	12.10	1
2470	L	1	F	3	41.70	13.70	3
2472	L	1	F	3	49.10	10.20	3
2484	L	1	F	3	33.40	3.90	2
2487	L	1	F	3	33.50	12.60	4
2493	L	1	F	3	33.10	10.10	2
2498	L	1	F	3	37.50	9.70	3
2500	L	1	F	2	27.20	13.50	2
2507	L	1	F	3	34.40	15.20	4
2518	L	1	F	3	45.90	10.40	4
2526	L	1	F	3	30.60	9.60	2
2544	L	1	F	3	25.10	6.90	3
2551	L	1	F	3	49.10	9.00	2
2563	L	1	F	3	26.80	4.40	1
2565	L	0	F	3	.00	.00	0
2566	L	1	F	3	25.50	20.50	3
2568	L	1	F	3	42.70	6.30	2
2569	L	1	F	3	30.90	9.60	4
2579	L	1	F	3	42.30	14.70	4
2604	L	1	F	3	32.90	5.70	2
2642	L	1	F	3	25.10	13.90	3
2647	L	1	F	3	48.00	12.10	3
2670	L	0	F	3	.00	.00	0
2708	L	1	F	2	20.00	8.40	1
2710	L	1	F	3	32.70	12.40	2
2748	L	1	F	3	39.30	10.30	2
2751	L	1	F	3	36.30	14.80	4
2787	L	1	F	3	38.70	11.00	3
2789	R	1	F	3	34.00	9.90	1
2817	L	1	F	3	35.50	6.00	2
2872	L	1	F	2	36.30	9.60	3
2882	L	1	F	3	31.70	11.00	2
2889	L	1	F	3	41.20	9.60	2
2921	L	1	F	2	33.30	14.90	3
2930	L	0	F	2	.00	.00	0
2956	L	1	F	3	40.70	9.40	3

St Brides

Skeleton	Side	Presence	Sex	Age	Max. Length	Max. Width	Grade
2	L	1	M	2	34.39	3.96	1
7	L	1	L	3	45.32	9.26	2
8	L	1	L	3	37.35	40.87	3
10	L	1	L	1	38.80	14.87	1
11	L	0	M	2	.00	.00	0
12	L	1	M	2	42.75	7.19	2
13	L	1	L	2	31.26	6.57	2
14	L	1	M	2	39.86	6.32	1
15	L	1	M	2	37.91	35.83	2
16	L	1	F	3	22.14	9.68	3
17	L	1	F	3	60.28	14.17	4
18	L	0	M	1	.00	.00	0
20	L	1	M	3	37.81	7.21	1
28	L	0	M	3	.00	.00	0
29	L	0	M	3	.00	.00	0
31	L	1	F	2	42.66	12.15	3
33	L	1	F	3	34.28	14.99	3
43	L	1	F	2	26.73	12.38	3
44	L	1	F	2	31.63	16.02	3
45	L	1	F	3	35.54	13.78	3
46	L	0	M	1	.00	.00	0
47	L	0	M	3	.00	.00	0
50	L	1	M	1	33.09	9.49	1
51	L	1	M	2	30.07	18.51	1
52	L	1	F	1	35.07	18.94	3
53	L	1	M	1	44.64	4.67	1
54	L	1	M	2	24.76	15.10	3
56	L	1	M	2	34.68	9.27	2
58	L	0	M	3	.00	.00	0
59	L	0	M	3	.00	.00	0
60	L	0	M	1	.00	.00	0
61	L	0	M	1	.00	.00	0
62	L	1	F	2	29.90	10.90	4
63	L	1	F	2	43.94	20.44	3
64	L	0	M	3	.00	.00	0
65	L	0	M	1	.00	.00	0
66	L	1	F	3	34.32	7.98	1
67	L	0	M	1	.00	.00	0
68	L	1	M	2	32.75	11.94	1
69	L	1	F	2	41.74	17.36	1
70	L	0	M	2	.00	.00	0
71	L	0	M	3	.00	.00	0
72	L	1	F	1	39.10	6.24	1
73	L	0	M	2	.00	.00	0
74	L	1	F	1	39.03	9.31	1
75	L	0	M	1	.00	.00	0
76	L	1	F	3	44.72	11.63	3
77	L	1	F	1	43.44	11.49	3

78	L	1	M	3	28.61	6.58	2
79	L	1	M	3	34.21	11.32	1
81	L	1	M	2	34.17	12.71	2
83	L	1	F	3	36.18	12.45	3
84	L	0	M	3	.00	.00	0
86	L	1	M	3	48.70	9.15	1
88	L	1	F	3	36.97	11.85	3
89	L	1	F	3	44.45	11.14	3
90	L	1	M	3	28.31	7.43	2
92	L	0	M	3	.00	.00	0
93	L	1	F	3	35.40	13.36	4
94	L	1	M	3	25.89	4.69	1
97	L	1	F	3	55.07	12.70	3
98	L	1	F	2	24.95	9.95	2
99	L	1	F	3	28.57	8.64	2
100	L	1	M	3	22.35	6.98	1
101	L	1	F	3	35.08	11.98	4
103	L	1	F	2	25.76	14.54	4
104	L	1	F	3	29.96	6.98	2
105	L	0	M	3	.00	.00	0
106	L	1	F	2	44.16	8.61	3
107	L	1	M	3	37.86	6.22	1
108	L	0	M	2	.00	.00	0
109	L	1	1	3	26.93	12.09	2
110	L	1	M	3	22.67	4.64	1
112	L	0	M	3	.00	.00	0
113	L	1	F	3	42.08	8.34	3
115	L	0	M	2	.00	.00	0
116	L	1	F	3	27.50	7.76	2
117	L	1	F	3	30.78	13.19	3
118	L	1	M	3	43.98	6.84	1
119	L	1	M	2	36.35	11.31	2
120	L	1	F	3	33.01	12.09	3
121	L	1	F	3	41.43	16.09	4
122	L	1	F	2	36.78	10.71	4
123	L	1	F	3	33.65	7.04	3
124	L	0	M	3	.00	.00	0
125	L	0	M	3	.00	.00	0
126	L	1	F	3	21.76	8.97	2
127	L	1	M	3	36.98	15.80	2
128	L	1	F	3	36.10	9.32	3
129	L	1	F	3	36.28	11.15	2
130	L	1	F	3	40.53	13.30	2
131	L	0	M	3	.00	.00	0
132	L	1	M	3	35.50	6.94	1
133	L	1	F	3	44.01	14.62	4
134	L	1	F	3	37.69	13.20	4
135	L	1	F	3	22.73	9.52	3
137	L	1	M	3	36.41	10.21	2
139	L	0	M	3	.00	.00	0
140	L	1	M	3	27.90	3.94	1
141	L	1	M	3	35.41	9.34	1

