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Deconstructing 'Parturition Scars': An Osteoarcheological assessment on the contributing factors of Pelvic features, beyond Parity.

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Deconstructing ‘Parturition Scars’: An osteoarchaeological assessment on the contributing factors of Pelvic features, beyond Parity.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

PAS – Preauricular sulcus

DPP – Dorsal pubic pitting

VPP – Ventral pubic pitting

IG – Interosseous groove

IT – Iliac tuberosity

EPT – Extended pubic tubercle

SPE – Sacral preauricular extension

MAG – Margo auricularis groove

MIB – Minimum iliac breadth

MAL – Maximum auricular length

MIPL – Maximum ischiopubic length

MIH – Maximum innominate height

IB – Iliac breadth

AHS – Anterior height of the sacrum

ABS – Anterior breadth of the sacrum

TDSs1 – Transverse diameter of sacral segment 1

APDSs1 – Anterior posterior diameter of sacral segment 1

Chapter 1: Introduction

In the field of Archaeology, researchers work towards reconstructing past lifeways. One aspect they look at besides death, is childbirth. Although they look at death more than the procedure of the beginning of life, both are events which can provide us with information on the way people used to live. In the field of Osteology, skeletal proof of childbirth has been linked to parturition scars. These scars were seen as evidence on the skeleton of female individuals believed to prove the event of childbirth (Beausang, 2000, p. 82).

These specific scars are defined as pittings, grooves or depressions on the ventral and dorsal part of the pubic symphysis and on the ilium and sacrum of the Pelvis. Today, parturition scars remain a scientific issue, out of the most extensively investigated ones. These skeletal features were used by bioarchaeologists to estimate parity in past populations (Bergfelder & Herrmann, 1980; Dunlap, 1981; Gilbert & McKern, 1973; Houghton, 1974; Suchey et al., 1979) or in modern ones (Waltenberger et al., 2022). Simultaneously, research is ongoing. This is caused by the fact that these features of the Oss coxa are found also in male individuals and in women without parity history or not found in women who have given birth (Waltenberger et al., 2022, p. 2).

Despite their long history of use, the reliability of these marks on the pubic bone is an issue that has the scientific community conflicted, at even the starting of the 20th century (Derry, 1909). Zaaijer (1866), Lohr (1894) and Aeby (1858) "had detected human variation in anatomical features of the pelvis" (Ubelaker & De

La Paz, 2012, p. 866). Most recently, the same researchers noted that until today, pregnancy and parturition can modify the bones, however it is relevant that these alterations are distinctive of the status of parity (Ubelaker & De La Paz, 2012, p. 869).

While the original hypothesis linked the formation of parturition scars to ligamentous laxity and mechanical stress during delivery, subsequent studies have proposed alternative, non- obstetric causes. For instance, Waltenberger et al. (2021) suggested a direct link to age-related, degenerative changes in the pelvic girdle, while others, like attribute the remodeling to general pelvic stress, trauma, or habitual strain (e.g., heavy labor). Most importantly, parturition scars have been observed on a large number of male individuals from different studies (Maass, 2012; Praxmarer et al., 2020; Waltenberger et al., 2021). Historically, researchers have been studying the association of the presence of these scars with obstetrical events, an apparent explanation which has been questioned firmly. Consequently, these lesions are now increasingly being viewed as non-specific indicators of pelvic stress rather than definitive proof of parity which seriously undermines their utility for precise demographic analysis. Subsequently, the term 'Parturition scars' feels outdated (as it implicates that of the event of childbirth), and a more general one has been introduced and will be used in this research: 'pelvic features' (Pany- Kucera et al., 2019).

It is clear from the scientific literature that there can be different explanations on why these scars appear on the pelvic bone, such as working conditions, hard labor, or stature, as well as the age of an individual (Cox, 1989). However, some studies have linked the relation of pelvic features with pelvic shape and size, from the current literature (Waltenberger et al., 2021). At present, we lack the foundational knowledge to determine which individual factors exert the greatest influence on pelvic morphology, or how their interplay contributes to the observed skeletal features. To address this gap, this thesis will undertake a comprehensive investigation to assess the relative contributions of various biomechanical and physiological factors such as age, weight, stature, biomechanical and musculoskeletal conditions, pelvic dimensions, hormonal influences (relaxin, progesterone and oestrogens) and childbirth positions to the appearance of pelvic features on the Os coxae (Borg-Stein et al., 2005; Rebay-Salisbury et al., 2018, p. 92).

1.1 Research questions

The aim of this study is to investigate the factors that may contribute to the formation and presence of pelvic features. Within the process of this research, our comprehension and knowledge on the matter could be increased. The main research question is: Are pelvic dimensions and size of the pelvis related to the appearance of the features?

Following this primary research question, smaller sub-questions have been developed as follows:

1. What is the prevalence of pelvic features in the skeletal population under study?
2. Are there differences in occurrence rates between female and male individuals?
3. Is there any measurement mostly correlated with the presence of pelvic features? Can this explain anything about the causation of the features?

1.2 Approach

The material that was assessed for this thesis comes from the post-medieval city of Delft, a city located in the South of Holland, which had greatly increased in population between the sixteenth and seventeenth centuries. Specifically, the material derives from the cemetery of the Nieuwe Kerk (New church). The construction of the church started in 1381, and in 1396 in a western part of the market, the cemetery was made. The cemetery was used until 1829, ca., for 450 years.

The collection of skeletal material from the cemetery of the Nieuwe Kerk at Delft falls into the Dutch Post-medieval age period. This is a period of noticeable social inequality which followed the intense period of Black death pandemic lasting until the early 19th century. (Alfani, 2021, p.30). Moreover, urbanization as well as industrialization later on, were factors which created difficult living conditions for the people's health. Delft held a steady and thriving pace in the economic sector. Producing beer and dairy products, as well as the famous 'delftware' ceramics which made it globally well-known (Oosten et al., 2018). Delft's gradual economic growth gave its inhabitants a generally high socio-economic status.

In this research, an assessment of the possible correlation of the shape and size of the pelvis to the presence or absence of pelvic features will be tried. During the data collection process, eight pelvic features were assessed through macroscopic analysis (preauricular sulcus (PAS), dorsal pubic pitting (DPP), ventral pubic pitting (VPP), iliac tuberosity (IT) extended pubic tubercle (EPT), interosseous groove (IG), margo auricularis groove (MAG), sacral preauricular extension (SPE). Five measurements were taken from each of the pelvic bones (minimum iliac breadth (MIB), maximum auricular length (MAL), maximum ischio-pubic length (MIPL), maximum innominate height (MIH), iliac breadth (IB). Four measurements were taken from the sacra of the overall sample (anterior height of the sacrum (AHS), anterior breadth of the sacrum (ABS), transverse diameter of sacral segment 1 (TDSs1), Anterior-posterior diameter of Sacral segment 1 (APDSs1).

1.3 Ethical considerations

Studying human remains has long been issued as a field where ethical considerations need to be taken. Skeletons are not just another material category. Skeletons were once living people. Collecting relevant data and sharing them need prior ethical approval. For the benefit of our discipline, it is important to briefly state that mandatory inclusion will make researchers more aware of the ethical implications of their work (Squires et al., 2022, p. 617).

Archaeological associations such as the Society of American Archaeology (SAA) and the European Association of Archaeologists (EAA) have devised ethical guidelines and codes of practice to establish standards of conduct for their members to follow (Oosten et al., 2018, p. 11).

Moreover, the researcher using relevant methodology should have in mind the preservation and conservation of the material so it can be ensured that other research can be replicated. In this research, non-destructive methods will be used that will not alter the bones and that will allow future researchers to be able to conduct their own analysis. This research meets the ethical standards of the Laboratory for Human Osteoarchaeology at Leiden University, and it is approved by Gemeente Delft, the curating institution of the skeletal population under study.

1.4 Thesis structure

This chapter served as an introduction to the thesis. Chapter 2 will provide the reader with information on the anatomy of the pelvis and the sacrum. With that, it will be understood, which exactly are the pelvic features and their anatomical place on the bony pelvis. Then, a background on how the features have been studied and the correlations which have been found on pelvic shape and size will follow. In this section, all the scientific research on the features will be stated chronologically, contributing to better understanding of the current situation on the matter. Chapter 3 will introduce the materials of this study, namely the population of the city of Delft and the excavation it originates from. Concluding this chapter, all the methodologies of the skeletal analysis are presented along with the statistical analyses. In Chapter 4, the results of the descriptive statistics as well as the statistical analysis are presented. Chapter 5 will refer to the discussion of the results, addressing the research questions. Limitations of this research will also be discussed in this chapter. Chapter 6 will concern the final reflections of the research as well as future perspectives for alike investigations.

Chapter 2. Background

2.1 Anatomy of the skeletal pelvis

The bones of the pelvic girdle (or Os coxae) are part of the axial skeleton. Their main function is to maintain stability and "to transfer the weight of the upper body from the axial to the lower appendicular skeleton for standing and walking" (Moore et al., 2011, p. 205).

The pelvic girdle consists of the two coxal bones (left and right) and the sacrum. Along with the coccyx, they form the Pelvis (Figure 1). Each Os coxa is formed by three different bones (the ilium, ischium and the pubis) which fuse in early adolescence. The ilium is posteriorly connected with the sacrum via the sacroiliac joint. The ischium is the part which is the most inferior of the coxal bone while the pubis is the most antero- inferior part of the coxal bone. The two pubic bones are united anteriorly by a cartilaginous joint, i.e. the pubic symphysis. These areas which surround the joints of the pelvis are studied for the presence of pelvic features, commonly.

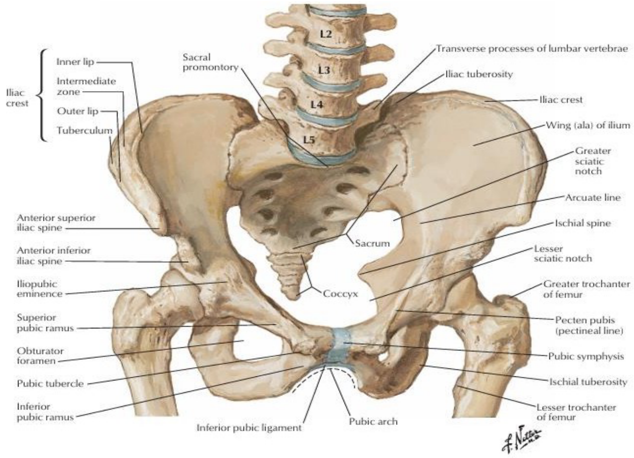

Figure 1 Bony Framework of Pelvis. (Netter, 2014, p.373, Figure 330).

Besides the bony features, other landmarks of the pelvis will be referred to throughout this thesis (White, 2011, pp. 227, 232-233):

1. **Sacropelvic surface**: the dorsal portion of the internal surface of the iliac blade. The sacropelvic surface includes:
    1. **Auricular surface**: the ear-shaped sacral articulation on the medial surface of the ilium.
    2. **Iliac tuberosity:** is the roughened surface posterosuperior to the auricular surface. It is an attachment site for sacroiliac ligaments.
2. **Iliac crest**: the superior edge of the ilium.
3. **The tuberculum of the iliac crest**: the thickening at the superior end of the iliac pillar.
4. **Preauricular sulcus**: an uneven groove along the anteroinferior edge of the auricular surface.
5. **Greater sciatic notch**: the wide notch just inferior to the posterior inferior iliac spine.
6. **Ischial spine:** located just inferior to the greater sciatic notch, for attachment of the sacrospinous ligament.
7. **Ischiopubic (or inferior pubic) ramus:** the thin, flat bridge of bone

connecting the pubic body to the ischial body.

8. **Pubic tubercle (or spine):** the pronounced projection on the anterosuperior aspect of the pubic body.

2.1.2 Anatomy of the Sacrum

The sacrum (Figure 2) sits between the two ossa coxae and is composed by five vertebrae which fuse between the age of 18 and 30. It is located at the base of the vertebral column, and it is connected inferiorly with the coccyx. The sacrum embodies the area of weight transmission from the upper to the lower extremities (Pany-Kucera et al., 2019, p. 1014). Provided below is a list with the features of the sacrum which are included in this research (White, 2011, pp. 227, 232-233):

1. **Base:** is the wide anterosuperior side of the bone connecting both alae.
2. **Alae:** are the "wings" which extend from the first sacral segment, laterally from the center of the base.
3. **Sacral plateau:** is the wide, flat part of the first sacral segment which is connected to the last lumbar vertebra.
4. **Sacral promontory:** is the anterior ridge of the sacral plateau.

Auricular surface: is the part where the creation of the articulation of the sacroiliac ligament is formed.

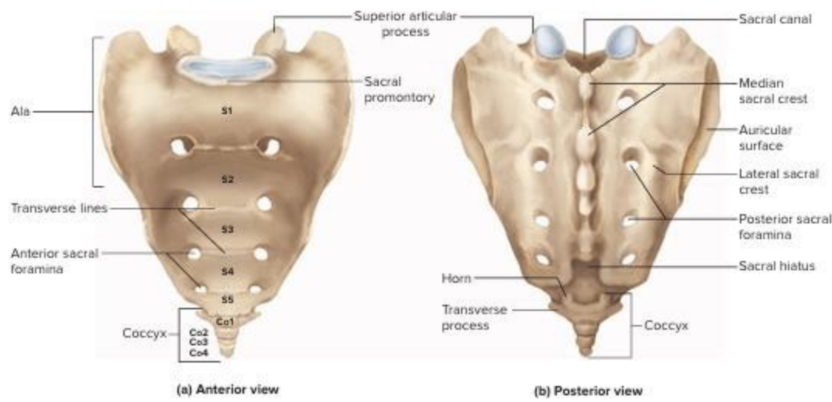

Figure 2 The Sacrum and Coccyx. (a) The anterior view. (b) The posterior view.
(Saladin, 2021, p. 246).

2.2 Pelvic features

Pelvic features, are some characteristics of the bony pelvis, shaped in different forms and in different parts of the pelvic bones and sacrum.

In the center of this study lie the pelvic features which need to be presented next, explained and placed in position where they are usually found at the Ossa coxae. These are:

1. Preauricular sulcus
2. Dorsal pubic pitting
3. Ventral pubic pitting
4. Iliac tuberosity
5. Extended pubic tubercle
6. Interosseous groove

7. Margo auricularis groove
8. Sacral preauricular extension

1. Preauricular sulcus

The preauricular sulcus has been used to estimate sex in skeletal samples (Figure 3). Waltenberger et al. (2021, p. 2) defines the preauricular sulcus as ‘a horizontal groove at the inferior border of the ilium next to the sacroiliac joint’. According to Molleson et al. (1993) and Maass (2012), the prevalence of the preauricular sulcus is higher in females and the severity is more pronounced as well. Houghton (1974) categorized the sulcus into two types: the groove of pregnancy (GP) and the groove of ligament (GL). For this study, a link of the features with pregnancy and/or parturition is not being attempted, this is why the two categories by Houghton are just being mentioned.