143	L	1	M	3	33.62	3.46	1
144	R	1	F	3	33.89	11.46	4
145	L	1	M	3	51.83	12.04	2
146	L	1	F	3	47.12	10.14	3
147	L	1	F	3	29.73	8.18	2
148	L	1	F	3	28.55	6.80	2
149	L	0	M	3	.00	.00	0
151	L	1	F	3	32.55	11.89	4
152	L	1	F	2	43.31	7.51	1
153	L	1	F	2	37.51	8.05	2
154	L	1	F	2	50.55	6.48	2
155	R	1	M	3	27.17	7.79	1
156	L	1	F	2	32.81	16.97	4
157	L	0	M	3	.00	.00	0
158	R	0	M	3	.00	.00	0
159	R	1	F	3	31.64	10.45	1
161	L	0	M	3	.00	.00	0
164	L	0	M	3	.00	.00	0
165	L	1	F	3	36.64	9.84	3
166	R	1	M	3	17.66	4.76	1
167	L	1	F	3	32.30	10.18	2
168	L	1	F	3	16.49	11.95	3
169	L	0	M	3	.00	.00	0
170	L	1	M	2	37.24	13.03	1
171	L	0	M	2	.00	.00	0
172	L	1	F	3	29.60	9.02	2
173	L	0	M	3	.00	.00	0
174	L	1	F	3	38.23	10.78	3
175	L	1	F	3	33.96	7.87	3
176	L	0	M	3	.00	.00	0
177	L	1	F	2	31.47	9.51	2
178	L	1	F	2	38.57	9.03	2
179	L	1	M	3	28.54	10.42	2
180	L	1	M	3	25.46	10.66	1
181	L	1	M	3	37.41	10.86	1
182	L	1	F	3	34.45	11.62	2
183	L	1	M	3	42.82	10.30	2
184	L	1	F	3	34.25	13.07	3
185	L	1	F	3	31.93	4.63	1
186	L	1	F	3	40.63	11.86	3
187	L	1	F	3	44.03	9.73	2
188	L	1	M	3	27.97	6.14	1
190	R	1	F	3	30.69	6.80	3
191	L	0	M	3	.00	.00	0
192	L	1	M	3	46.85	5.56	1
193	L	0	F	3	.00	.00	0
194	L	0	M	2	.00	.00	0
195	L	1	M	3	34.39	6.39	1
196	L	0	M	3	.00	.00	0
198	L	1	M	3	30.18	4.54	1
199	L	1	M	3	29.75	5.00	1
200	L	1	F	2	37.11	10.11	4

201	L	1	M	3	42.90	11.64	1
202	R	1	F	3	35.64	13.39	3
203	L	1	F	1	39.37	11.72	3
204	L	1	F	3	38.60	11.01	4
205	L	1	M	3	39.13	9.46	1
206	L	0	M	3	.00	.00	0
207	L	1	M	3	27.12	7.40	1
208	L	1	F	3	35.02	14.04	3
211	L	1	F	3	35.58	15.07	4
212	L	0	M	3	.00	.00	0
213	L	0	M	3	.00	.00	0
214	L	1	F	2	32.99	6.82	2
215	L	1	F	3	44.50	11.06	4
216	R	0	M	3	.00	.00	0
218	L	1	M	3	30.15	8.15	1
219	L	1	F	3	33.70	14.44	3
220	L	1	F	3	54.76	15.76	3
221	L	1	M	3	39.38	13.92	1
222	L	1	M	3	44.41	6.12	1
223	L	1	F	3	24.48	13.55	2
224	L	0	M	3	.00	.00	0
225	L	1	F	2	41.09	15.63	3
226	L	1	M	2	44.72	13.09	1
227	L	1	F	2	34.14	12.28	3
228	L	1	F	3	40.79	10.80	1
229	L	1	F	3	20.55	5.40	2
230	R	1	F	3	40.95	11.12	3
231	L	0	M	3	.00	.00	0
232	R	1	F	3	23.83	4.68	2
233	R	0	M	3	.00	.00	0
235	L	1	F	3	40.66	14.53	4
236	L	1	F	3	29.60	9.43	1
237	L	0	M	3	.00	.00	0
239	R	0	M	2	.00	.00	0
240	L	0	M	3	.00	.00	0
241	R	1	F	3	38.41	12.48	3
243	R	0	M	3	.00	.00	0
244	L	1	M	3	24.28	5.81	1

South African Blacks

Skeleton	Side	Presence	Sex	Age Category	Grade
1543	L	0	F	2	0
1696	L	1	F	3	4
2632	L	1	F	3	3
2858	L	1	F	3	3
2866	L	1	F	2	3
2885	L	1	F	3	3
2905	L	1	F	3	1
2939	L	1	F	3	4

3015	L	1	F	3	3
3041	L	1	F	2	2
3120	L	1	F	3	4
3154	L	1	F	2	4
3266	L	0	F	2	0
3385	L	1	F	2	1
3538	L	0	F	3	0
3609	L	1	F	3	1
3843	L	0	F	2	0
4198	L	1	F	2	3
4240	L	1	F	3	4
4256	L	1	F	3	2
4436	L	1	F	2	2
4448	L	0	F	2	0
4464	L	1	F	3	1
4492	L	1	F	3	4
4541	L	1	F	3	4
4543	L	1	F	3	2
4544	L	1	F	3	2
4564	L	1	F	3	4
4565	L	1	F	3	3
4575	L	1	F	2	3
4584	L	1	F	3	1
4598	L	0	F	2	0
4763	L	0	F	3	0
4786	L	1	F	2	2
4835	L	0	F	3	0
4956	L	1	F	2	4
4990	L	0	F	3	0
4998	L	1	F	3	2
5005	L	1	F	3	4
5013	L	1	F	3	4
5018	L	1	F	3	2
5033	L	1	F	3	1
5039	L	1	F	3	3
5073	L	1	F	3	1
5086	L	0	F	2	0
6094	L	1	F	2	2
6139	L	0	F	2	0
6144	L	1	F	3	3
6145	L	1	F	3	2
6157	L	1	F	2	3
6172	L	1	F	3	4
6290	L	1	F	1	4
1153	L	1	F	2	2
1156	L	1	F	2	4
1158	L	1	F	3	3
1178	L	1	F	2	3
1182	L	1	F	2	3
1209	L	0	F	2	0
122	L	1	F	2	2
1226	L	1	F	3	3

123	L	1	F	3	4
1263	L	1	F	2	2
1278	L	1	F	1	2
1381	L	1	F	2	4
1397	L	1	F	3	2
1448	L	1	F	2	4
1455	L	1	F	1	3
1458	L	1	F	1	3
1527	L	1	F	3	4
1552	L	1	F	2	2
1577	L	1	F	2	3
1601	L	1	F	3	4
1642	L	1	F	3	2
1644	L	1	F	1	2
1645	L	1	F	1	4
1646	L	1	F	3	2
1648	L	1	F	2	2
1663	L	0	F	3	0
1682	L	1	F	1	1
1730	L	1	F	3	3
1740	L	1	F	1	3
1745	L	1	F	2	2
1757	L	1	F	1	4
1758	L	1	F	2	2
1759	L	1	F	3	3
1761	L	0	F	2	0
1772	L	0	F	3	0
181	L	1	F	3	3
192	L	1	F	3	1
194	L	1	F	3	1
196	L	1	F	3	1
450	L	1	F	3	2
520	L	1	F	3	2
661	L	1	F	2	3
846	L	1	F	2	3
884	L	0	F	2	0
894	L	1	F	2	3
1694	L	0	M	2	0
2019	L	1	M	1	1
2053	L	0	M	3	0
2786	L	0	M	3	0
2788	L	0	M	3	0
2813	L	0	M	3	0
2855	L	1	M	3	1
2865	L	0	M	3	0
2906	L	1	M	3	1
2940	L	0	M	3	0
2949	L	0	M	3	0
2950	L	1	M	3	1
2978	L	0	M	3	0
2991	L	1	M	3	1
3003	L	0	M	3	0