Figure 3 The preauricular sulcus shown with the yellow arrow. Anterior view of the right innominate. (Photograph: Maria Farmaki).

2. Dorsal pubic pitting

The Dorsal pubic pitting (Figure 4) can appear on the dorsal side of the pubic symphysis. It can be several grooves parallel to the symphyseal margin possibly due to the formation of cysts, presenting themselves in parous women (Stewart, 1970; Waltenberger et al., 2021, p. 2).

Figure 4 The Dorsal pubic pitting shown with the yellow arrow. Dorsal side of the left pubic bone. (Photograph: Maria Farmaki).

3. Ventral pubic pitting

The Ventral pubic pitting (Figure 5) may appear on the ventral side of the pubic symphysis.

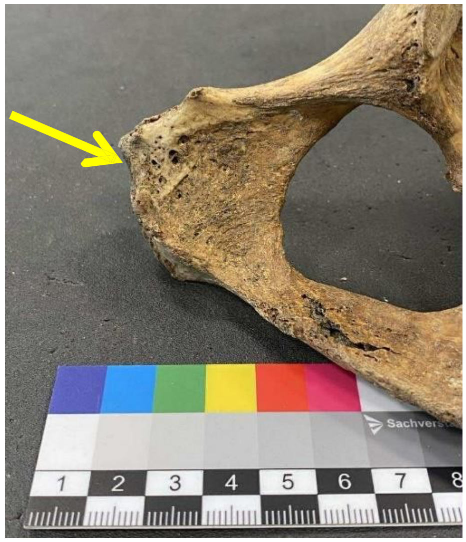

Figure 5 The ventral pubic pitting shown with the yellow arrow. Ventral side of the left pubic bone. (Photograph: Maria Farmaki).

4. Iliac tuberosity

Iliac tuberosity (Figure 6) is a landmark of the ilium of the pelvis. It is found posterosuperior to the auricular surface. Andersen (1986) stated that this thick tuberosity could be measured and classified into three categories regarding its thickness and width.

Figure 6 The iliac tuberosity shown with the yellow arrow. Anterosuperior view of the right innominate bone. (Photograph: Maria Farmaki).

5. Extended pubic tubercle

The Extended pubic tubercle (Figure 7) can be found superior-anterior of the pubic articulation surface. It is also considered to be a pelvic feature, as it can appear as a lengthening of the anatomical 'pubic tubercle' as described by Ullrich (1975) and Bergfelder and Herrmann (1978). It has been correlated with pregnancy and parturition by the latter researchers, however, Snodgrass and Galloway (2003), Decrausaz (2012), Maass (2012), and Aurigemma (2015) also reported a correlation with body height in both sexes.

Figure 7 The Extended pubic tubercle shown with the yellow arrow. Ventral side of the right pubic bone. (Photograph: Maria Farmaki).

6. Interosseous groove

Close to the preauricular sulcus on the pelvic surface of the sacrum, 'sacral scarring' can usually be observed (Cox, 1989). These grooves have been described by Ullrich (1975) as 'interosseous grooves' (Figure 8). Andersen (1986) stated that pitting was presented more on females than male individuals and that no significant association with parity was found.

Figure 8 The interosseous groove shown with the yellow arrow. Anterior view of the left innominate bone. (Photograph: Maria Farmaki).

7. Sacral auricular extension

The Sacral preauricular extension (Figure 9) is a thin, osseous extension ventrally pointing, located at the ventro-superior margin of the sacral wings, and is seen more frequently in female individuals (Pany-Kucera et al. 2019, p. 1015).

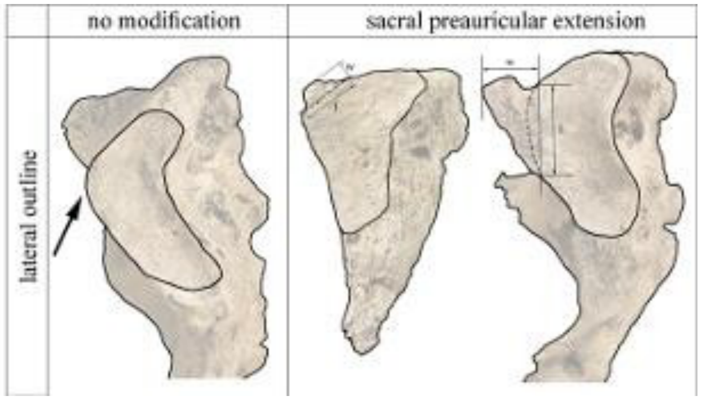

Figure 9 Bony modifications at the ventral apex region of the sacrum. Left: no modification. Right: sacral preauricular extension. (Adapted from Pany-Kucera et al., 2019, p. 1016, Figure 2).

8. Margo auricularis groove

The Margo auricularis groove (Figure X) is a new term adapted from Rebay-Salisbury et al. (2018, p. 96). It is a groove located at the margin of the sacral auricular facet, and it can be presented bilaterally. It is possible that this feature is linked more to age or sex than births (Cox, 2006; Maass, 2012.

2.3 History of research on Pelvic features

The published literature has been extensive on Pelvic features. The idea of pregnancy and/ or parturition 'imprints' being apparent on the pelvis goes long back to the late 19th century but still has the scientific community varied. Historical retrospection is critical and important to assess all those years of research on the issue.

Anatomists Zaaijer (1866) and Lohr (1894) had noticed human variation in the anatomy of exact features of the pelvis. It was not until Derry (1909) an anatomist from London, linked pregnancy, after noticing the preauricular sulcus as an indicator of female sex. He noted that the preauricular sulcus was the site of attachment of the anterior sacroiliac ligaments to the ilium (Derry, 1909, p. 270). He also noted that there was some relaxation of the ligaments which could potentially influence the presence of the sulcus.

Those ideas were enough for the anatomist Todd to step in into issue, which was confusing scientists. In 1920, he added how difficult it was to assess if pregnancy and childbirth could leave permanent imprints upon skeletons. In 1934, Abramson et al. added that it was hormones which stimulated the relaxation of pelvic joints, while Putschar (1931), gave evidence of variations in the anatomy of the pelvis and talked about the possibility of pregnancy and/ or parturition being influencing factors.

Wiltse and Frautz (1956) presented that this condition can occur in women and in men as well. The idea of the 'relaxation of the joints of the pelvis during pregnancy' was then supported (Stewart, 1957, p.17). In 1969, J. Lawrence Angel made an important observation, stating that the alterations which were produced by pregnancy and/ or parturition were able to be quantified, depending on the number of childbirths. The next years, many studies were published with the aim to make Angel's method, simpler (Maass, 2012, p. 19). Stewart (1970) studied the pubic symphysis of 205 female skeletons. The results showed that females who have given birth presented little or no scarring. Other women who had not given birth, presented scars (Maass, 2012, p. 19; Stewart, 1970, pp. 127-135).

Later, Gillbert & McKern (1973) studied the changes in the female pubic bone, related to age. They mention that women who had given birth to one child, presented severe scars than other females with more children. Moreover, they suggested that the size of the fetus and the shape and size of the pelvis contribute to the appearance of the features (Gilbert & McKern, 1973, pp. 31-38). The features on the preauricular surface were described by Houghton (1974). He divided the sulcus into the groove of ligament (GL) and groove of pregnancy (GP) (Houghton, 1974).

In the late 1980s, the results of the study of Cox (1989), showed that the presence of features was not relevant to obstetric events (Maass, 2012, p. 24).

In a sample study of male and female individuals from the Broze Age, results showed that sacral preauricular extensions and sacral preauricular notches are related to pregnancy and parturition. The laxening of ligaments due to hormones during pregnancy influences the sacroiliac joint as well as the changes in posture and weight gain which causes sacral preauricular extensions and notches to appear (Pany-Kucera et al., 2019, p. 1013). Another study examined the influences of sex, age, body size, pelvic dimensions on three pelvic features (dorsal pubic pit, pubic tubercle and preauricular sulcus) in male and female individuals. This study resulted in the presence of the features in both sexes, frequently in females without a clear indication of pregnancy (Praxmarer et al., 2020, pp. 629, 639).

In a modern sample of female individuals from New Mexico (USA) where the association of pelvic features with birth, was studied, the results yielded that the only feature which was associated with the number of births was the dorsal pubic pitting. The expression of most of the other pelvic features increased with age, regardless of parity status. Consequently, only the feature of dorsal pubic pitting may be seen as 'parturition scar' (Waltenberger et al., 2022, pp. 1, 8).

In 2022, the results of a study confirmed that the pelvis changes in size during adulthood, more in females than in males. The changes in the shape of the pelvis and in the expression of the features in adults, come from a combination of hormonal factors in females and mechanical factors in males. (Waltenberger et al., 2022, pp. 1, 10).

2.4 Etiological factors

The pelvic features which appear on the pelvis are associated with plenty of factors. It is highly important to refer to those factors for the assessment of their appearance and formation.

Out of these factors, an important one is age of the individual. The first pregnancy of female in a very young age can influence the appearance of pelvic features (Snodgrass & Galloway, 2003, p. 1). Because at a young age, the epiphyses of the pelves have not yet fused, this can mean that pregnancy can influence the shape of the pelvis (Abitbol, 1987, pp. 243-255). At this young age, there is a possibility of a complication appearing, known as cephalopelvic disproportion (Van Bogaert, 1999). Thus, pelvic features could be formed from the birthing process. According to Suchey et al. (1979, p. 517) nullipara females older than 30 years old, presented pelvic features more frequently than younger females. Cox (1989, p. 3) found an association of the appearance of pelvic features with age. Older individuals tend to have larger pelves with more features. Snodgrass & Galloway (2003, p. 3) suggested that dorsal pubic pitting and pubic tubercle height were associated with the age and body mass index of an individual.

Another factor which is associated with the presence of pelvic features, is body and pelvic size (Snodgrass & Galloway, 2003, p. 4). The correlation between pelvic features and body size, which influences their manifestation, has not been studied much (Maass, 2012. p. 28). Cox (1989) resulted in the fact that the features form in larger pelves than smaller ones, as it was believed. This underlies that other factors are responsible for the formation of the features.

Other studies refer to different factors which influence pelvic size and possibly the formation of pelvic features, like environmental and genetic factors (Maass, 2012, p. 28). The heigh frequency of caesarean sections, an obstetric practice, reduces the frequency of formation of traumata, which could have been formed during the event of birth (Schemmer et al., 1995, p. 208). In males, the strain caused by weight, on the ligaments, can cause alike pelvic features (Maass, 2012,

p. 1).

Moreover, in females, the increased secretion of hormones (relaxin, progesterone and oestrogens) can cause the ligaments to become lax, to prepare women for the process of birth (Lindsey et al., 1988, p. 289). Oestrogens and pregnancy can remodel the bone in females of the reproductive period while the same process of remodelling from mechanical factors, can present in males and women in the postmenopausal period (Waltenberger et al., 2022, p. 1).

2.5 Chapter summary

In this chapter, the anatomy of the skeletal pelvis has been presented, in order to understand the basic landmarks of the bony pelvis. The knowledge of the anatomy of the pelvis is needed to understand where exactly the pelvic features are observed. Next, this chapter presented the exact way pelvic features are formed. Because the scientific research on the features has been intensive, a historical retrospection was done, in order to assess how researchers have studied the presence and formation of pelvic features till the most recent studies until today. Lastly, a description of factors which can influence the morphology of the pelvis and form pelvic features was made, besides parity and parturition.

Chapter 3. Materials and Methodology

3.1. Materials

In this chapter the materials of the study are presented, along with the historical background of the excavation from which the bones of the individuals come from.

For the purpose of this research, the individuals studied belonged to the skeletal collection of the city of Delft. The sample of the study consists of 44 individuals, 21 females and 23 males. The sample has a relevantly even number of individuals, males and females, because the aim of this study could be achieved through research on the presence or absence of the pelvic features in both sexes.

3.1.1 Historical background of Delft

Delft has a long history in the country of Holland, dating back to 1246. From being an agrarian village till the 14th century, it was mostly inhabited by maximum 2.000 people (Oosten et al., 2018, p. 117). In the 15th century Delft was transformed into a proper town with brick houses and trade of local products. Between 1580 and 1650, it was Holland's 'Golden age' (Epko, 2008, p. 31). In the span of these years, the people of Delft doubled in size. This can show that people who were moving to the city, to work, remained there, because the economic growth provided many opportunities. From this condition, it can be understood that inequality was present, because people with wealth, increased in size, while in contrast a working class lived in poorness.

An important factor of the change Delft went through was the claiming of nearly 7.000 people from the plague in 1557/1558. In the early modern period, there were many active graveyards in the general area of Delft, two of them being the Oude Kerk and the Nieuwe Kerk (Figure 10). The construction of the Nieuwe Kerk began in 1381 and was concluded in 1829.

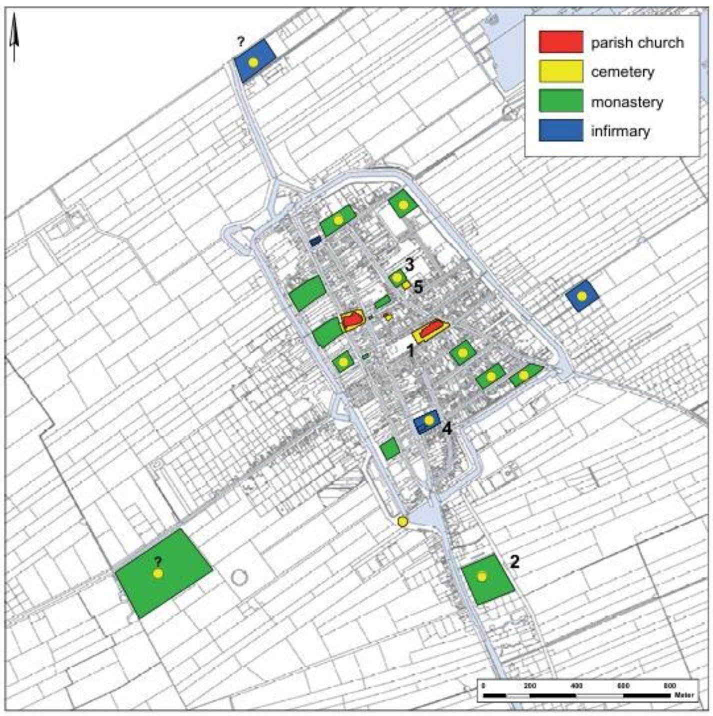

Figure 10 The location of the graveyards in and around Delft. The five cemeteries are 1=Nieuwe Kerk; 2=Koningsveld Priory; 3=Maria Magdalena Convent; 4=Oude en Nieuwe Gasthuis; 5=Cemetery of the Plague, Schutterstraat (Wiliams, 2022, p. 119, Figure 2).