3004	L	0	M	3	0
3008	L	0	M	3	0
3023	L	1	M	3	1
3038	L	0	M	2	0
3066	L	0	M	3	0
3096	L	1	M	2	2
3153	L	1	M	2	2
3298	L	1	M	2	1
3441	L	1	M	3	1
3670	L	1	M	3	2
3676	L	0	M	3	0
3718	L	0	M	2	0
4196	L	1	M	3	1
4200	L	0	M	3	0
4236	L	1	M	2	1
4244	L	0	M	3	0
4258	L	0	M	3	0
4265	L	0	M	3	0
4396	L	1	M	3	1
4405	L	1	M	3	1
4421	L	0	M	3	0
4487	L	0	M	3	0
4500	L	1	M	3	1
4522	L	0	M	2	0
4535	L	0	M	2	0
4542	L	0	M	3	0
4583	L	0	M	3	0
4591	L	1	M	2	2
4592	L	0	M	2	0
4599	L	0	M	2	0
5958	L	0	M	2	0
6186	L	0	M	2	0
6209	L	1	M	3	1
110	L	0	M	3	0
1100	L	0	M	2	0
1101	L	0	M	2	0
1110	L	1	M	3	1
1122	L	0	M	2	0
1128	L	0	M	3	0
113	L	1	M	2	2
1130	L	1	M	2	1
1132	L	0	M	1	0
114	L	0	M	2	0
1142	L	0	M	2	0
1143	L	0	M	3	0
1144	L	0	M	1	0
1148	L	1	M	2	1
1149	L	0	M	2	0
115	L	1	M	3	1
1150	L	0	M	2	0
1155	L	1	M	1	1
1157	L	0	M	3	0

1159	L	0	M	2	0
1160	L	0	M	2	0
1163	L	0	M	1	0
1165	L	1	M	3	1
1167	L	0	M	2	0
117	L	0	M	2	0
1170	L	0	M	2	0
1171	L	0	M	2	0
1172	L	0	M	3	0
118	L	0	M	3	0
12177	L	0	M	3	0
1218	L	0	M	1	0
12317	L	0	M	3	0
12318	L	0	M	2	0
12335	L	0	M	3	0
125	L	0	M	2	0
158	L	1	M	2	1
160	L	1	M	3	1
161	L	0	M	2	0
1785	L	0	M	2	0
1797	L	1	M	2	1
18	L	1	M	2	2
180	L	0	M	2	0
1812	L	0	M	3	0
182	L	0	M	3	0
183	L	0	M	3	0
1835	L	0	M	3	0
1841	L	1	M	3	1
1844	L	0	M	3	0
1847	L	1	M	1	1
186	L	0	M	3	0
188	L	0	M	3	0
19	L	0	M	1	0
190	L	0	M	3	0
193	L	0	M	3	0
195	L	1	M	2	1
197	L	0	M	2	0
1970	L	1	M	3	1
198	L	1	M	2	2

South African Whites

Skeleton	Side	Presence	Sex	Age Category	Grade
3700	L	1	F	3	4
4046	L	0	F	3	0
5452	L	1	F	3	2
5473	L	1	F	3	3
5489	L	1	F	3	3
5499	L	1	F	3	4
5533	L	1	F	3	1
5534	L	1	F	3	4

5583	L	1	F	3	2
5593	L	1	F	3	3
5605	L	1	F	3	2
5610	L	1	F	3	4
5634	L	1	F	3	4
5651	L	1	F	3	3
5660	L	1	F	3	2
5673	L	0	F	3	0
5682	L	0	F	3	0
5684	L	0	F	3	0
5696	L	1	F	3	2
5710	L	1	F	3	3
5716	L	1	F	3	2
5720	L	1	F	3	2
5750	L	1	F	3	4
5765	L	0	F	3	0
5769	L	1	F	3	4
5774	L	1	F	3	3
5790	L	1	F	3	4
5806	L	1	F	3	4
5818	L	1	F	3	4
5824	L	1	F	3	1
5827	L	1	F	3	4
5838	L	1	F	3	2
5895	L	1	F	3	2
5898	L	1	F	3	4
5918	L	1	F	3	2
5948	L	0	F	3	0
5970	L	1	F	3	4
5972	L	1	F	3	4
5983	L	1	F	3	3
5986	L	1	F	3	2
5998	L	1	F	3	2
6041	L	1	F	3	3
6064	L	1	F	3	4
6068	L	1	F	3	3
6117	L	1	F	3	2
6185	L	1	F	3	3
6187	L	1	F	3	3
6208	L	1	F	3	4
6213	L	1	F	3	2
6215	L	1	F	3	2
6226	L	1	F	3	2
6227	L	1	F	3	1
6229	L	1	F	3	1
11562	L	1	F	3	2
11934	L	1	F	3	2
11962	L	1	F	3	4
12092	L	1	F	3	4
12109	L	1	F	3	2
12115	L	1	F	3	4
12127	L	1	F	3	1

12179	L	1	F	1	2
12184	L	1	F	3	4
12185	L	0	F	3	0
12189	L	0	F	3	0
12201	L	1	F	3	4
12228	L	1	F	3	4
12256	L	1	F	3	4
12286	L	1	F	3	2
12351	L	1	F	3	1
12357	L	1	F	3	2
12358	L	1	F	3	1
12383	L	1	F	3	2
12397	L	1	F	3	1
12399	L	1	F	3	1
12400	L	1	F	3	3
12412	L	1	F	3	1
12424	L	1	F	3	1
12425	L	1	F	3	3
12437	L	1	F	3	2
12445	L	1	F	3	2
12453	L	1	F	3	4
12457	L	1	F	3	1
12459	L	1	F	3	3
12462	L	1	F	3	2
12472	L	1	F	3	1
12473	L	1	F	3	1
12481	L	1	F	3	2
12493	L	1	F	3	4
12511	L	1	F	3	3
12597	L	1	F	3	4
12602	L	1	F	3	1
12604	L	1	F	3	3
12644	L	1	F	3	1
12657	L	1	F	3	1
12660	L	1	F	3	1
12669	L	0	F	3	0
12681	L	1	F	3	4
1701	L	0	F	3	0
4006	L	0	M	3	0
4220	L	0	M	2	0
4372	L	1	M	3	2
4458	L	0	M	3	0
4572	L	0	M	3	0
4589	L	0	M	3	0
4601	L	0	M	3	0
4754	L	0	M	3	0
4837	L	0	M	3	0
4877	L	0	M	3	0
4926	L	0	M	3	0
4953	L	0	M	3	0
5066	L	1	M	3	1
5115	L	1	M	3	1

5122	L	0	M	3	0
5127	L	0	M	3	0
5155	L	0	M	3	0
5173	L	0	M	3	0
5225	L	0	M	3	0
5304	L	0	M	3	0
5325	L	0	M	3	0
5328	L	1	M	3	1
5347	L	1	M	3	1
5348	L	0	M	3	0
5407	L	0	M	3	0
5409	L	1	M	3	2
5434	L	0	M	3	0
5531	L	0	M	3	0
5570	L	0	M	3	0
5573	L	0	M	3	0
5587	L	0	M	3	0
5587	L	0	M	3	0
5608	L	0	M	3	0
5626	L	0	M	3	0
5640	L	0	M	3	0
5642	L	0	M	3	0
5674	L	0	M	3	0
5677	L	1	M	3	3
5683	L	0	M	3	0
5688	L	0	M	3	0
5711	L	0	M	3	0
5715	L	0	M	3	0
5724	L	0	M	3	0
5731	L	0	M	3	0
5748	L	1	M	3	2
5755	L	0	M	3	0
5759	L	0	M	3	0
11	L	0	M	2	0
11057	L	0	M	3	0
11231	L	0	M	3	0
11253	L	0	M	3	0
11257	L	1	M	3	1
11334	L	0	M	3	0
1138	L	0	M	3	0
11805	L	1	M	3	1
11926	L	0	M	2	0
11948	L	0	M	3	0
11959	L	0	M	3	0
11992	L	0	M	3	0
11996	L	0	M	3	0
12007	L	0	M	3	0
1201	L	0	M	3	0
12010	L	0	M	3	0
12031	L	0	M	3	0
12039	L	0	M	3	0
12047	L	0	M	3	0

12050	L	0	M	3	0
12081	L	1	M	3	1
12104	L	0	M	3	0
12160	L	0	M	3	0
12166	L	0	M	3	0
1217	L	0	M	3	0
12176	L	0	M	3	0
12186	L	0	M	3	0
12187	L	0	M	2	0
12195	L	0	M	3	0
12196	L	1	M	3	2
12197	L	0	M	3	0
12198	L	1	M	3	1
12210	L	0	M	3	0
12218	L	0	M	3	0
12219	L	1	M	3	1
12220	L	1	M	3	1
12250	L	1	M	3	1
12259	L	1	M	3	1
12276	L	0	M	3	0
12277	L	1	M	3	1
12284	L	1	M	3	1
12285	L	0	M	3	0
12293	L	1	M	3	1
12294	L	1	M	2	1
12308	L	0	M	3	0
12311	L	0	M	3	0
1495	L	0	M	3	0
1704	L	0	M	3	0

CT Scans

Skeleton	Side	Presence	Sex	Age Category	Grade
2	L	0	F	3	0
3	L	0	F	3	0
4	L	1	F	2	1
5	L	1	F	3	2
6	L	1	F	3	3
7	L	1	F	2	2
8	L	1	F	1	1
9	L	1	F	3	2
10	L	1	F	3	4
11	L	0	F	3	0
12	L	1	F	1	1
13	L	1	F	3	3
14	L	1	F	3	1
15	L	1	F	3	1
16	L	1	F	3	2
17	L	1	F	2	1
18	L	0	F	3	0
19	L	1	F	3	3
21	L	0	F	1	0
23	L	0	F	3	0

24	L	1	F	2	1
25	L	1	F	3	2
26	L	1	F	2	1
27	L	0	F	3	0
28	L	1	F	3	4
29	L	1	F	3	3
30	L	1	F	2	3
31	L	1	F	3	4
32	L	0	F	1	0
33	L	0	F	3	0
34	L	1	F	3	2
35	L	0	F	2	0
36	L	0	F	2	0
38	L	1	F	3	1
39	L	1	F	3	3
40	L	0	F	1	0
41	L	1	F	3	1
42	L	1	F	2	3
43	L	0	F	3	0
44	L	1	F	3	4
45	L	1	F	3	2
46	L	1	F	3	2
47	L	1	F	3	1
48	L	1	F	3	2
49	L	1	F	3	1
50	L	1	F	3	1
51	L	0	M	3	0
52	L	1	M	3	1
53	L	0	M	3	0
54	L	0	M	3	0
55	L	0	M	3	0
56	L	1	M	3	1
57	L	1	M	3	1
58	L	0	M	3	0
59	L	1	M	3	1
60	L	0	M	3	0
61	L	0	M	3	0
62	L	1	M	3	1
63	L	0	M	3	0
64	L	1	M	3	1
65	L	1	M	3	1
66	L	0	M	3	0
67	L	0	M	3	0
68	L	1	M	3	1
69	L	0	M	3	0
70	L	0	M	3	0
71	L	1	M	3	1
72	L	1	M	3	1
73	L	1	M	3	2
74	L	0	M	3	0
75	L	0	M	3	0

Appendix 12

Statistical Output for Results without Parity Information

Poulton

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Side	.538	92	.000	.266	92	.000
Presence	.462	92	.000	.547	92	.000
Sex	.346	92	.000	.636	92	.000
Age	.291	92	.000	.765	92	.000
Length	.202	92	.000	.831	92	.000
Width	.144	92	.000	.866	92	.000
Grade	.188	92	.000	.889	92	.000

a. Lilliefors Significance Correction

Test Statistics[a]

	Side	Presence	Age	Length	Width	Grade
Mann-Whitney U	1104.500	587.500	1100.000	456.500	300.500	66.500
Wilcoxon W	2232.500	1715.500	2228.000	1584.500	1428.500	1194.500
Z	.000	-5.176	-.038	-4.736	-5.966	-8.052
Asymp. Sig. (2-tailed)	1.000	.000	.970	.000	.000	.000

a. Grouping Variable: Sex

Test Statistics[a,b]

	Side	Presence	Age	Length	Width	Grade
Kruskal-Wallis H	.000	26.793	.001	22.434	35.592	64.832
df	1	1	1	1	1	1
Asymp. Sig.	1.000	.000	.970	.000	.000	.000

a. Kruskal Wallis Test

b. Grouping Variable: Sex

Correlations

			Side	Presence	Sex	Age	Length	Width	Grade
Spearman's rho	Side	Correlation Coefficient	1.000	.053	.000	-.072	.008	-.029	-.014
		Sig. (2-tailed)	.	.611	1.000	.492	.943	.782	.894
		N	94	94	94	94	92	92	94
	Presence	Correlation Coefficient	.053	1.000	-.537**	-.124	.767**	.767**	.775**
		Sig. (2-tailed)	.611	.	.000	.235	.000	.000	.000
		N	94	94	94	94	92	92	94
	Sex	Correlation Coefficient	.000	-.537**	1.000	.004	-.497**	-.625**	-.835**
		Sig. (2-tailed)	1.000	.000	.	.970	.000	.000	.000
		N	94	94	94	94	92	92	94
	Age	Correlation Coefficient	-.072	-.124	.004	1.000	-.123	-.154	-.076
		Sig. (2-tailed)	.492	.235	.970	.	.242	.144	.469
		N	94	94	94	94	92	92	94
	Length	Correlation Coefficient	.008	.767**	-.497**	-.123	1.000	.685**	.734**
		Sig. (2-tailed)	.943	.000	.000	.242	.	.000	.000
		N	92	92	92	92	92	92	92
	Width	Correlation Coefficient	-.029	.767**	-.625**	-.154	.685**	1.000	.800**
		Sig. (2-tailed)	.782	.000	.000	.144	.000	.	.000
		N	92	92	92	92	92	92	92
	Grade	Correlation Coefficient	-.014	.775**	-.835**	-.076	.734**	.800**	1.000
		Sig. (2-tailed)	.894	.000	.000	.469	.000	.000	.
		N	94	94	94	94	92	92	94