3.1.2 The excavation

The material for this study was taken from the Excavation of the planned expansion of an existing cellar in the Nieuwe Kerk (New church) in the city of Delft, South Holland. The excavation took place from July 26th, 2021 till January 26th, 2022. 'ADC ArchaeoProjecten' was commissioned by 'Van Hoogevest Architecten' to carry out the excavation. The information below, are derived from the scientific report of the excavation taking place in the 'Nieuwe Kerk' of the city of Delft. The report was published in December 2022.

At the first phase of the excavation, nearly 170 m2 of surface area was investigated. 581 inhumations and 237 charnel pits/charnel coffins were excavated. Historically, burials have been found in and around the Nieuwe Kerk since 1396. The space inside and outside the church was divided into squares. The squares consisted of one or more rows of east-west graves while the number of graves per square varies. Inside the church there were two types of graves: private graves and rented graves. In the 1800s, the first nine squares and half of square 10 contained 34 private graves. In the span of the excavation, the municipality of Delft conducted an archival study for the area of research. The burial registers of the Nieuwe Kerk were examined. These records about private or rented graves exist from 1624 to 1766.

In the period 1453-1476 the church expanded, near the southern part of the choir aisle and graves came to lie within the church.

The graves within the Oude Kerk had a clear hierarchy and location was the most important factor. The choir was the most popular location. If one individual needed a grave, it was crucial to ask for it very quickly because some of the graves registered in 1367 were still owned by the same family in 1619. That was not relevant to the location of the grave. The same mentality worked with the Nieuwe Kerk. The archival research shows that the graves were accessible to anyone who had the amount to pay for it. In total, four burial vaults were found.

All skeletons have been described in the field by a senior physical anthropologist. The biggest part of the skeletons is buried oriented east-west, with feet in the east and the head in the west. Some of them are buried differently. This can be explained by relation with the Christian faith and tradition, where people are buried oriented east-west.

The evaluation from the Physical anthropologist, Steffen Baetsen, was made through the protocol that was held for all the skeletal materials of the excavation. According to the protocol, each individual skeleton from a primary context had its own unique track number which also functioned as a find and photo number.

During the research in the Nieuwe Kerk in the city of Delft, 550 out of the 581 find numbers of primary graves, contained human skeletal material. All burials date to the post-medieval period between 1600 and 1830, with most between 1750 and 1830. Regarding age at death, two groups of the individuals excavated consists of 107 (20%) non-adults and 427 (80%) adults. There are individuals present from every age group. There does not seem to be a big difference at the age of death of men and women. Regarding the sex of the individuals excavated, it consists of 186 (51%) males and 152 (42%) females (Williams, 2022).

3.1.3 The sample

The osteological sample size consists of 44 pelvic bones. The sample size also consists of 44 sacra which has to be mentioned that not all of them correspond to the same identification number of the pelves. The sample is divided between 21 female and 23 male individuals as shown in table 2.

During the sample selection, probable females and probable males were included in the database made for this study, because the sample size would otherwise be much smaller. No indescribable individuals were included in the sample. Regarding the age-at-death of the individuals of the sample, six of them (13.6 %) are from an ‘Early young adult’ age range. 38 (86.4%) individuals come from a ‘Middle adult’ age range (table 1). These age ranges correspond to 18-25 and 35-50 years of age respectively. Age-at-death and sex estimation were already done during the study for the archaeological report of the excavation. The estimations were not repeated, because of time deficiency.

The skeletal material from this study is located and stored in the Laboratory of Human Osteoarchaeology of the University of Leiden.

Table 1 Distribution of age of the sample

AGE	N (%)
EARLY YEAR ADULTS	6(13.6)
MIDDLE ADULTS	38(86.4)
TOTAL	44(100)

Table 2 Distribution of sex of the sample

SEX	N (%)
FEMALE	21(47.7)
MALE	23(52.3)
TOTAL	44(100)

3.2 Methodology

3.2.1 Data collection

Eight pelvic features were assessed bilaterally and their presence or absence on the bone was estimated for all the sample size. Because the focus of this study is to find out firstly, whether the features are present or absent in the Delft collection, the search for the expression of the features and as such the severity of them, were excluded from this study. The phenomenon of pelvic features is multifactorial and as discussed in the introduction of this study many elements of a person's genetic history and daily life habits can contribute to the formation of the features. However, not all factors which contribute to their appearance are studied thoroughly, like if pelvic shape and size play a part in their formation. Waltenberger et al., (2021) studied the possibility of other biomechanical factors being the etiology of the presence of the features like pelvic shape and size. Even though recorded, the expression of the features was not considered for the statistical analysis. Initially, the presence and absence of the features as well their expression were measured in both the left and right sides of the pelvic bones but afterwards the measurements on the two sides were merged into one group. That was done due to the absence of this element from the research questions of this study.

3.2.1.1 Sample selection

The Delft collection consists of 550 skeletons. The first step into this study methodologically, was to refer to the database of skeletal populations of the Laboratory for Human Osteoarchaeology at Leiden University. This database could be studied at the Colibris library software (https://app.colibris.be/osteoleiden/).

Approximately 300 boxes contain the bones of the overall number of the skeletons. During the data collection process, I went through the boxes to find out which of the material could be assessed for this research. After opening each box, I looked for the pelvis and sacrum of each individual. I excluded from this research all bones which seemed to fall in the scope of pathological lesions and the bones which had very high levels of fragmentation. This was decided upon the fact that the selected bones should not overlap with pathological lesions, thus the features would become 'invisible'. In general, bone preservation was good with low fragmentation. Regarding sex and age-at-death estimation, for this research it was based on previous studies from the initial research by lead physical anthropologist Steffen Baetsen, on the Nieuwe Kerk excavation in 2021.

In the process of data collection, for this study, a simple form was created. The form included the title and ID the sex and age-at-death estimations of every bone. Next, eight columns were made for every pelvic feature, which included the presence or absence of the features. Another five columns were created to record the five measurements of the pelvic bones. Afterwards a different form was created for the recording of the sacra with columns referring to the ID, sex and age-at-death of bones, along with four columns for the measurements of the sacrum.

A thorough description of the methods used to identify the presence or absence of the features along with figures will follow, to be made clear how each of these characteristics were evaluated. The methodology of the measurements of the pelvic bones and sacra will follow in section 3.2.3.

3.2.2 Evaluation of presence or absence of Pelvic features

1. Preauricular sulcus

Every individual was examined for the presence or absence of a preauricular sulcus (PAS). (Figure 11). The feature was recorded according to Waltenberger et al. (2022, p. 3). Those methods were specifically adapted from Cox (1989) and Houghton (1975). The trait was not distinguished by type, only by stage. The feature's presence or absence was categorized in a scale of 0 to 1 where the former category shows no presence of sulcus and the latter category shows presence of sulcus as table X shows (Table 3).

Table 3 The Preauricular sulcus presence or absence categorization.

SCORE	DESCRIPTION
0	'area is smooth, with no clear evidence of a sulcus'
1	'present sulcus'

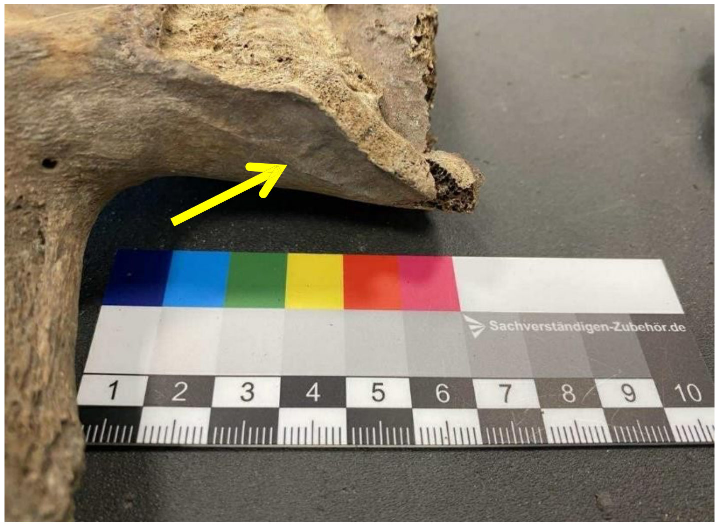

Figure 11 The preauricular sulcus shown with the yellow arrow. Anterior view of the right innominate. (Photograph: Maria Farmaki).

2. Dorsal pubic pitting

Every individual was examined for the presence or absence of the Dorsal pubic pitting (DPP) (Figure 12). The DPP was recorded according to Waltenberger et al. (2022, p. 3). Although the DPP's depth, width and height can be measured, in this study this was not included, due to the necessity of scoring only if DPP was present or not. The feature was categorized as table 4 shows.

Table 4 Categorization of the presence /or absence of the Dorsal pubic pitting

SCORE	DESCRIPTION
0	'Absence of Dorsal pubic pitting'
1	'Presence of Dorsal pubic pitting'

Figure 12 The dorsal pubic pitting.
Anterior view of the left pubic bone.
(Photograph: Maria Farmaki).

3. Ventral pubic pitting

Every individual was examined for the presence or absence of the Ventral pubic pitting (VPP) (Figure 13). The VPP was recorded according to the same way the DPP was, in Waltenberger et al. (2022, p. 522) and was adapted from Rebay-Salisbury et al. (2018). The feature was categorized according to its presence or absence as table 5 shows.

Table 5 Categorization of the presence or absence of the Ventral pubic pitting

SCORE	DESCRIPTION
0	'Absence of Ventral pubic pitting'
1	' Presence of Ventral pubic pitting'

Figure 13 Exostoses and lesions at the ventral pubic surface. (Rebay- Salisbury, 2018, p. 95, Figure 13).

4. Iliac tuberosity

Every individual was examined for the presence or absence of Iliac tuberosity (IT) (Figure 14). The Iliac tuberosity was recorded according to Maass & Friedling (2016, p. 123) as described by Andersen (1986). To understand if the feature was present or absent, the thickness of the iliac tuberosity was measured from its highest point to the posterior of the ilium, allowing the tuberosity to be classified as 'no eminence' (<20.0 mm) and a present iliac tuberosity (>20.0mm) as table 6 shows.

Table 6 Categorization of the presence or absence of the Iliac tuberosity

SCORE	DESCRIPTION
0	'Absence of Iliac tuberosity(<20.0mm)'
1	' Presence of Iliac tuberosity(>20.0mm)'

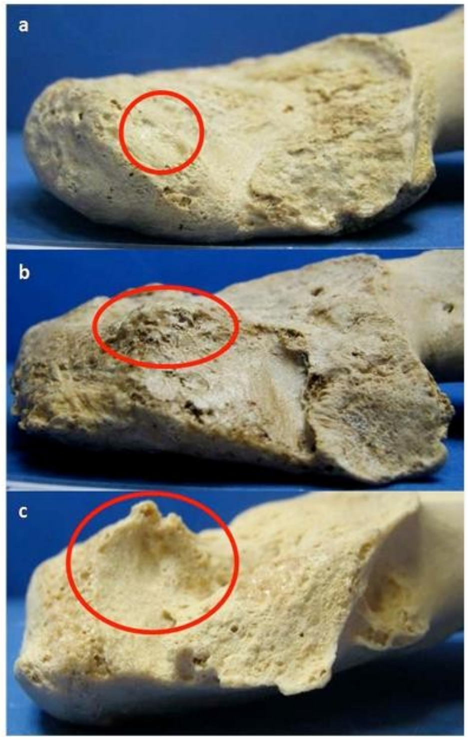

Figure 14 Inferior view of the left auricular region, showing examples of the classifications of the iliac tuberosity: a. "No eminence", b. "Depressed mound", and c. "Pointed mound". (Maass, 2012, p. 37, Figure 3.8).

5. Extended pubic tubercle

Every individual was examined for the presence or absence of the extended pubic tubercle (EPT) (Figure 15). The height of the EPT was recorded according to Snodgrass & Galloway (2003, p. 2). In general, the pubic tubercle is a landmark of the pubic bone with normal variation. To comprehend if the EPT was present or absent, the feature was measured from the ventral side of the pubis, using a wooden stick and the sliding caliper. If the EPT was present the measurement would be larger than 1.0

mm (>1.0 mm). If the EPT was absent it would have been smaller than 1.0 mm (<1.0 mm), as table 7 shows.

Table 7 Categorization of the presence and absence of the Extended pubic tubercle

SCORE	DESCRIPTION
0	'Absence of Extended pubic tubercle (<1.0 mm)'
1	'Presence of Extended pubic tubercle (>1.0 mm)'

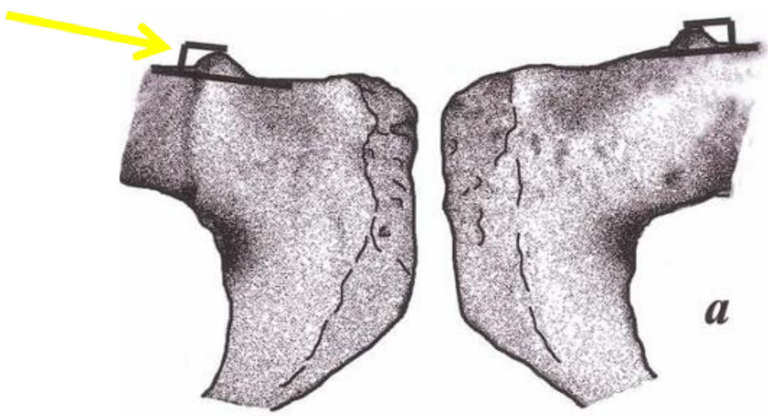

Figure 15 Anterior view of the right and left pubic bones, showing (with the yellow arrow) the height of the extended pubic tubercle on the ventral side. (Adapted from Snodgrass and Galloway, 2003, p. 2, Figure 1).

6. Interosseous groove

Every individual was examined for the presence or absence of the Interosseous groove (IG) (Figure 16). The interosseous groove was recorded according to Maass & Friedling (2016, p.122-123). To understand if the groove was present or absent, the maximum depth and width would have to be measured. As previously stated, this study evaluated the presence or absence of the features and not the way they express. The IG was evaluated as present when its depth was smaller than 3.0 mm where it is presented as shallow. When its depth was close to zero, it was evaluated as absent, as shown in table 8.