**. Correlation is significant at the 0.01 level (2-tailed).

St Owens

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Side	.532	65	.000	.328	65	.000
Presence	.415	65	.000	.605	65	.000
Sex	.343	65	.000	.636	65	.000
Age	.378	65	.000	.692	65	.000
Length	.251	65	.000	.820	65	.000
Width	.208	65	.000	.783	65	.000
Grade	.216	65	.000	.860	65	.000

a. Lilliefors Significance Correction

Test Statistics[a]

	Side	Presence	Age	Length	Width	Grade
Mann-Whitney U	497.000	290.000	472.000	265.000	224.000	157.000
Wilcoxon W	1025.000	851.000	1033.000	826.000	785.000	718.000
Z	-.811	-3.770	-.852	-3.530	-4.080	-5.050
Asymp. Sig. (2-tailed)	.417	.000	.394	.000	.000	.000

a. Grouping Variable: Sex

Test Statistics[a,b]

	Side	Presence	Age	Length	Width	Grade
Chi-Square	.658	14.215	.725	12.460	16.648	25.501
df	1	1	1	1	1	1
Asymp. Sig.	.417	.000	.394	.000	.000	.000

a. Kruskal Wallis Test

b. Grouping Variable: Sex

Correlations

			Side	Presence	Sex	Age	Length	Width	Grade
Spearman's rho	Side	Correlation Coefficient	1.000	.125	.101	-.080	.156	.043	-.025
		Sig. (2-tailed)	.	.322	.422	.524	.213	.731	.843
		N	65	65	65	65	65	65	65
	Presence	Correlation Coefficient	.125	1.000	-.471**	-.176	.847**	.847**	.859**
		Sig. (2-tailed)	.322	.	.000	.161	.000	.000	.000
		N	65	65	65	65	65	65	65
	Sex	Correlation Coefficient	.101	-.471**	1.000	-.106	-.441**	-.510**	-.631**
		Sig. (2-tailed)	.422	.000	.	.399	.000	.000	.000
		N	65	65	65	65	65	65	65
	Age	Correlation Coefficient	-.080	-.176	-.106	1.000	-.150	-.107	-.182
		Sig. (2-tailed)	.524	.161	.399	.	.233	.396	.146
		N	65	65	65	65	65	65	65
	Length	Correlation Coefficient	.156	.847**	-.441**	-.150	1.000	.877**	.835**
		Sig. (2-tailed)	.213	.000	.000	.233	.	.000	.000
		N	65	65	65	65	65	65	65
	Width	Correlation Coefficient	.043	.847**	-.510**	-.107	.877**	1.000	.835**
		Sig. (2-tailed)	.731	.000	.000	.396	.000	.	.000
		N	65	65	65	65	65	65	65
	Grade	Correlation Coefficient	-.025	.859**	-.631**	-.182	.835**	.835**	1.000
		Sig. (2-tailed)	.843	.000	.000	.146	.000	.000	.
		N	65	65	65	65	65	65	65

**. Correlation is significant at the 0.01 level (2-tailed).

St Brides

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Side	.537	190	.000	.286	190	.000
Presence	.459	190	.000	.553	190	.000
Sex	.352	190	.000	.636	190	.000
Age	.429	190	.000	.618	190	.000
Length	.204	190	.000	.842	190	.000
Width	.162	190	.000	.871	190	.000
Grade	.189	190	.000	.884	190	.000

a. Lilliefors Significance Correction

Test Statistics[a]

	Side	Presence	Age	Length	Width	Grade
Mann-Whitney U	4476.500	2279.000	4487.000	2074.500	1380.500	571.500
Wilcoxon W	9426.500	7229.000	9437.000	7024.500	6330.500	5521.500
Z	-.163	-7.657	-.058	-6.480	-8.331	-10.658
Asymp. Sig. (2-tailed)	.870	.000	.954	.000	.000	.000

a. Grouping Variable: Sex

Test Statistics[a,b]

	Side	Presence	Age	Length	Width	Grade
Kruskal-Wallis H	.027	58.629	.003	41.992	69.402	113.594
df	1	1	1	1	1	1
Asymp. Sig.	.870	.000	.954	.000	.000	.000

a. Kruskal Wallis Test

b. Grouping Variable: Sex

Correlations

			Side	Presence	Sex	Age	Length	Width	Grade
Spearman's rho	Side	Correlation Coefficient	1.000	-.056	-.012	.140	-.112	-.079	-.027
		Sig. (2-tailed)	.	.439	.871	.054	.124	.277	.710
		N	190	190	190	190	190	190	190
	Presence	Correlation Coefficient	-.056	1.000	-.557**	.022	.775**	.775**	.788**
		Sig. (2-tailed)	.439	.	.000	.765	.000	.000	.000
		N	190	190	190	190	190	190	190
	Sex	Correlation Coefficient	-.012	-.557**	1.000	-.004	-.471**	-.606**	-.775**
		Sig. (2-tailed)	.871	.000	.	.954	.000	.000	.000
		N	190	190	190	190	190	190	190
	Age	Correlation Coefficient	.140	.022	-.004	1.000	-.058	-.056	.027
		Sig. (2-tailed)	.054	.765	.954	.	.425	.443	.709
		N	190	190	190	190	190	190	190
	Length	Correlation Coefficient	-.112	.775**	-.471**	-.058	1.000	.699**	.661**
		Sig. (2-tailed)	.124	.000	.000	.425	.	.000	.000
		N	190	190	190	190	190	190	190
	Width	Correlation Coefficient	-.079	.775**	-.606**	-.056	.699**	1.000	.823**
		Sig. (2-tailed)	.277	.000	.000	.443	.000	.	.000
		N	190	190	190	190	190	190	190
	Grade	Correlation Coefficient	-.027	.788**	-.775**	.027	.661**	.823**	1.000
		Sig. (2-tailed)	.710	.000	.000	.709	.000	.000	.
		N	190	190	190	190	190	190	190

**. Correlation is significant at the 0.01 level (2-tailed).

South African Blacks

Tests of Normality[a]

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Presence	.374	204	.000	.631	204	.000
Sex	.353	204	.000	.636	204	.000
Age	.334	204	.000	.734	204	.000
Grade	.255	204	.000	.813	204	.000

a. Side is constant. It has been omitted.

b. Lilliefors Significance Correction

Test Statistics[a]

	Side	Presence	Age	Grade
Mann-Whitney U	5189.500	2505.000	5112.500	1437.500
Wilcoxon W	10967.500	8283.000	9865.500	7215.500
Z	.000	-7.422	-.205	-9.371
Asymp. Sig. (2-tailed)	1.000	.000	.837	.000

a. Grouping Variable: Sex

Correlations

			Side	Presence	Sex	Age	Grade
Spearman's rho	Side	Correlation Coefficient	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.
		N	204	204	204	204	204
	Presence	Correlation Coefficient	.	1.000	-.521**	.015	.903**
		Sig. (2-tailed)	.	.	.000	.826	.000
		N	204	204	204	204	204
	Sex	Correlation Coefficient	.	-.521**	1.000	.014	-.658**
		Sig. (2-tailed)	.	.000	.	.838	.000
		N	204	204	204	204	204
	Age	Correlation Coefficient	.	.015	.014	1.000	-.014
		Sig. (2-tailed)	.	.826	.838	.	.848
		N	204	204	204	204	204
	Grade	Correlation Coefficient	.	.903**	-.658**	-.014	1.000
		Sig. (2-tailed)	.	.000	.000	.848	.
		N	204	204	204	204	204