Table 8 Categorization of the presence and absence of the Interosseous groove

SCORE	DESCRIPTION
0	'Absence of Interosseous groove (0 mm)'
1	' Presence of Interosseous groove (>3.0mm)'

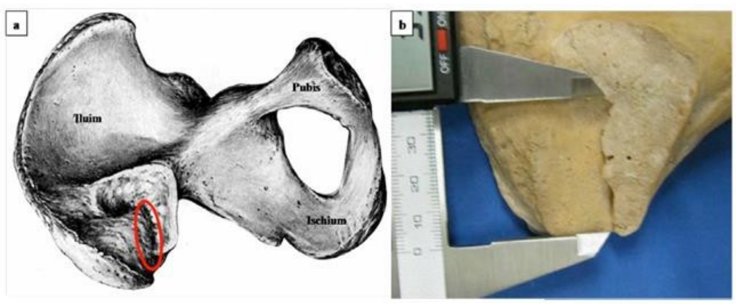

Figure 16 a. Medial view of the left innominate, showing the location of the interosseous groove, and b. an example of the measurement of the maximum length of the interosseous groove. (Maass, 2012, p. 36, Figure 3.5).

7. Sacral preauricular extension

Every individual was examined for the presence or absence of the Sacral preauricular extension (SPE) (Figure 9, Chapter 2). The SPE is recorded by Pany-Kucera et al. (2019, p. 1016). The trait was recorded as absent (no bony modification) or present as shown in the table 9 below.

Table 9 Categorization of the presence or absence of the Sacral preauricular extension

SCORE	DESCRIPTION
0	'Absence of Sacral preauricular extension (No bony modification)'
1	' Presence of Sacral preauricular extension'

8. Margo auricularis groove

Every individual was examined for the presence or absence of the Margo auricularis groove (MAG) (Table 10). It is a newly described feature which is located at margin of the sacral auricular facet (Pany-Kucera et al., 2019, p. 1014).

Table 10 Categorization of the presence or absence of the Margo auricularis groove

SCORE	DESCRIPTION
0	'Absence of Margo auricularis groove'
1	' Presence of Margo auricularis groove'

3.2.3 Measurements of the Pelvis and Sacrum

In this section, the measurements of the pelvic bones and sacrum will be presented. All the bones were measured in the process of the data collection, using a sliding caliper and in millimeters. Starting with the pelvic measurements (Arun et al., 2012, p. 2), the sacral ones follow (Langley et al., 2018, p. 77).

1. Minimum iliac breadth (MIB)

The MIB is the distance from the point where the arch of the greater sciatic notch meets the postero-superior margin of the acetabulum, to the point where anterior border of the ilium meets the antero-superior margin of the acetabulum (Figure 17)

Figure 17 Maximum auricular length (shown as 'A'). (Arun et al., 2012, p. 3, Figure 1).

2. Maximum auricular length (MAL)

The MAL is the maximum vertical distance between the superior and inferior borders of the auricular surface of the ilium (Figure 18)

Figure 18 Minimum iliac breadth (shown as 'B'). (Arun et al., 2012, p. 4, Figure 2).

3. Maximum Ischio-pubic length (MIPL)

The MIPL is the distance between the pubic crest and the most projecting point on femoral surface of the ischial tuberosity (Figure 19).

Figure 19 Maximum Ischio-pubic length (shown as 'C').
(Arun et al., 2012, p. 5, Figure 3).

4. Maximum Innominate height (MIH)

The MIH distance is the distance from the most superior point on the iliac crest to the most inferior point on the ischial tuberosity (Figure 20).

5. Maximum Iliac breadth (MIB)

The MIB is the distance from the anterior superior iliac spine to the posterior superior iliac spine. (Figure 20)

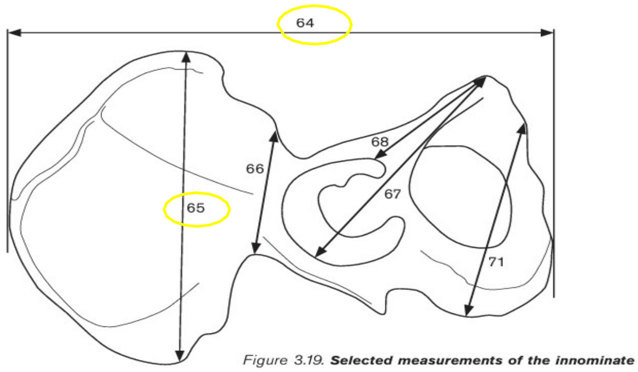

Figure 20 Selected measurements of the innominate. Measurements in yellow circles are used in this study. (Adapted from Langley et al., 2018, p. 77, Figure 3.19).

6. Anterior height of the sacrum (AHS)

The AHS distance is from the point of the promontory in the mid-sagittal plane to the corresponding point on the anterior border of the distal tip of the sacrum (Figure 21).

7. Anterior breadth of the sacrum (ABS)

The ABS is the maximum transverse breadth of the sacrum at most anterior projection of the auricular surfaces (Figure 21).

8. Transverse diameter of sacral segment 1 (TDSs1)

The TDSs1 is the distance between the two most lateral points on the superior articular surface measured perpendicular to the mid-sagittal plane (Figure 21).

9. Anterior- posterior diameter of sacral segment 1 (APSSs1)

The APSSs1 distance is between the anterior and posterior borders of the superior articular surface of S1, taken in the mid-sagittal plane (Figure 21).

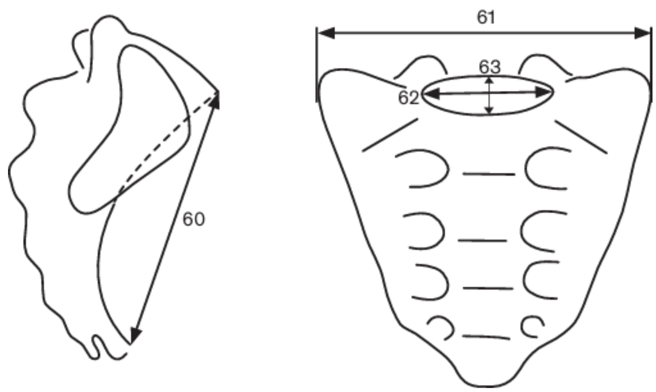

Figure 21 Selected measurements of the sacrum. 60= AHS, 61= ABS, 62= TDSs1, 63= APSSs. (Langley et al., 2018, p. 76, Figure 3.18).

3.2.4 Statistical methods

The statistical analysis was performed using IBM SPSS Statistics (version 29.0.0.0). Descriptive statistics (means, standard deviations, frequencies, and percentages) were used to summarize the distribution of the sample. The normality of continuous variables was assessed using the Shapiro–Wilk test.

Comparisons between two independent groups (absent and present group) were performed using the non-parametric Mann–Whitney U test, as the assumption of normality was not consistently met. Statistical significance was set at $p = 0.05$.

Intra-observer error was assessed on a randomly selected subset of the sample measured independently by the observer. For qualitative variables, intra-observer agreement was evaluated using Cohen's kappa coefficient (κ). For quantitative variables, intra-observer error was assessed using the Technical Error of Measurement (TEM).

3.3 Chapter summary

In this chapter (Chapter 3) the materials of this study were presented. The materials consist of 44 pelvic bones and 44 sacral bones. The specific bones come from the 'Nieuwe Kerk' church cemetery of the city of Delft. The excavation which resulted in the revealing of the skeletal material, was carried out between 2021 and 2022. Historically, the period of interest for this study is the Dutch Post-medieval age period which lies chronologically between 1600 and 1830. Afterwards, the sample size for this study was presented.

In the second part of this chapter the methodology applied was presented. The way with which the sample was first chosen and recorded was referred to in the chapter. Lastly, the way the macroscopic observations of the pelvic features, along with the measurements of the pelves and sacra, were shown analytically.

Chapter 4: Results

In this chapter, all the results obtained from the methodology recorded in the previous chapter, are presented through the statistical analysis. Firstly, the descriptive statistics of pelvic bones are presented. This gathers the information of the results about the age-at-death and sex sample distribution as well as the prevalence of the features and the occurrence rates between male and female individuals. The results of the mean values of the pelvic measurements are presented next. Afterwards, the descriptive statistics of the sacra and the intra-observer error testing will follow along with the age-at-death and sex sample distribution results.

At the last part of this chapter the results of the statistical analyses regarding the correlation of pelvic and sacral measurements with the presence or absence of the features, are presented.

4.1 Descriptive statistics of pelvic bones

4.1.1 Age-at-death and sex sample distribution

The sample consisted of 44 individuals, including six young adults (13.6%) and 40 middle- aged individuals (86.4%), indicating a predominance of the middle-aged group**. (**Table 11).

Table 11 Age-at-death sample distribution

AGE	N (%)
EYA	6(13.6)
MA	38(86.4)
TOTAL	44(100)

The sample consisted of 44 individuals, including 21 females (47.7%) and 23 males (52.3%), indicating a nearly balanced sex distribution with a slight predominance of males. (Table 12)

Table 12 Sex distribution of the sample

SEX	N(%)
FEMALE	21(47.7)
MALE	23(52.3)
TOTAL	44(100)

4.1.2 Prevalence of Pelvic features and occurrence rates in male and female individuals.

The Preauricular sulcus was present in 27 (61.4%) individuals. The sulcus was absent in 12 individuals (27.3%), and unobservable in 5 (11.4%) of cases.

Among females, the sulcus was present in 18 (87.5%) individuals and absent in two (9.5%). It was unobservable in one female (4.8%). Among males the sulcus was present in nine (39.1%) individuals while it was absent in ten (43.5%). It was unobservable in four (17.4%) male individuals. (Table 13)

Table 13 The prevalence of preauricular sulcus in male and female individuals

PREAURICULAR SULCUS	N (%)	MALE (%)	FEMALE (%)
ABSENT	12(27.3)	10(43.5)	2(9.5)
PRESENT	27(61.4)	9(39.1)	18(87.5)
UNOBSERVABLE	5(11.4)	4(17.4)	1(4.8)
TOTAL	44 (100)	23(100)	21(100)

The Dorsal pubic pitting was present in nine (20.5%) individuals. The pitting was absent in 20 individuals (45.5%), and unobservable in 15 (34.1%) of cases.

Among females the dorsal pubic pitting was present in six (28.6%) individuals and absent in ten (47.6%) individuals. It was unobservable in 5(23.8%) individuals. Among males the dorsal pubic pitting was present in three (13%) and absent in ten (43.5%) individuals. The feature was unobservable in ten (43.5%) individuals (Table 14).

Table 14 The Prevalence of Dorsal pubic pitting in male and female individuals

DORSAL PUBIC PITTING	N (%)	MALE (%)	FEMALE (%)
ABSENT	20 (45.5)	10(43.5)	10(47.6)
PRESENT	9(20.5)	3(13)	6(28.6)

UNOBSERVABLE	15(34.1)	10(43.5)	5(23.8)
TOTAL	44(100)	23(100)	21(100)

The Ventral pubic pitting was present in 14 (31.8%) individuals. The pitting was absent in 13 individuals (29.5%), and unobservable in 17 (38.6%) of cases.

Among females the ventral pubic pitting was present nine (42.9%) and absent in five (23.8%). It was unobservable in seven (33.3%) individuals. Among males the feature was present in five (21.7%) individuals and absent in eight (34.8%) individuals. It was unobservable in ten (43.5%) individuals (Table 15).

Table 15 *The Prevalence of Ventral pubic pitting in male and female individuals*

VENTRAL PUBIC PITITNG	N (%)	MALE (%)	FEMALE (%)
ABSENT	13 (29.5)	8(34.8)	5(23.8)
PRESENT	14 (31.8)	5(21.7)	9(42.9)
UNOBSERVABLE	17 (38.6)	10(43.5)	7(33.3)
TOTAL	44 (100)	23(100)	21(100)

The Iliac tuberosity was present in 31 (70.5%) individuals. The pitting was unobservable in 13 (29.5%) of cases.

The results show that among females the tuberosity was present in 15 (71.4%) individuals. It was unobservable in six (28.6%). No individual was found to not have the feature.

Among males the tuberosity was present in 16 (69.6%). It was unobservable in seven (30.4%) individuals (Table 16).

Table 16 *The Prevalence of Iliac tuberosity in male and female individuals*

ILIAC TUBEROSITY	N (%)	MALE (%)	FEMALE (%)
PRESENT	31 (70.5)	16(69.6)	15(71.4)
UNOBSERVABLE	13 (29.5)	7(30.4)	6(28.6)
TOTAL	44 (100)	23(100)	21(100)

The Extended pubic tubercle was present in four (9.1%) of the cases. The feature was absent in 19 (43.2%) of the cases and unobservable in 21 (47.7%).

Among females in terms of occurrence, the tubercle was present in two (9.5%). It was absent in eight (38.1%) while unobservable in ten (47.6%) individuals. In terms of occurrence among male individuals the feature was found present in two (87%), absent in 11(47.8%), while unobservable in ten (43.5%) individuals (Table 17).

Table 17 *The Prevalence of Extended pubic tubercle in male and female individuals*

EXTENDED PUBIC TUBERCLE	N (%)	MALE (%)	FEMALE (%)
ABSENT	19 (43.2)	11(47.8)	8(38.1)
PRESENT	4 (9.1)	2(87)	2(9.5)
UNOBSERVABLE	21(47.7)	10(43.5)	10(47.6)

TOTAL	44 (100)	23(100)	21(100)

The Interosseous groove was present in 37 (84.1%) of the cases and absent in four (9.1%). It was unobservable in three (6.8%) of the cases. The results show that among females the groove was present in 20 (95.2%) individuals and absent in no individuals. It was unobservable in one (4.8%) individual. Among males the groove was present in 17 (73.9%) individuals. It was absent in four (17.94%) individuals. It was unobservable in two (8.7%) individuals (Table 18).

Table 18 The Prevalence of Interosseous groove in male and female individuals

INTEROSSEOUS GROOVE	N (%)	Male (%)	FEMALE (%)
ABSENT	4 (9.1)	4(17.4)	-
PRESENT	37 (84.1)	17(73.9)	20(95.2)
UNOBSERVABLE	3(6.8)	2(8.7)	1(4.8)
Total	44 (100)	23(100)	21(100)

The Margo auricularis groove was present in 40 (90.9%) of the cases and absent in two (4.5%) individuals. It was unobservable in two (4.5%) individuals.

In terms of occurrence among females, the Margo auricularis groove was present in 20 (95.2%) individuals. It was absent in one (4.8%) individual. It was not reported unobservable in any individual. In terms of occurrence among males, the

Margo auricularis groove was present in 20(87%) individuals. It was reported as absent in one (4.3%). It was unobservable for two (8.7%) individuals (Table 19)

Table 19 The Prevalence of Margo auricularis groove in male and female individuals

MARGO AURICULARIS GROOVE	N (%)	MALE (%)	FEMALE (%)
ABSENT	2 (4.5)	1(4.3)	1(4.8)
PRESENT	40 (90.9)	20(87)	20(95.2)
UNOBSERVABLE	2 (4.5)	2(8.7)	-
TOTAL	44(100)	23(100)	21(100)

The Sacral preauricular extension was present in eight (18.3%) individuals and absent in 27 (61.4%) of cases. It was unobservable in nine (20.5%) of cases.

In terms of occurrence among females the Sacral preauricular extension was present in four (19%) individuals. It was absent in 13(61.9%) and was unobservable for four (19%) individuals. In terms of occurrence among males, the feature was present in four (17.4) and absent in 14 (60.9) individuals. It was reported as unobservable for five (21.7%) individuals (Table 20)

Table 20 The prevalence of Sacral preauricular extension in male and female individuals

SACRAL PREAURICULAR EXTENSION	N (%)	MALE (%)	FEMALE (%)
ABSENT	27(61.4)	14 (60.9)	13(61.9)
PRESENT	8(18.2)	4(17.4)	4(19)
UNOBSERVABLE	9 (20.5)	5(21.7)	4(19)
TOTAL	44(100)	23(100)	21(100)

4.1.3 Pelvic measurements

Table 21 Mean values of the pelvic measurements

Pelvic measurements	N	MEAN ± SD
Minimum iliac breadth (MIB)	44 (100)	64.25 ± 6.56
Maximum auricular length (MAL)	40 (90.9)	52.26 ± 7.51
Maximum ischio-pubic length (MIPL)	23 (52.3)	121.82 ± 10.76

Maximum Innominate height (MIH)	33 (75.0)	210.62 ± 13.46
Iliac breadth (IB)	28 (63.6)	159.02 ± 9.52

Table 21 presents descriptive statistics of five pelvic measurements collected from the sample of 44 individuals (100% of the sample). For each variable, the mean value and standard deviation (SD) are presented. Standard deviation was calculated based on the mathematical type below:

$$s = \sqrt{\frac{\sum(X - \bar{X})^2}{n-1}}$$

The mean minimum iliac breadth (MIB) was 64.25 ± 6.56 mm (n = 44). The mean maximum auricular length (MAL) was 52.26 ± 7.51 mm (n = 40). The mean maximum ischiopubic length (MIPL) was 121.82 ± 10.76 mm (n = 23). The mean maximum innominate height (MIH) was 210.62 ± 13.46 mm (n = 33). The mean iliac breadth (IB) was 159.02 ± 9.52 mm (n = 28).

4.2 Descriptive statistics of the Sacrum

Table 22 Mean values of the sacral measurements

SACRA	N (%)	MEAN ± SD
Anterior Height of the Sacrum	23 (52.3)	112.87 ± 12.47
Anterior Breadth of the Sacrum	32 (72.7)	117.67 ± 6.24
Transverse Diameter of Sacral Segment 1	35 (79.5)	49.33 ± 5.40
Anterior-Posterior Diameter of Sacral Segment 1	33 (75.0)	32.41 ± 4.07
Total	44(100)	

The sample consisted of 44 bones of sacra. The measurements which were taken were four: Anterior height of the sacrum (AHS), Anterior breadth of the sacrum (ABS), Transverse diameter of Sacral segment 1 (TDSs1) and Anterior-posterior diameter of Sacral segment 1 (APSs1) (Table 22)

The Anterior height of the sacrum was measured in 23 (52.3%) individuals, while it was unobservable in 21 (47.7%), with a mean value of 112.87 ± 12.47 mm. The Anterior breadth of the sacrum was measured in 32 (72.7%) individuals and was unobservable in 12 (27.3%), with a mean value of 117.67 ± 6.24 mm. The Transverse diameter of Sacral segment 1 was measured in 35 (79.5%) individuals and was unobservable in 9 (20.5%) cases, with a mean value of 49.33 ± 5.40 mm. The Anterior- posterior diameter of Sacral segment 1 was measured in 33 (75.0%) individuals and was unobservable in 11 (25.0%) cases, with a mean value of 32.41 ± 4.07 mm.

4.3 Intra observer error testing

4.3.1 Pelvic features

1. Preauricular sulcus

Although the Kappa index could not be calculated due to lack of variance, complete stability was observed in the recordings (all values were the same before and after), indicating an absence of intra-observer variability for the left side. The intra-observer reliability of the right side of the preauricular sulcus yielded in perfect agreement between the two measurements (Kappa = 1.00, p = 0.046), indicating an absence of intra-observer variability in this sample.

2. Dorsal pubic pitting

The intra-observer agreement for the DPP left side was moderate (Cohen's Kappa = 0.556), with no statistically significant difference from random agreement (p = 0.082). The intra- observer agreement for DPP right side was good (Cohen's Kappa = 0.636) and statistically significant (p = 0.046).

3. Ventral pubic pitting

Perfect intra-observer agreement was observed between the two measurements (Cohen's Kappa = 1.00) for the VPP left side, which was statistically significant ($p = 0.046$). The intra-observer agreement was moderate to good (Cohen's Kappa = 0.600) for the right side VPP, without being statistically significant ($p = 0.070$).

4. Interosseous groove

Although the Kappa index could not be calculated due to lack of variance, complete stability was observed in the recordings (all values were the same before and after), indicating an absence of intra-observer variability for both sides.

5. Iliac tuberosity

Although the Kappa index could not be calculated due to lack of variance, complete stability was observed in the recordings (all values were the same before and after), indicating an absence of inter-observer variability. The intra-observer agreement for measuring the right iliac tuberosity was moderate (Cohen's Kappa = 0.500), with no statistically significant difference from random agreement ($p = 0.248$).

6. Extended pubic tubercle

The intra-observer agreement for the left side Extended pubic tubercle measure was perfect (Cohen's Kappa = 1.000) and reached statistical significance (p =

0.046).

7. Margo auricularis groove

The intra-observer agreement for the left side Margo auricularis groove measure was weak (Cohen's Kappa = 0), indicating no agreement beyond chance, despite the high raw agreement (3 out of 4 cases). Although the Kappa index could not be calculated due to lack of variance, complete stability was observed in the recordings (all values were the same before and after), indicating an absence of inter-observer variability for the right side.

8. Sacral preauricular extension

The intra-observer agreement for the left side Sacral preauricular extension measure was weak (Cohen's Kappa = 0), showing no agreement beyond chance, despite high raw agreement (3 out of 4 cases). The intra-observer agreement for the right side Sacral preauricular extension measure appears perfect (all observed values are identical), but Cohen's Kappa cannot be calculated due to lack of variability in the ratings.

4.3.2 Pelvic measurements

1. Minimum iliac breadth (MIB)

The intra-observer error for the left side of MIB was estimated using the Technical Error of Measurement (TEM = 3.70). The mean difference between repeated measurements was 4.29. For the right side the intra-observer error was estimated using the Technical Error of Measurement (TEM = 4.15). The mean difference between repeated measurements was 2.08, indicating a small systematic bias.

2. Maximum auricular length (MAL)

The intra-observer error for the left side was small (TEM = 1.08). The mean difference between repeated measurements was 1.06, indicating minimal systematic bias. The intra-observer error for the right side was very small (TEM = 0.38). The mean difference between repeated measurements was -0.42, indicating minimal systematic bias.

3. Maximum ischio-pubic length (MIPL)

Due to the many unobservable values, the MIPL could not be calculated.

4. Maximum Innominate height (MIH)

For the left side the intra-observer error for this variable was moderate (TEM = 1.60). The mean difference between repeated measurements was -0.76, indicating a small. The intra-observer error for the right side of this variable was moderate (TEM = 1.68). The mean difference between repeated measurements was 0.99.

5. Iliac breadth

The intra-observer error for the left side was low (TEM = 0.57). The mean difference was - 1.06, indicating a small systematic underestimation.

4.3.3 Sacral measurements

1. Anterior Height of the Sacrum

The intra-observer error for Anterior Height was low (TEM = 1.16). The mean difference between repeated measurements was near zero (0.005), indicating minimal systematic bias.

2. Anterior Breadth of the Sacrum

The intra-observer error for Anterior Breadth was very low (TEM = 0.68). The mean difference between repeated measurements was small (-0.28), suggesting minimal systematic bias.

3. Transverse Diameter of Sacral Segment 1

The intra-observer error for Transverse Diameter S1 was moderate (TEM = 1.51). The mean difference was 0.46, indicating small systematic bias.

4. Anterior-Posterior Diameter of Sacral Segment 1

The intra-observer error for Anterior-Posterior Diameter S1 was low (TEM = 1.01). The mean difference was 0.11, showing minimal systematic bias.

4.4 Correlation between pelvic measurements and presence or absence of pelvic features

Normality of the pelvic measurements was assessed using the Shapiro-Wilk test, separately for pelves with and without a preauricular sulcus (Table 23). Minimum iliac breadth (MIB), maximum auricular length (MAL), maximum innominate height (MIH), and iliac breadth (IB) showed no significant deviation from normality in either group ($p > 0.05$). However, maximum ischiopubic length (MIPL) demonstrated a significant deviation from normality in the group with a preauricular sulcus ($W = 0.843$, $p = 0.035$). Therefore, parametric independent samples t-tests were applied for MIB, MAL, MIH, and IB, while the non-parametric Mann-Whitney U test was used for MIPL.

Table 23 Test of Normality of Pelvic Measurements

TEST OF NORMALITY/ Shapiro-Wilk Normality Test		Statistic	df	P-value

Preauricular sulcus - Minimum iliac breadth (MIB)	Absent	0.976	6	0.928
	Present	0.949	11	0.629
Preauricular sulcus - Maximum auricular length (MAL)	Absent	0.914	6	0.460
	Present	0.933	11	0.442
Preauricular sulcus - Maximum ischiopubic length (MIPL)	Absent	0.912	6	0.452
	Present	**0.843**	**11**	**0.035**
Preauricular sulcus - Maximum innominate height (MIH)	Absent	0.952	6	0.757
	Present	0.917	11	0.294
Preauricular sulcus - Iliac breadth (IB)	Absent	0.910	6	0.438
	Present	0.937	11	0.488

Table 24 Correlation of Pelvic Measurements and presence/ absence of a Preauricular Sulcus

RESULTS MEASUREMENTS / Preauricular sulcus	Absent	Present	Statistics

	N	MEAN ± SD	N	MEAN ± SD	Test	p-value
Minimum iliac breadth (MIB)	**12**	**67.60 ± 5.77**	**27**	**61.50 ± 5.88**	**t = 3.005**	**0.005**
Maximum auricular length (MAL)	10	54.01 ± 4.47	27	51.37 ± 8.64	t = 0.915	0.367
Maximum ischiopubic length (MIPL)	6	120.04 ± 4.63	15	119.75 ± 14.11	U= 37.00	0.301
Maximum innominate height (MIH)	9	220.09 ± 8.12	22	204.73 ± 11.28	t=3.698	0.001
Iliac breadth (IB)	7	155.51± 7.43	19	158.26 ± 7.98	t= -0.792	0.436

Table 24 presents the comparison of pelvic measurements between individuals with and without the presence of a preauricular sulcus. A 't' represents independent sample t-tests while 'U' Mann-Whitney U tests.

For minimum iliac breadth (MIB), the mean value was higher in individuals without the sulcus (67.60 ± 5.77 mm; N = 12) compared to those with the sulcus (61.50 ± 5.88 mm; N = 27), and this difference was statistically significant (t = 3.005, p = 0.005). For maximum auricular length (MAL), the mean value was 54.01 ± 4.47 mm (N = 10) in individuals without a preauricular sulcus and 51.37 ± 8.64 mm (N = 27) in those with the sulcus; however, this difference was not statistically significant (t = 0.915, p = 0.367).

For maximum ischiopubic length (MIPL), the mean value was 120.04 ± 4.63 mm (N = 6) in the absent group and 119.75 ± 14.11 mm (N = 15) in the present group.

The Mann-Whitney U test indicated no statistically significant difference between the groups ($U = 37.000$, $Z = -1.086$, $p = 0.301$). For maximum innominate height (MIH), individuals without a preauricular sulcus had a higher mean value (220.09 ± 8.12 mm; N = 9) compared to those with the sulcus (204.73 ± 11.28 mm; N = 22), and this difference was statistically significant ($t = 3.698$, $p = 0.001$). Finally, for iliac breadth (IB), the mean value was 155.51 ± 7.43 mm (N = 7) in individuals without a preauricular sulcus and 158.26 ± 7.98 mm (N = 19) in those with the sulcus, with no statistically significant difference observed ($t = -0.792$, $p = 0.436$).

Table 25 Test of Normality of Pelvic Measurements according to Dorsal Pubic Pitting

TEST OF NORMALITY/ Shapiro-Wilk Normality Test		Statistic	df	P-value
Dorsal pubic pitting-Minimum iliac breadth (MIB)	Absent	.925	10	.401
	Present	.948	8	.693
Dorsal pubic pitting- Maximum auricular length (MAL)	Absent	.952	10	.691
	Present	.927	8	.488
Dorsal pubic pitting- Maximum ischiopubic length (MIPL)	Absent	.906	10	.256
	Present	.814	8	.040
Dorsal pubic pitting- Maximum innominate height (MIH)	Absent	.978	10	.955
	Present	.962	8	.824
Dorsal pubic pitting- Iliac breadth (IB)	Absent	.962	10	.808
	Present	.917	8	.403

Normality of the pelvic measurements was assessed using the Shapiro-Wilk test, separately for individuals with and without dorsal pubic pitting (Table 25).

Minimum iliac breadth (MIB), maximum auricular length (MAL), maximum innominate height (MIH), and iliac breadth (IB) showed no significant deviation from normality in either group ($p > 0.05$). Similarly, maximum ischiopubic length (MIPL) did not deviate significantly from normality in individuals without dorsal pubic pitting ($W = 0.906$, $p = 0.256$). However, in individuals with dorsal pubic pitting, MIPL demonstrated a statistically significant deviation from normality ($W = 0.814$, $p = 0.040$). Based on these results, parametric tests were considered appropriate for all variables except MIPL, for which a non-parametric approach was deemed more suitable.