**. Correlation is significant at the 0.01 level (2-tailed).

South African Whites

Tests of Normality[a]

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Presence	.374	193	.000	.630	193	.000
Sex	.345	193	.000	.636	193	.000
Age	.536	193	.000	.161	193	.000
Grade	.253	193	.000	.805	193	.000

a. Side is constant. It has been omitted.

b. Lilliefors Significance Correction

Test Statistics[a]

	Side	Presence	Age	Grade
Mann-Whitney U	4655.000	1504.000	4460.000	903.000
Wilcoxon W	9215.000	6064.000	9020.000	5463.000
Z	.000	-9.458	-1.672	-10.169
Asymp. Sig. (2-tailed)	1.000	.000	.095	.000

a. Grouping Variable: Sex

Correlations

			Side	Presence	Sex	Age	Grade
Spearman's rho	Side	Correlation Coefficient	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.
		N	193	193	193	193	193
	Presence	Correlation Coefficient	.	1.000	-.683**	.082	.903**
		Sig. (2-tailed)	.	.	.000	.255	.000
		N	193	193	193	193	193
	Sex	Correlation Coefficient	.	-.683**	1.000	-.121	-.734**
		Sig. (2-tailed)	.	.000	.	.095	.000
		N	193	193	193	193	193
	Age	Correlation Coefficient	.	.082	-.121	1.000	.098
		Sig. (2-tailed)	.	.255	.095	.	.174
		N	193	193	193	193	193
	Grade	Correlation Coefficient	.	.903**	-.734**	.098	1.000
		Sig. (2-tailed)	.	.000	.000	.174	.
		N	193	193	193	193	193

**. Correlation is significant at the 0.01 level (2-tailed).

CT Scans

Tests of Normality[a]

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Presence	.401	71	.000	.615	71	.000
Sex	.416	71	.000	.604	71	.000
Age	.479	71	.000	.506	71	.000
Grade	.246	71	.000	.827	71	.000

a. Side is constant. It has been omitted.

b. Lilliefors Significance Correction

Test Statistics[a]

	Side	Presence	Age	Grade
Mann-Whitney U	575.000	415.500	400.000	316.500
Wilcoxon W	900.000	740.500	1481.000	641.500
Z	.000	-2.283	-3.040	-3.267
Asymp. Sig. (2-tailed)	1.000	.022	.002	.001

a. Grouping Variable: Sex

Correlations

			Side	Presence	Sex	Age	Grade
Spearman's rho	Side	Correlation Coefficient	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.
		N	71	71	71	71	71
	Presence	Correlation Coefficient	.	1.000	-.273*	-.006	.883**
		Sig. (2-tailed)	.	.	.021	.960	.000
		N	71	71	71	71	71
	Sex	Correlation Coefficient	.	-.273*	1.000	.363**	-.391**
		Sig. (2-tailed)	.	.021	.	.002	.001
		N	71	71	71	71	71
	Age	Correlation Coefficient	.	-.006	.363**	1.000	.049
		Sig. (2-tailed)	.	.960	.002	.	.685
		N	71	71	71	71	71
	Grade	Correlation Coefficient	.	.883**	-.391**	.049	1.000
		Sig. (2-tailed)	.	.000	.001	.685	.
		N	71	71	71	71	71

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 13

Grade/Age within Parity Information

Spitalfields

Parous

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 0 0%	N= 1 100%	N= 0 0%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 1 **11%**	N= 1 11%	N= 2 22%	N= 4 45%	N= 1 11%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 2 **4%**	N= 6 13%	N= 17 36%	N= 13 28%	N= 9 19%

Nulliparous

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 3 **75%**	N= 0 0%	N= 0 0%	N= 1 25%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 1 25%	N= 3 75%	N= 0 0%	N= 0 0%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 1 8%	N= 4 33%	N= 4 33%	N= 3 26%

St Brides

Parous

Age Category 1

Age Cat 1	Age Cat 2	Age Cat 3
N= 0 **0%**	N= 11 37%	N= 19 63%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 0 0%	N= 3 27%	N= 7 64%	N= 1 9%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 1 **5%**	N= 1 5%	N= 9 47%	N= 6 32%	N= 2 11%

Nulliparous

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 2 50%	N= 0 0%	N= 2 50%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 0 0%	N= 1 100%	N= 0 0%	N= 0 0%

For this sample there were no nulliparous in Age Category 3

CT Scans

Parous

For this sample there were no parous in Age Category 1

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 2 **40%**	N= 2 40%	N= 0 0%	N= 1 20%	N= 0 0%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 6 **26%**	N= 5 22%	N= 4 17%	N= 5 22%	N= 3 13%

Nulliparous

Age Category 1

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 6 **60%**	N= 2 40%	N= 0 0%	N= 0 0%	N= 0 0%

Age Category 2

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 0 **0%**	N= 2 50%	N= 1 25%	N= 1 25%	N= 0 0%

Age Category 3

Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
N= 2 **22%**	N= 2 22%	N= 4 45%	N= 0 0%	N= 1 11%

Appendix 14

Data Recorded by Author with Parity Information

Spitalfields

Skeleton	Side	Presence	Age Category	Max. Length	Max. Width	Grade	Parity Status
2004	L	1	3	36.60	11.80	2	P
2070	L	1	2	47.20	14.70	4	P
2098	R	1	3	42.60	9.00	3	P
2099	L	1	3	33.80	6.00	2	P
2111	L	1	3	34.70	9.90	4	P
2142	L	1	2	33.40	7.10	2	N
2152	L	1	3	19.80	7.10	3	N
2166	L	1	3	22.60	13.30	3	P
2169	L	1	3	42.50	8.30	2	N
2175	L	0	1	.00	.00	0	N
2184	L	1	3	36.50	11.00	2	P
2189	L	1	3	31.80	12.70	3	N
2192	L	1	3	.00	.00	1	P
2204	L	1	3	35.50	10.50	3	P
2205	L	1	3	40.10	15.20	4	N
2243	L	1	3	38.40	11.00	1	P
2259	L	1	3	38.50	11.50	2	P
2263	L	1	3	33.80	9.40	2	P
2281	L	1	2	44.10	9.60	1	N
2298	L	1	3	41.60	22.50	3	P
2301	L	1	2	29.20	8.60	2	P
2327	L	1	1	27.90	12.40	2	P
2335	L	1	3	37.10	6.20	2	N
2368	L	1	3	30.40	7.20	2	P
2371	L	1	3	31.20	15.10	4	P
2382	L	1	3	43.80	14.90	4	N
2399	L	1	2	33.80	11.80	3	P
2407	L	1	3	23.50	4.50	1	P
2432	L	1	3	33.30	17.50	4	P
2465	L	1	2	29.10	7.10	3	P
2467	L	1	3	32.50	12.10	1	P
2470	L	1	3	41.70	13.70	3	P
2472	L	1	3	49.10	10.20	3	P
2477	L	1	2	34.10	9.60	2	N
2484	L	1	3	33.40	3.90	2	P
2487	L	1	3	33.50	12.60	4	P
2493	L	1	3	33.10	10.10	2	P
2498	L	1	3	37.50	9.70	3	P
2500	L	1	2	27.20	13.50	2	P
2507	L	1	3	34.40	15.20	4	P
2518	L	1	3	45.90	10.40	4	P
2521	L	1	3	36.40	11.50	3	N
2526	L	1	3	30.60	9.60	2	P
2544	L	1	3	25.10	6.90	3	P