Table 26 Correlation of Pelvic Measurements and presence/absence of Dorsal pubic pitting

RESULTS MEASUREMENTS / Dorsal pubic pitting	Absent		Present		Statistics	
	N	MEAN ± SD	N	MEAN ± SD	Test	p-value
Minimum iliac breadth (MIB)	20	63.76 ± 5.77	9	62.37 ± 6.15	t = 0.588	0.561
Maximum auricular length (MAL)	19	51.63 ± 3.92	9	48.73 ± 4.51	t = 1.741	0.094
Maximum ischiopubic length (MIPL)	14	115.85 ± 7.94	9	126.62 ± 13.12	U = 75.00	0.357
Maximum innominate height (MIH)	18	211.08 ± 10.85	9	207.21 ± 18.95	t = 0.680	0.503
Iliac breadth (IB)	14	157.66 ± 7.32	8	157.92 ± 14.10	t = -0.059	0.954

Table 26 presents the comparison of pelvic measurements between individuals with and without dorsal pubic pitting. For minimum iliac breadth (MIB), the mean value was 63.76 ± 5.77 mm (N = 20) in individuals without dorsal pubic pitting and 62.37 ± 6.15 mm (N = 9) in those with dorsal pubic pitting. However, this difference was not statistically significant (t = 0.588, p = 0.561). For maximum auricular length (MAL), the mean value was 51.63 ± 3.92 mm (N = 19) in individuals without dorsal pubic pitting and 48.73 ± 4.51 mm (N = 9) in those with dorsal pubic pitting, with no statistically significant difference observed (t = 1.741, p = 0.094). For maximum ischiopubic length (MIPL), the mean value was 115.85 ± 7.94 mm (N = 14) in the absent group and 126.62 ± 13.12 mm (N = 9) in the present group. The Mann-Whitney U test indicated no statistically significant difference between the groups (U = 75.00, p = 0.357). For maximum innominate height (MIH), the mean value was 211.08 ± 10.85 mm (N = 18) in individuals without dorsal pubic pitting and 207.21 ± 18.95 mm (N = 9) in those with dorsal pubic pitting, with no statistically significant difference (t = 0.680, p = 0.503). Finally, for iliac breadth (IB), the mean value was 157.66 ± 7.32 mm (N = 14) in individuals without dorsal pubic pitting and 157.92 ± 14.10 mm (N = 8) in those with dorsal pubic pitting, also showing no statistically significant difference (t = −0.059, p = 0.954).

Table 27 Test of Normality of Pelvic Measurements according to Ventral pubic pitting

TEST OF NORMALITY/ Shapiro-Wilk Normality Test		Statistic	df	P-value
Ventral pubic pitting-Minimum iliac breadth (MIB)	Absent	.949	8	.702
	Present	.967	9	.869
Ventral pubic pitting- Maximum auricular length (MAL)	Absent	.967	8	.875
	Present	.931	9	.493
Ventral pubic pitting- Maximum ischiopubic length (MIPL)	Absent	.878	8	.180
	Present	.821	9	.036
Ventral pubic pitting- Maximum innominate height (MIH)	Absent	.956	8	.776
	Present	.955	9	.743
Ventral pubic pitting- Iliac breadth (IB)	Absent	.964	8	.848
	Present	.892	9	.210

Normality of the pelvic measurements was assessed using the Shapiro-Wilk test, separately for individuals with and without ventral pubic pitting (Table 27). Minimum iliac breadth (MIB), maximum auricular length (MAL), maximum innominate height (MIH), and iliac breadth (IB) showed no significant deviation from normality in either group ($p > 0.05$). Similarly, maximum ischiopubic length (MIPL) did not deviate significantly from normality in individuals without ventral pubic pitting ($W = 0.878$, $p = 0.180$). However, in individuals with ventral pubic pitting, MIPL demonstrated a statistically significant deviation from normality ($W = 0.821$, $p = 0.036$). Based on these results, parametric tests were considered appropriate for all variables except MIPL, for which a non-parametric approach was deemed more suitable.

Table 28 Comparison of Pelvic Measurements and presence/absence of a Ventral pubic pitting

RESULTS MEASUREMENTS / Ventral pubic pitting	Absent		Present		Statistics	
	N	MEAN ± SD	N	MEAN ± SD	Test	p-value
Minimum iliac breadth (MIB)	13	64.33 ± 5.67	14	62.61 ± 6.39	t = 0.735	0.469
Maximum auricular length (MAL)	12	51.53 ± 4.77	14	50.28 ± 3.58	t = 0.764	0.452
Maximum ischiopubic length (MIPL)	8	116.36 ± 8.83	14	124.14 ± 13.59	U = 75.00	0.365
Maximum innominate height (MIH)	13	213.19 ± 10.64	12	206.99 ± 17.32	t = 1.089	0.287
Iliac breadth (IB)	10	157.17 ± 7.35	11	158.06 ± 12.61	t = -0.195	0.848

Table 28 presents the comparison of pelvic measurements between individuals with and without ventral pubic pitting. For minimum iliac breadth (MIB), the mean value was 64.33 ± 5.67 mm (N = 13) in individuals without ventral pubic pitting and 62.61 ± 6.39 mm (N = 14) in those with ventral pubic pitting. However, this difference was not statistically significant (t = 0.735, p = 0.469). For maximum auricular length (MAL), the mean value was 51.53 ± 4.77 mm (N = 12) in individuals without ventral pubic pitting and 50.28 ± 3.58 mm (N = 14) in those with ventral pubic pitting, with no statistically significant difference observed (t = 0.764, p = 0.452). For maximum ischiopubic length (MIPL), the mean value was 116.36 ± 8.83 mm (N = 8) in the absent group and 124.14 ± 13.59 mm (N = 14) in the present group. The Mann-Whitney U test indicated no statistically significant difference between the groups (U = 75.00, p = 0.365). For maximum innominate height (MIH), the mean value was 213.19 ± 10.64 mm (N = 13) in individuals without ventral pubic pitting and 206.99 ± 17.32 mm (N = 12) in those with ventral pubic pitting, with no statistically significant difference (t = 1.089, p = 0.287). Finally, for iliac breadth (IB), the mean value was 157.17 ± 7.35 mm (N = 10) in individuals without ventral pubic pitting and 158.06 ± 12.61 mm (N = 11) in those with ventral pubic pitting, also showing no statistically significant difference (t = −0.195, p = 0.848).

Table 29 Test of Normality of Pelvic Measurements according to Interosseous groove

TEST OF NORMALITY/ Shapiro-Wilk Normality Test		Statistic	df	P-value
Interosseous groove-Minimum iliac breadth (MIB)	Absent	-	-	-
	Present	.972	17	.845
Interosseous groove- Maximum auricular length (MAL)	Absent	-	-	-
	Present	.959	17	.605
Interosseous groove- Maximum ischiopubic length (MIPL)	Absent	-	-	-
	Present	.866	17	.019
Interosseous groove- Maximum innominate height (MIH)	Absent	-	-	-
	Present	.983	17	.980
Interosseous groove- Iliac breadth (IB)	Absent	-	-	-
	Present	.908	17	.093

The distribution of pelvic measurements according to the presence of an interosseous groove could not be statistically compared between groups. This is because the measurements in the group without an interosseous groove were constant, resulting in zero variance. As a result, inferential statistical tests such as the independent samples t-test or Mann-Whitney U test were not applicable. Therefore, only descriptive statistics are presented for this variable.

Table 30 Comparison of Pelvic Measurements and presence/absence of Interosseous groove

RESULTS MEASUREMENTS / Interosseous groove	Absent		Present	
	N	MEAN ± SD	N	MEAN ± SD
Minimum iliac breadth (MIB)	0	-	17	62.52 ± 5.48
Maximum auricular length (MAL)	0	-	17	50.22 ± 4.49
Maximum ischiopubic length (MIPL)	0	-	17	121.13 ± 11.76
Maximum innominate height (MIH)	0	-	17	210.43 ± 15.76
Iliac breadth (IB)	0	-	17	157.42 ± 9.97

Pelvic measurements according to the presence of an interosseous groove are presented descriptively in Table 30. Due to the absence of variability in the group without an interosseous groove, statistical comparisons between groups could not be performed. Therefore, only descriptive statistics are reported for individuals with the presence of an interosseous groove. The mean values were 62.52 ± 5.48 mm for minimum iliac breadth (MIB), 50.22 ± 4.49 mm for maximum auricular length (MAL), 121.13 ± 11.76 mm for maximum ischiopubic length (MIPL), 210.43 ± 15.76 mm for maximum innominate height (MIH), and 157.42 ± 9.97 mm for iliac breadth (IB).

Table 31 Test of Normality of Pelvic Measurements according to Iliac Tuberosity

TEST OF NORMALITY/ Shapiro-Wilk Normality Test		Statistic	df	P-value
Iliac Tuberosity-Minimum iliac breadth (MIB)	Absent	-	-	-
	Present	.971	16	.852
Iliac Tuberosity- Maximum auricular length (MAL)	Absent	-	-	-
	Present	.954	16	.553
Iliac Tuberosity- Maximum ischiopubic length (MIPL)	Absent	-	-	-
	Present	.867	16	.024
Iliac Tuberosity- Maximum innominate height (MIH)	Absent	-	-	-
	Present	.985	16	.990
Iliac Tuberosity- Iliac breadth (IB)	Absent	-	-	-
	Present	.898	16	.075

The distribution of pelvic measurements according to the presence of iliac tuberosity could not be statistically compared between groups. This is because the measurements in the group without iliac tuberosity were constant, resulting in zero variance. As a result, inferential statistical tests such as the independent samples t-test or Mann-Whitney U test were not applicable. Therefore, only descriptive statistics are presented for this variable.

Table 32 Comparison of Pelvic Measurements and presence/absence of Iliac Tuberosity

RESULTS MEASUREMENTS / Iliac Tuberosity	Absent		Present	
	N	MEAN ± SD	N	MEAN ± SD
Minimum iliac breadth (MIB)	0	-	16	62.18 ± 5.38
Maximum auricular length (MAL)	0	-	16	50.61 ± 5.02
Maximum ischiopubic length (MIPL)	0	-	16	120.22 ± 12.28
Maximum innominate height (MIH)	0	-	16	209.21 ± 15.26
Iliac breadth (IB)	0	-	16	157.55 ± 10.05

Pelvic measurements according to the presence of Iliac Tuberosity are presented descriptively in Table 32. Due to the absence of variability or lack of valid data in the group without Iliac Tuberosity, statistical comparisons between groups could not be performed. Therefore, only descriptive statistics are reported for individuals with the presence of this feature. The mean values were 62.18 ± 5.38 mm for minimum iliac breadth (MIB), 50.61 ± 5.02 mm for maximum auricular length (MAL), 120.22 ± 12.28 mm for maximum ischiopubic length (MIPL), 209.21 ± 15.26 mm for maximum innominate height (MIH), and 157.55 ± 10.05 mm for iliac breadth (IB).

Table 33 Test of Normality of Pelvic Measurements according to Extended Pubic Tubercle

TEST OF NORMALITY/ Shapiro-Wilk Normality Test		Statistic	df	P-value
Extended Pubic Tubercle-Minimum iliac breadth (MIB)	Absent	.977	14	.956
	Present	.973	3	.684
Extended Pubic Tubercle- Maximum auricular length (MAL)	Absent	.924	14	.248
	Present	.976	3	.704
Extended Pubic Tubercle- Maximum ischiopubic length (MIPL)	Absent	.883	14	.063
	Present	.900	3	.385
Extended Pubic Tubercle- Maximum innominate height (MIH)	Absent	.986	14	.996
	Present	.984	3	.755
Extended Pubic Tubercle- Iliac breadth (IB)	Absent	.835	14	.014
	Present	.900	3	.386

Normality of the pelvic measurements according to the presence of an extended pubic tubercle was assessed using the Shapiro-Wilk test (Table 33). Minimum iliac breadth (MIB), maximum auricular length (MAL), maximum ischiopubic length (MIPL), and maximum innominate height (MIH) showed no significant deviation from normality in either group ($p > 0.05$). However, iliac breadth (IB) demonstrated a statistically significant deviation from normality in the group without an extended pubic tubercle ($W = 0.835$, $p = 0.014$). Based on these results, independent samples t-tests were applied for the comparison of MIB, MAL, MIPL, and MIH, while the Mann-Whitney U test was used for IB due to its non-normal distribution.

Table 34 Comparison of Pelvic Measurements and presence/absence of an extended pubic tubercle

RESULTS MEASUREMENTS / Extended pubic tubercle	Absent		Present		Statistics	
	N	MEAN ± SD	N	MEAN ± SD	Test	p-value
Minimum iliac breadth (MIB)	19	63.57 ± 6.44	4	66.44 ± 4.95	t = -0.834	0.414
Maximum auricular length (MAL)	18	50.93 ± 4.68	4	50.06 ± 3.44	t = 0.348	0.732
Maximum ischiopubic length (MIPL)	18	121.12 ± 11.78	4	124.58 ± 6.96	t = -0.560	0.581
Maximum innominate height (MIH)	18	210.88 ± 14.99	3	209.01 ± 20.65	t = 0.192	0.850
Iliac breadth (IB)	14	158.79 ± 9.64	5	148.68 ± 8.32	U = 24.00	0.596

Table 34 presents the comparison of pelvic measurements between individuals with and without an extended pubic tubercle. For minimum iliac breadth (MIB), the mean value was 63.57 ± 6.44 mm (N = 19) in individuals without the feature and 66.44 ± 4.95 mm (N = 4) in those with the feature. This difference was not statistically significant (t = −0.834, p = 0.414). For maximum auricular length (MAL), the mean value was 50.93 ± 4.68 mm (N = 18) in the absent group and 50.06 ± 3.44 mm (N = 4) in the present group, with no statistically significant difference (t = 0.348, p = 0.732). For maximum ischiopubic length (MIPL), the mean value was 121.12 ± 11.78 mm (N = 18) in individuals without the feature and 124.58 ± 6.96 mm (N = 4) in those with the feature; this difference was not statistically significant (t = −0.560, p = 0.581). For maximum innominate height (MIH), the mean value was 210.88 ± 14.99 mm (N = 18) in the absent group and 209.01 ± 20.65 mm (N = 3) in the present group, also showing no statistically significant difference (t = 0.192, p = 0.850). Finally, for iliac breadth (IB), the mean value was 158.79 ± 9.64 mm (N = 14) in individuals without the feature and 148.68 ± 8.32 mm (N = 5) in those with the feature. The Mann-Whitney U test indicated no statistically significant difference between the groups (U = 24.00, p = 0.596).

Table 35 Test of Normality of Pelvic Measurements according to Margo auricularis groove

TEST OF NORMALITY/ Shapiro-Wilk Normality Test		Statistic	df	P-value
Margo auricularis groove-Minimum iliac breadth (MIB)	Absent	-	-	-
	Present	.968	18	.750
Margo auricularis groove- Maximum auricular length (MAL)	Absent	-	-	-
	Present	.958	18	.559
Margo auricularis groove- Maximum ischiopubic length (MIPL)	Absent	-	-	-
	Present	.865	18	.015
Margo auricularis groove- Maximum innominate height (MIH)	Absent	-	-	-
	Present	.984	18	.980
Margo auricularis groove- Iliac breadth (IB)	Absent	-	-	-
	Present	.902	18	.062

The distribution of pelvic measurements according to the presence of Margo auricularis groove could not be statistically compared between groups. This is because the measurements in the group without Margo auricularis groove were constant, resulting in zero variance. As a result, inferential statistical tests such as the independent samples t-test or Mann-Whitney U test were not applicable. Therefore, only descriptive statistics are presented for this variable.

Table 36 Comparison of Pelvic Measurements and presence/absence of a Margo auricularis groove

RESULTS MEASUREMENTS / Margo auricularis groove	Absent		Present	
	N	MEAN ± SD	N	MEAN ± SD
Minimum iliac breadth (MIB)	0	-	18	62.66 ± 5.35
Maximum auricular length (MAL)	0	-	18	50.69 ± 4.80
Maximum ischiopubic length (MIPL)	0	-	18	120.64 ± 11.60
Maximum innominate height (MIH)	0	-	18	210.29 ± 15.30
Iliac breadth (IB)	0	-	18	157.19 ± 9.73

Pelvic measurements according to the presence of a margo auricularis groove are presented descriptively in Table 36. Due to the absence of valid cases in the group without a margo auricularis groove, statistical comparisons between groups could not be performed. Therefore, only descriptive statistics are reported for individuals with the presence of this feature. The mean values were 62.66 ± 5.35 mm for minimum iliac breadth (MIB), 50.69 ± 4.80 mm for maximum auricular length (MAL), 120.64 ± 11.60 mm for maximum ischiopubic length (MIPL), 210.29 ± 15.30 mm for maximum innominate height (MIH), and 157.19 ± 9.73 mm for iliac breadth (IB).

Table 37 Test of Normality of Pelvic Measurements according to Sacral Preauricular Extension

TEST OF NORMALITY/ Shapiro-Wilk Normality Test		Statistic	df	P-value
Sacral Preauricular Extension-Minimum iliac breadth (MIB)	Absent	.965	15	.777
	Present	-	-	-
Sacral Preauricular Extension- Maximum auricular length (MAL)	Absent	.937	15	.341
	Present	-	-	-
Sacral Preauricular Extension- Maximum ischiopubic length (MIPL)	Absent	.877	15	.043
	Present	-	-	-
Sacral Preauricular Extension- Maximum innominate height (MIH)	Absent	.978	15	.954
	Present	-	-	-
Sacral Preauricular Extension- Iliac breadth (IB)	Absent	.912	15	.145
	Present	-	-	-

The distribution of pelvic measurements according to the presence of a sacral preauricular extension could not be statistically compared between groups. This is because the group with a sacral preauricular extension contained constant or invalid values, resulting in a lack of variability and preventing meaningful statistical comparison. Consequently, inferential statistical tests such as the independent samples t-test or Mann-Whitney U test were not applicable. Therefore, only descriptive statistics are presented for this variable.

Table 38 Comparison of Pelvic Measurements and presence/absence of a Sacral preauricular extension

RESULTS MEASUREMENTS / Sacral preauricular extension	Absent		Present	
	N	MEAN ± SD	N	MEAN ± SD
Minimum iliac breadth (MIB)	15	63.11 ± 5.36	0	-
Maximum auricular length (MAL)	15	50.42 ± 5.20	0	-
Maximum ischiopubic length (MIPL)	15	121.36 ± 12.45	0	-
Maximum innominate height (MIH)	15	210.72 ± 16.78	0	-

Iliac breadth (IB)	15	157.21 ± 10.66	0	-

Table 38 presents the pelvic measurements in individuals without a sacral preauricular extension. A total of 15 individuals showed absence of the feature, while the group with the feature could not be included in the analysis due to constant values. The mean minimum iliac breadth (MIB) was 63.11 ± 5.36 mm. The mean maximum auricular length (MAL) was 50.42 ± 5.20 mm. The mean maximum ischiopubic length (MIPL) was 121.36 ± 12.45 mm. The mean maximum innominate height (MIH) was 210.72 ± 16.78 mm. The mean iliac breadth (IB) was 157.21 ± 10.66 mm.

4.5. Correlation between sacral measurements and presence or absence of pelvic features

Normality of the variable anterior height of the sacrum was assessed using the Shapiro-Wilk test, separately for individuals with and without an interosseous groove. For the group without a groove (N = 4), the Shapiro-Wilk test indicated no significant deviation from normality ($W = 0.844$, $p = 0.207$). Similarly, for the group with the presence of an interosseous groove (N = 19), the distribution did not significantly deviate from normality ($W = 0.972$, $p = 0.819$). Since the assumption of normality was met in both groups, an independent samples t-test was conducted to compare the two groups. The results showed that the mean anterior height of the sacrum was 115.40 ± 16.22 mm in individuals without an interosseous groove and 112.33 ± 12.02 mm in those with the groove. This difference was not statistically significant (t = 0.439, p = 0.665).

Table 39 The test of Normality for the correlation of sacral measurements and presence/ absence of the features

TEST OF NORMALITY/ Shapiro-Wilk Normality Test		Statistic	df	P-value
Interosseous groove- Anterior Height of the Sacrum	Absent	.844	4	.207
	Present	.972	19	.819

Table 40 The correlation between sacral measurements and presence /absence of the AHS

Interosseous groove / Anterior Height of the Sacrum	Absent		Present		Statistics	
	N	MEAN ± SD	N	MEAN ± SD	t	p-value
Anterior Height of the Sacrum	4	115.40 ± 16.22	19	112.33 ± 12.02	-2.234	0.665

Chapter 5: Discussion

The formation of pelvic scars has been a controversial scientific issue. Numerous studies have examined these features to detect if indeed these are bony 'imprints' of pregnancy and/ or parturition. As research has shown many factors affect the presence of the features, and the strictness of the term 'parturition scars' may thus not show enough flexibility.

From a starting point, the formation of these features on the pelvic bone may be caused by a hormonal change during pregnancy and parturition, as the separation of pelvic joints is carried out. These changes can be the main triggers for the formation of pelvic features (Houghton, 1975, p. 661). In contrast some other studies have brought into consideration the presence of other factors playing a role in the formation of the features (Snodgrass & Galloway, 2003). Hypotheses include factors such as age, body size, pelvic flexibility and pelvic dimensions (Praxmarer et al., 2020, p. 630). Other studies have shown that nulliparae women, which never had been pregnant, and even men presented pelvic features (Maass & Friedling, 2016, pp. 121- 131).

This chapter will discuss the results which were presented in Chapter 4. The present study examines a main question which is whether there is an association of pelvic dimensions and size of the pelvis related to the appearance of pelvic features. Two sub-questions arise after the main question regarding the prevalence of pelvic features in the post-medieval population of the city of Delft and the differences in occurrence rates between male and female individuals. Moreover, this study will try to answer if there is any measurement mostly correlated with the presence of pelvic features, and if that can explain anything about the causation of the features.

5.1 Preauricular sulcus

For both sexes, the preauricular sulcus could be assessed in a large amount of the sample (61.4%). As shown in Table 13 (Chapter 4) the prevalence of the feature was 39.1% present for the male individuals while the female's feature was present in 87.5%. This indicates that women show a greater amount of presence of this exact feature than men. The appearance of the features in females relates with the necessity to preserve the stability of the pelvis, when the weight gain in pregnancy increases, and this could be responsible for the formation of the features. In this study, the only result which was statistically significant refers to the presence of PAS with MIB. The measurement was significantly smaller in individuals who presented the feature than in individuals without it ($Z = 3.005$, $p = 0.005$). This could mean that individuals without PAS had larger MIB than individuals without it in both sexes.

The frequency of the feature was higher in females than males also according to McFadden & Oxenham (2018) and Maass and Friendling (2016) who found among other features in females, more severe scarring as the preauricular sulcus. Praxmarer et al. (2020, p. 638) found that 19% of the female sample did not present dorsal pits, while 3.2% not preauricular sulcus. Earlier research of Angel (1969), Houghton (1974) and Kelley (1979) found that females without pelvic features were nulliparous.

In general, historical and archaeological collections of skeletons do not give transparent data on parity and parturition. That is a factor which prevents the connection of pelvic feature presence with the event of childbirth or childbearing. In contrast, in modern population collections, labor, a potential cause of pelvic features, is significantly affecting less, the presence of the features due to obstetric interventions, compared to historic collections. Thus, age-related, biomechanical, and genetic factors may be more connected to the presence of pelvic features than childbirth in modern populations (Waltenberger et al., 2021, p. 2).

The fact that pelvic features were present in 39.1% of the male sample suggests that parity and/ or parturition cannot solely be the only cause for the features to be appearing on the pelvic bones. The factors of larger body size and abdomen weight of male individuals are a possible cause of the formation of the features, along with hard labour. Angel (1969) suggests that the presence of the features correlates possibly with disease or trauma. The tension which exerts on the ligaments is possibly the cause for the formation of the features in both sexes, but the small sample size of this study limits the power of the results.

5.2 Dorsal pubic pitting

In the overall sample for the feature of Dorsal pubic pitting, it appeared that 20.5% of individuals had presented the feature. The sample was unobservable for 34.1% due to missing parts of the bone, therefore the data collection could not be done for these pelves. From the overall sample, 45.5% were not found to have the feature. According to the results shown in the table 14 (Chapter 4), the prevalence of the feature was found present in 13% of male individuals and 28.6% of females. The appearance of the feature shows in both sexes, and it can be observed more in females. This result concurs with research on the features, which present that higher frequencies are seen in women who have had children than nullipara or men (Gilbert & McKern, 1973, pp. 31-38; Stewart, 1970). The frequencies of appearance of the DPP can also increase with age (Snodgrass & Galloway, 2003, p. 4). However, several multipara women have not exhibited DPP (Waltenberger et al., 2022, p. 7). While the presence of DPP in the dorsal area of pubic bones has been studied considerably, the factors which contribute to its appearance remain unclear due to its presence in both sexes. Another factor which could be playing a role in the formation of the features could be the function of weight-bearing of the bony pelvis and the motions involving heavy loads, which can raise stress levels on muscles and ligaments. The event of scarring in both sexes implies that similar strains act on the ligaments attached to these sites. The scarring in female individuals is reported to be higher and more severe than males where the scarring is lower and less intense (Maass & Friedling, 2016, p.126). In this study, the severity of the features was not measured, and it was only observed regarding its presence or absence. The pubic bone specifically has been researched over decades, due to the presence of these features and is keeping researchers concerned. This could be caused by the appearance of pelvic features in parous females, although further research until today shows that these also appear in women without having given birth and in men.

Moreover, females appear to have three phases of change in the shape of the pelvis related to age. Our sample is small due to the two categories of age range in females, one as early young adult (18-25) and one as middle adult (35-50). Our sample lacks from females of 50 years old and older, who belong in the post-menopausal period. If our sample, consisted of women from post-menopausal age periods, where the features appear and remain, the argument of this study would have been justified, since the features would appear in an even larger size of the sample, regardless of if they had given birth or not.

5.3 Ventral pubic pitting

The VPP was present in 31.8% and absent in 29.5% of the overall sample. According to the results shown in table 15 (Chapter 4), the feature was present for 21.7% (N=5) of the male sample. The feature was found present in 42.9% (N=9) of the female overall sample. VPP was found more present in females than in males. In other studies, VPP was rarely present as a feature or present in a few individuals (Waltenberger et al., 2022, p. 5; Waltenberger et al., 2021, p. 4). In the sample of this study, VPP was present, and the sample consists of only adult individuals. From previous research, the human pelvis remodels throughout life and continues to do so even after the overall growth (Miterroecker & Fischer, 2016). The presence of pelvic features increased with age. Male individuals appear to have a very small increase of the features, which could be due to mechanical factors (Waltenberger et al., 2022). The pelvis is the central point of the human skeleton which supports the weight of the upper body and cranium. Especially in female individuals, changes which are observed in the pelvis, like depressions, craters, grooves, pits or cavities, are gathered as the age of individuals grows and it is appearing due to pressures in pregnancy and/or parturition (Waltenberger et al., 2022, p. 2). Pelvic architecture contributes to the formation and appearance of the features. Females have a broader pelvis and subsequently smaller articular surfaces of the pelvis. Thus, a flexible pelvis is formed. This results in the need for more stability of the ligaments, which can influence the formation of features (Praxmarer et al., 2020, p. 639). The weight increase during the pregnancy period of females causes increased stress and pressure on the pelvic bone. The existence of the features in both sexes implies that more factors are responsible for the development of these features (Decrausaz, 2012). However, the parity history is unknown in our sample, and it is not clear whether the female individuals from our sample were nullipara or not.

5.4 Iliac tuberosity

The IT was unobservable in 29.5% of the overall sample. The presence of this feature was identified in 70.5% of the sample, including 69.6% males (N=16) and 71.4% females (N=15) of the overall sample, as shown in Table 16. The IT yielded results regarding both sexes. The IT was correlated with age and was increased in size, not reduced (Maass, 2012, p. 75). This suggests that the pressure on the ligaments increased with age. In a historic male sample, the formation of the interosseous groove, was negatively correlated with the IT. From this, it can be seen, that the pressure on the interosseous groove became more tense and that the pressure on the IT reduced. That could explain that the need for extra attachment is reduced (Maass, 2012, p. 77).

5.5 Extended pubic tubercle

The extended pubic tubercle was found present in 9.1% of the overall sample size. Specifically, according to the results of the prevalence of the EPT, two female and two male individuals appeared to have the feature (9.5% and 8.7% respectively). The larger number of bones came from individuals who were unobservable of the feature. Individuals who did not appear to present the EPT were 43.2% of the overall sample. Possible traces of changes at the bony pelvis from pregnancy and/ or parturition were seen and observed since 1969 (Angel, 1969). Although in most of the recent studies, pelvic features appear to both sexes, their severity and frequency were significantly higher in women than men (Praxmarer et al., 2020, p. 638). The same result has been seen in the study of Maass (2012, p. 45). This estimation was also supported from the studies of McFadden & Oxenham (2018) and Maass & Friedling (2016). It has been observed that longer pubic bones can present thicker tubercles regarding their diameter. Snodgrass & Galloway (2003) refer to the fact that females with longer pubic bones, have extended pubic tubercles, while in shorter pubic bones there was no extension.

In general, age is one of the factors which affects the presence of pelvic features. As age advances, pelvic features appear more frequently or remain unchanged

(Praxmarer et al., 2020, p. 639). Moreover, there is an association between body size and body weight with pubic tubercle diameter. Obese individuals which have increased abdominal circumference, as pregnant women due to weight gain, have similarities. During pregnancy, the increase of weight, especially in the last trimester, results in the formation of pelvic features, due to pressure involved on the ligaments and muscles of the pelvis (Praxmarer et al., 2020, p. 639).

In general, the fact that males are more muscular than females, shows that they carry heavier loads and their activities involve flexion of the trunk (Ruff, 1987; Abitbol, 1996). The fact that EPT can be seen in both sexes could be reflecting in the different body sizes and activity patterns between male and female individuals. In this study, EPT was found in both sexes, however the overall sample size was small (N=44). Mass, (2012, p. 97) found that the presence of larger EPT, suggests that it can appear in individuals with larger bodies and small pelves in size. On the other hand, females who had more developed features, had small body size but larger size of the pelves.