2551	L	1	3	49.10	9.00	2	P
2557	L	1	3	41.70	9.60	4	N
2563	L	1	3	26.80	4.40	1	P
2565	L	0	3	.00	.00	0	P
2566	L	1	3	25.50	20.50	3	P
2568	L	1	3	42.70	6.30	2	P
2569	L	1	3	30.90	9.60	4	P
2579	L	1	3	42.30	14.70	4	P
2604	L	1	3	32.90	5.70	2	P
2605	L	0	1	.00	.00	0	N
2609	L	1	3	26.90	6.30	3	N
2642	L	1	3	25.10	13.90	3	P
2647	L	1	3	48.00	12.10	3	P
2667	L	1	2	35.40	10.40	2	N
2670	L	0	3	.00	.00	0	P
2698	L	0	1	.00	.00	0	N
2708	L	1	2	20.00	8.40	1	P
2710	L	1	3	32.70	12.40	2	N
2747	L	1	3	21.80	6.30	1	2
2748	L	1	3	39.30	10.30	2	P
2751	L	1	3	36.30	14.80	4	P
2752	L	1	1	25.10	11.30	3	N
2787	L	1	3	38.70	11.00	3	P
2789	R	1	3	34.00	9.90	1	P
2817	L	1	3	35.50	6.00	2	P
2867	L	1	3	33.60	11.60	2	N
2872	L	1	2	36.30	9.60	3	P
2882	L	1	3	31.70	11.00	2	P
2889	L	1	3	41.20	9.60	2	P
2918	L	1	3	27.80	10.50	2	N
2921	L	1	2	33.30	14.90	3	P
2930	L	0	2	.00	.00	0	P
2956	L	1	3	40.70	9.40	3	P

<u>St Brides</u>

Skeleton	Side	Presence	Age Category	Max. Length	Max. Width	Grade	Parity Status
7	L	1	3	45.32	9.26	2	P
8	L	1	3	37.35	40.87	3	N
10	L	1	1	38.80	14.87	1	P
13	L	1	2	31.26	6.57	2	P
31	L	1	2	42.66	12.15	3	P
43	L	1	2	26.73	12.38	3	P
44	L	1	2	31.63	16.02	3	P
45	L	1	3	35.54	13.78	3	P
52	L	1	1	35.07	18.94	3	N
63	L	1	2	43.94	20.44	3	P
72	L	1	1	39.10	6.24	1	N
99	L	1	3	28.57	8.64	2	P
101	L	1	3	35.08	11.98	4	P

106	L	1	2	44.16	8.61	3	P
109	L	1	3	26.93	12.09	2	P
121	L	1	3	41.43	16.09	4	P
123	L	1	3	33.65	7.04	3	P
130	L	1	3	40.53	13.30	2	P
146	L	1	3	47.12	10.14	3	P
148	L	1	3	28.55	6.80	2	P
153	L	1	2	37.51	8.05	2	P
156	L	1	2	32.81	16.97	4	P
177	L	1	2	31.47	9.51	2	N
178	L	1	2	38.57	9.03	2	P
182	L	1	3	34.45	11.62	2	P
184	L	1	3	34.25	13.07	3	P
187	L	1	3	44.03	9.73	2	P
193	L	0	3	.00	.00	0	P
203	L	1	1	39.37	11.72	3	N
208	L	1	3	35.02	14.04	3	P
223	L	1	3	24.48	13.55	2	P
225	L	1	2	41.09	15.63	3	P
227	L	1	2	34.14	12.28	3	P
229	L	1	3	20.55	5.40	2	P
236	L	1	3	29.60	9.43	1	P

CT Scans

Skeleton	Side	Presence	Age Category	Grade	Parity Status
2	L	0	3	0	P
3	L	0	3	0	P
4	L	1	2	1	P
5	L	1	3	2	N
6	L	1	3	3	P
7	L	1	2	2	N
8	L	1	1	1	N
9	L	1	3	2	P
10	L	1	3	4	P
11	L	0	3	0	P
12	L	1	1	1	N
13	L	1	3	3	P
14	L	1	3	1	P
15	L	1	3	1	P
16	L	1	3	2	N
17	L	1	2	1	P
18	L	0	3	0	N
19	L	1	3	3	P
21	L	0	1	0	N
23	L	0	3	0	P
24	L	1	2	1	N
25	L	1	3	2	P
26	L	1	2	1	N
27	L	0	3	0	P
28	L	1	3	4	P

29	L	1	3	3	P
30	L	1	2	3	N
31	L	1	3	4	P
32	L	0	1	0	N
33	L	0	3	0	P
34	L	1	3	2	P
35	L	0	2	0	P
36	L	0	2	0	P
38	L	1	3	1	N
39	L	1	3	3	P
40	L	0	1	0	N
41	L	1	3	1	P
42	L	1	2	3	P
43	L	0	3	0	N
44	L	1	3	4	N
45	L	1	3	2	P
46	L	1	3	2	N
47	L	1	3	1	P
48	L	1	3	2	N
49	L	1	3	1	P
50	L	1	3	1	N

Appendix 15

Statistical Output for Results with Parity Information

Spitalfields

Tests of Normality[b]

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Side	.538	77	.000	.148	77	.00(
Presence	.536	77	.000	.297	77	.00(
Age	.461	77	.000	.553	77	.00(
Length	.166	77	.000	.840	77	.00(
Width	.126	77	.004	.952	77	.00(
Grade	.184	77	.000	.903	77	.00(
Parity	.462	77	.000	.546	77	.00(
Age1stbirth	.234	77	.000	.847	77	.00(

a. Lilliefors Significance Correction

b. Sex is constant. It has been omitted.

Test Statistics[a]

	Side	Presence	Sex	Age	Length	Width	Grade
Mann-Whitney U	522.500	484.500	541.500	392.500	472.000	452.500	486.000
Wilcoxon W	712.500	674.500	731.500	582.500	662.000	642.500	676.000
Z	-.822	-1.464	.000	-2.409	-.834	-1.069	-.691
Asymp. Sig. (2-tailed)	.411	.143	1.000	.016	.404	.285	.490

a. Grouping Variable: Parity

Test Statistics[a,b]

	Side	Presence	Sex	Age	Length	Width	Grade
Chi-Square	.676	2.143	.000	5.805	.696	1.142	.477
df	1	1	1	1	1	1	1
Asymp. Sig.	.411	.143	1.000	.016	.404	.285	.490

a. Kruskal Wallis Test

b. Grouping Variable: Parity

Correlations

			Side	Presence	Sex	Age	Length	Width	Grade	Parity
Spearman's rho	Side	Correlation Coefficient	1.000	.047	.	.090	.125	-.048	-.052	-.087
		Sig. (2-tailed)	.	.682	.	.439	.279	.680	.656	.453
		N	77	77	77	77	77	77	77	77
	Presence	Correlation Coefficient	.047	1.000	.	.345**	.458**	.458**	.482**	-.172
		Sig. (2-tailed)	.682	.	.	.002	.000	.000	.000	.135
		N	77	77	77	77	77	77	77	77
	Sex	Correlation Coefficient	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.
		N	77	77	77	77	77	77	77	77
	Age	Correlation Coefficient	.090	.345**	.	1.000	.276*	.134	.238*	-.284*
		Sig. (2-tailed)	.439	.002	.	.	.015	.244	.037	.012
		N	77	77	77	77	77	77	77	77
	Length	Correlation Coefficient	.125	.458**	.	.276*	1.000	.356**	.419**	-.113
		Sig. (2-tailed)	.279	.000	.	.015	.	.001	.000	.327
		N	77	77	77	77	77	77	77	77
	Width	Correlation Coefficient	-.048	.458**	.	.134	.356**	1.000	.626**	-.083
		Sig. (2-tailed)	.680	.000	.	.244	.001	.	.000	.471
		N	77	77	77	77	77	77	77	77
	Grade	Correlation Coefficient	-.052	.482**	.	.238*	.419**	.626**	1.000	-.063
		Sig. (2-tailed)	.656	.000	.	.037	.000	.000	.	.585
		N	77	77	77	77	77	77	77	77
	Parity	Correlation Coefficient	-.087	-.172	.	-.284*	-.113	-.083	-.063	1.000

	Sig. (2-tailed)	.453	.135	.	.012	.327	.471	.585	.
	N	77	77	77	77	77	77	77	77

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

St Brides

Tests of Normality[a,c]

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Presence	.539	35	.000	.161	35	.000
Age	.336	35	.000	.738	35	.000
Length	.122	35	.200*	.865	35	.001
Width	.158	35	.026	.786	35	.000
Grade	.244	35	.000	.877	35	.001
Parity	.513	35	.000	.418	35	.000

*. This is a lower bound of the true significance.

a. Side is constant. It has been omitted.

b. Lilliefors Significance Correction

c. Sex is constant. It has been omitted.

Test Statistics[a]

	Side	Presence	Sex	Age	Length	Width	Grade
Mann-Whitney U	75.000	72.500	75.000	5.500	62.000	71.000	52.000
Wilcoxon W	90.000	537.500	90.000	20.500	527.000	536.000	67.000
Z	.000	-.408	.000	-3.666	-.613	-.189	-1.163
Asymp. Sig. (2-tailed)	1.000	.683	1.000	.000	.540	.850	.245
Exact Sig. [2*(1-tailed Sig.)]	1.000[b]	.909[b]	1.000[b]	.000[b]	.567[b]	.873[b]	.299[b]

a. Grouping Variable: Parity

b. Not corrected for ties.

Test Statistics[a,b]

	Presence	Sex	Age	Length	Width	Grade
Chi-Square	.167	.000	13.436	.376	.036	1.352
df	1	1	1	1	1	1
Asymp. Sig.	.683	1.000	.000	.540	.850	.245

a. Kruskal Wallis Test

b. Grouping Variable: Parity

Correlations

			Presence	Sex	Age	Length	Width	Grade	Parity
Spearman's rho	Presence	Correlation Coefficient	1.000	.	-.152	.289	.289	.310	.070
		Sig. (2-tailed)	.	.	.383	.093	.093	.070	.689
		N	35	35	35	35	35	35	35
	Sex	Correlation Coefficient	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.
		N	35	35	35	35	35	35	35
	Age	Correlation Coefficient	-.152	.	1.000	-.208	-.134	-.066	-.629**
		Sig. (2-tailed)	.383	.	.	.230	.442	.705	.000
		N	35	35	35	35	35	35	35
	Length	Correlation Coefficient	.289	.	-.208	1.000	.227	.279	.105
		Sig. (2-tailed)	.093	.	.230	.	.189	.105	.548
		N	35	35	35	35	35	35	35
	Width	Correlation Coefficient	.289	.	-.134	.227	1.000	.584**	.032
		Sig. (2-tailed)	.093	.	.442	.189	.	.000	.854
		N	35	35	35	35	35	35	35
	Grade	Correlation Coefficient	.310	.	-.066	.279	.584**	1.000	-.199
		Sig. (2-tailed)	.070	.	.705	.105	.000	.	.251
		N	35	35	35	35	35	35	35
	Parity	Correlation Coefficient	.070	.	-.629**	.105	.032	-.199	1.000
		Sig. (2-tailed)	.689	.	.000	.548	.854	.251	.
		N	35	35	35	35	35	35	35

**. Correlation is significant at the 0.01 level (2-tailed).

CT Scans

Tests of Normality[b]

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Presence	.450	46	.000	.564	46	.000
Age	.422	46	.000	.627	46	.000
Grade	.209	46	.000	.879	46	.000
Parity	.395	46	.000	.620	46	.000

a. Lilliefors Significance Correction

b. Sex is constant. It has been omitted.

Test Statistics[a]

	Presence	Sex	Age	Grade
Mann-Whitney U	250.000	252.000	158.500	222.500
Wilcoxon W	656.000	423.000	329.500	393.500
Z	-.058	.000	-2.600	-.684
Asymp. Sig. (2-tailed)	.954	1.000	.009	.494

a. Grouping Variable: Parity

Correlations

			Presence	Sex	Age	Grade	Parity
Spearman's rho	Presence	Correlation Coefficient	1.000	.	.146	.803**	.009
		Sig. (2-tailed)	.	.	.333	.000	.955
		N	46	46	46	46	46
	Sex	Correlation Coefficient	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.
		N	46	46	46	46	46
	Age	Correlation Coefficient	.146	.	1.000	.271	-.388**
		Sig. (2-tailed)	.333	.	.	.068	.008
		N	46	46	46	46	46
	Grade	Correlation Coefficient	.803**	.	.271	1.000	-.102
		Sig. (2-tailed)	.000	.	.068	.	.500
		N	46	46	46	46	46
	Parity	Correlation Coefficient	.009	.	-.388**	-.102	1.000
		Sig. (2-tailed)	.955	.	.008	.500	.
		N	46	46	46	46	46

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 16

Statistical Output for Results Focusing on Age

Test Statistics[a,b]

	Age
Kruskal-Wallis H	2.226
df	4
Asymp. Sig.	.694

a. Kruskal Wallis Test

b. Grouping Variable: Grade

Correlations

			Age	Grade
Spearman's rho	Age	Correlation Coefficient	1.000	-.035
		Sig. (2-tailed)	.	.515
		N	349	349
	Grade	Correlation Coefficient	-.035	1.000
		Sig. (2-tailed)	.515	.
		N	349	349

Appendix 17

Statistical Output for Results Focusing on Ancestry

Test Statistics[a,b]

	Ancestry
Chi-Square	2.332
df	4
Asymp. Sig.	.675

a. Kruskal Wallis Test

b. Grouping Variable: Grade

Appendix 18

Statistical Output for Results Focusing on Location

Test Statistics[a,b]

	Presence	Grade
Chi-Square	21.190	15.575
df	5	5
Asymp. Sig.	.001	.008

a. Kruskal Wallis Test

b. Grouping Variable: Location