In Table 34 (Chapter 4) the comparison of pelvic measurements between individuals with and without an EPT is presented. Regarding minimum iliac breadth (MIB) it was found that its mean, was higher in individuals with an EPT (66.44 ± 4.95 mm) compared to those without the feature (63.57 ± 6.44 mm). This result suggests that the presence of the feature could be associated with a wider MIB. The individuals which had the EPT (N=4) had a mean MAL lower than the individuals which did not have EPT (N= 18) (50.06 ± 3.44 mm present; 50.93 ± 4.68 mm absent). Table 34 shows that MIPL, MIH and IB did not yield statistically significant results compared to the presence or absence of the EPT. However, an observation would be that individuals without EPT (N=18) had a higher mean MIH (210.88 ± 14.99 mm) compared to the individuals with the feature (209.01 ± 20.65 mm).

Nonetheless since this feature was possible to be measured in only 52.3% of the sample size, could probably limit the interpretations that could be obtained.

5.6 Interosseous groove

In this study the IG was found present in most of the sample, as in 84.1%. Its prevalence in the female sample was in 95.2% while on the male sample 73.9%. In this anatomical area, ligaments are attached. This area was observed by Houghton (1974) first and suggested that the ligaments attached to this area tend to experience the same pressure, as the one is the PAS area, during pregnancy. The feature is close to the preauricular sulcus, but it is less constant than PAS and should not be representative of parity status (Houghton, 1974; Kelley, 1979). This can be proved from the presence of features in male samples (Maass, 2012, p. 72). Females presented more severe features, and that can suggest that the extent of the pressure was larger in females than in males. When considering this feature, researchers consider the morphology of it, looking to see if the IG is expressed differently (shallow, moderate or developed). In this study a morphological observation was not made as the focus was to observe presence or absence of the feature. Since the expression of the interosseous groove was not recorded for the purpose of this study, this may constitute a limitation as the expression of the feature may be more relevant to the formation of pelvic features than solely the presence of this characteristic.

5.7 Sacral preauricular extension

SPE is a thin extension at the ventrosuperior margin of the ala of the sacrum. In this study 18.2% of sample was found to be having SPE. From that, four were male individuals and four were female. In another study, only females were affected from SPE and corresponding iliac changes and 78.6% of them had a distinct PAS (Pany-Kucera et al., 2019, p. 1019).

In comparison with males, the surface which carries weight is smaller in females at sacroiliac joint and they present a more horizontal sacrum (Vleeming et al., 2012). In males, greater stiffness is seen across the joint (Vleeming & Schuenke, 2019). During pregnancy, there is balance shift of the sacrum sliding forward and downward, in the phase of labor (Pany-Kucera et al., 2019, p. 1019). According to the same researchers, the SPE is linked to stress at the ventral sacral apex, the increase of weight and the change in posture during pregnancy and/ or parturition. The number of births and pregnancies and the space between the births, might play a role in the appearance and the interpretation of this feature. The development of SPE is linked to pressure in the ventral sacral apex, and the changes in posture from weight gain, during periods of pregnancy, are suggested to be important factors in the development of the feature (Pany-Kucera et al., 2019, p. 1020).

As shown in table 38 (Chapter 4), the comparison of pelvic measurements in individuals without an SPE is presented. The group with the feature could not be included in the analysis due to constant values. Regarding MIB, it was found that the mean value was 63.11 ± 5.36 mm in the absent group. Regarding MAL the mean is 50.42 ± 5.20 mm. MIPL has a mean 121.36 ± 12.45 mm. MIH shows 210.72± 16.78mm. IB shows a mean of 157.21 ± 10.66 mm.

5.8 Margo auricularis groove

The MAG is a new term in the scientific research of pelvic features and has been linked to 'sacral scarring' (Cox, 1989, p. 44). In this study, MAG was seen in both sexes and was not statistically significant to any other measurements of pelves or sacra.

5.9 Correlation of pelvic features with presence or absence of the pelvic measurements

In this study, the only statistically significant results were the correlation between the PAS and MIB. As shown in table 24 (Chapter 4), the results showed that pelves without a preauricular sulcus had a significantly greater minimum iliac breadth ($M = 67.60 \pm 5.77$) than pelves with a preauricular sulcus ($M = 61.50 \pm 5.88$). This difference was statistically significant ($Z = 3.005$, $p = 0.005$). The same difference was examined for all other traits and was found not statistically significant. The statistically significant result could be simply seen as when broader pelves have more possibilities to present a preauricular sulcus. In the results of this study, females had a higher occurrence rate than males. The differences between sexes are due to the different functions of the pelves. Males only have the bipedality function which reduces the pelvis size and thus males have smaller pelves (Kurki, 2007, p. 1052). The pelves of the females require the same functions, as males, but with the function of childbirth (Bruzek & Murail, 2006, p. 227).

5.10 Correlation of presence/ absence of pelvic features and sacral measurements

According to the results shown in table 39, the Anterior height of the sacrum was significantly differentiated accordingly to the presence of the interosseous groove. In our sample, individuals who did not have the feature had significantly higher anterior measurement of the sacrum (115.40± 16.22 mm) compared to individuals with the feature (112.33± 12.02 mm). This difference is statistically significant ($Z = -2.234$, $p = 0.665$).

The sacrum is an important bone which is useful to transfer the body weight from the abdomen to the lower limbs. Houghton (1974) was the first to suggest that changes on the sacral area at the attachment areas of ligaments could be seen. However, research which refers to the appearance of pelvic features on the sacrum, is less reliable (Houghton, 1974, p. 383). In the results of another study, the features on PAS and the sacrum were not related to obstetric events be- cause the absence of the features was found in nullipara females as well (Cox, 1989).

The sacrum can present anatomical sacral variations. Nastoulis et al. (2019, p. 653) categorizes these divergences into numerical, morphological and rare (unclassified) variations.

The result from this study, highlights the difference on the presence or absence of the IG compared to the AHS. Individuals who did not have the feature, were found to have higher AHS. This could form some questions regarding the morphology of the sacrum, the stature of individuals, the mechanical strain, the anatomical changes of the sacrum, sex, or even hormone secretion. Taken into consideration, that IG was absent only in males (table 18) but the number of males who did not have the IG was very small (N=4), this could be an indication of normal variation of measurements.

5.11 Limitations of research

There are some limitations to this research. Most importantly, the small sample size of this study is a limitation.

From a starting point, I chose those exact research questions because I believe answering them was feasible. After I carefully thought about the questions of this thesis, I tried to search for which materials and methods I would choose to have my results. Time wise, I believe that those choices would be more efficient to answer if more time was given. My sample consists of early young adults and middle adults. I excluded sub-adults and older adults for two main reasons.

i. Known sex of the individuals is very important for this research. For the individuals to have expressed sex marks, there must be an exact year of age than one has to surpass. Sexual dimorphism can happen after puberty (Mello-Gentil & Souza- Mello, 2022, p. 13). Thus, I excluded sub-adults for my research, knowing that some of them would not have fully expressed their sex marks.
ii. Older adults fall into the same category. That is because there has been proof that age related degenerative changes have been found in older age adults. To avoid being biased on this matter, I excluded older adults entirely from the sample. For instance, I could include these individuals in my research and could thus accidentally mix the presence of a feature with the expression of age-related changes on the pelvic bone or sacrum.

The population of the sample of this study derived from one place. Regarding the limitation of research focusing on one population, it can be said that comparative research is not able to be done with only one population. A combination of population samples would be a more comparative method. Also, the sample refers to one chronological period, which could mean that this study could not be compared with any other.

Chapter 6: Conclusions

This last chapter will answer the research questions posed in chapter 1.2 and will give the concluding statements. Subsequently proposals for future research will be stated.

6.1 Answers and conclusions to the research questions

This study examined the possible presence of pelvic features and specifically the preauricular sulcus, dorsal and ventral pubic pitting, interosseous groove, iliac tuberosity, extended pubic tubercle, sacral preauricular extension, margo auricularis groove and their relationship with the size of the pelvis and pelvic measurements.

The presence of pelvic features may be a result of a conglomeration of factors. Factors which can influence the manifestation of pelvic features can be age, body and pelvic size, sex and other factors such as environmental, genetic, hormonal, mechanical changes and parity or parturition.

The age of individuals can contribute to pelvic size and the measurements of the pelves. Females, in the reproductive period, present a change on their pelvic size to contribute to the birthing process. Parity and parturition can influence the manifestation of pelvic features. The secretion of hormones and specifically Relaxin, creates this phenomenon. Changes also appear in postmenopausal females in different degrees.

In male populations, where the body size is considered bigger, pelves are more compact, to serve locomotion and hard labour. Because of this compactness and the less flexibility of the male pelves, the ligaments attach more, to transfer the weight of the abdomen, which results in the formation of features. Both sexes presented the feature, although it was seen that people without PAS had larger MIB. This was the only statistically significant result referring to pelvic measurements. This could show that people with higher MIB and possibly more powerful ligaments, who do not strain them, do not show PAS.

6.1.1 What is the prevalence of pelvic features in the skeletal population under study?

In the population of Delft, the occurrence rates in the exact sample were high. Pelvic features were present for both sexes, and they were observed more in females. Because in our sample, the parity status of the females was unknown, we could suggest that parity and parturition is one of the factors which contributes to the formation of the features. Specifically, from the results, it was observed that females had a higher percentage of presence of PAS than males.

6.1.2 Are there differences in occurrence rates between female and male individuals?

In general, it was observed that pelvic features were present in both females and males. The bigger difference that was observed between the two sexes, was in the presence of PAS in females. The difference between the sexes is highly correlated with the functions of life. Females carry children and have to balance the weight gain which increases during pregnancy. The formation of the features in the posterior part of the pelvis is correlated with small body size. The formation of the scars in the anterior part is correlated with larger body size. Males adjust their body's weight to the needs of hard labour.

6.1.3 Is there any measurement mostly correlated with the presence of pelvic features? Can this explain anything about the causation of the features?

To answer the last question, all the results of this study were examined. The measurement which correlates the most with the presence of the features was MIB. It yielded that the pelves without the presence of PAS had larger measurements for the MIB. This difference was statistically significant. ($Z = 3.005$, $p = 0.005$) (table 24).

In general, the formation of the features is related, as stated before, with the functions in the pelvic area. The pelves of females are more flexible. This can serve as a factor which contributes to the formation of the features because of the movement and the weight gain of pregnancy due to hormonal changes.

Overall, the causation for the formation of the features could not solely be pregnancy or parturition, although females have smaller body size and larger pelves. The answer to this question could have been answered more precise, if in our sample there were nullipara females who would have small body size and larger pelves in the reproductive age period or even in the postmenopausal period.

6.2 Proposals for further research

After the conclusion of this study, the results were presented, forming new questions which researchers could continue studying.

A further study to assess the correlation between the presence or absence of pelvic features with the size of the pelvis in a younger sample size with a known parity history and known fetus weight, would be beneficial to the general research on the topic. Another idea for further research on the matter would be the study of nullipara women in relation to the formation of the features and the post-menopausal females older than 50 years old. This correlation of these two populations would give results which could be comparative with samples of male individuals. Geometric morphometric assessments of the association between the presence or absence of pelvic features and pelvic shapes would aid the overall research on pelvic features.

For the male population, the measurements of the body size and pelvis in relation to the kind of activity would be another interesting topic of research. This could be divided into two age groups, of younger and older age, and would make the results more reliable.

Abstract

Numerous studies regarding ‘Parturition scars’ continue to concern the scientific community. These characteristics have been seen as changes by the event of pregnancy and/ or parturition, on the pelvic bones. Today, a significant alteration on the name of the term has concluded, to them being referred to as ‘pelvic features’. The aim of this study is to research the correlation of the measurements of the pelvis and the sacrum with the presence or absence of the pelvic features and to test the measurement which appears to be correlating more with presence of the features along with their causation of formation. To test this correlation a sample of 44 young and middle-aged adult (21 females and 23 males) individuals

form Delft, the Netherlands is assessed for all the pelvic features. The features, preauricular sulcus, dorsal and ventral pubic pitting, iliac tuberosity, extended pubic tubercle, interosseous groove, margo auricularis groove and sacral preauricular extension, were examined in relation to their prevalence in the population of the sample as well the occurrence rates between male and female individuals. The results were statistically analyzed and showed presence of the features in both sexes, more frequently in females. Differences of the features appeared between the sexes. In this study, the only result which was statistically significant refers to the presence of PAS with MIB measurement. The measurement was significantly smaller in individuals who presented the feature that in individuals without it. According to the results the Anterior height of the sacrum was significantly differentiated according to the presence of the interosseous groove. In our sample, individuals who did not have the feature present significantly higher anterior measurement of the sacrum. In general, the presence of pelvic features may be a result of a conglomeration of factors. Factors which can influence the manifestation of pelvic features can be age, body and pelvic size, sex, environmental, genetic, hormonal, mechanical changes and parity or parturition. In male populations, where the body size is considered bigger, pelves are more compact, to serve locomotion and hard labour. Because of this compactness and less flexibility of the male pelves, the ligaments attach more, to transfer the weight of the abdomen, which results in the formation of features.

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APPENDIX

The Appendix with the Raw dataset from this thesis follows bellow. Appendix 1 shows the presence or absence of the features and the measurements of the pelves, while Appendix 2 shows the data of the sacra and the measurements of the sacral bones.

Colibris code	ID	Sex	Age	Box	Preauricular sulcus	Dorsal pubic pitting	Ventral pubic pitting	Interosseous groove	Iliac tuberosity	Extended pubic tubercle	Margo auricularis groove	Sacral preauricular extension	MIB	MAL	MIPL	MIH	IB
V0032	ID 000061	M	MA	21							0	0	72.065	UN	UN	UN	UN
V0052	ID 002069	PF	MA	38	1	1	1	1	1	0	1	0	50.345	42.8	113.31	178.92	153.61
V0108	ID 000118	M	MA	79	0	1	1	1		0	1	0	69.635	48.89	124.635	231.48	148.21
V0138	ID 000137	PM	MA	99	0	0	0	0	1	0	1	0	65.025	58.715	112.25	207.95	153.275
V0303	ID 000582	PF	EYA	212	1	0	0	1	1	0	1	0	60.74	49.46	111.96	200.025	166.26
V0327	ID 000253	PM	MA	223	0	0	0	1	1	0	1	0	68.045	51.525	118.31	213.935	149.78
V0360	ID 000303	PM	MA	237	1	0	0	1	1	0	1	0	67.125	47.975	125.12	215.4	161.66
V0009	ID 000046	PF	MA	5	0	0	0			0	0		76.5	UN	127.65	226.15	UN
V0174	ID 000164	PM	EYA	128	0	0	0	1	1	0	1	0	62	50.595	118.85	225.9	157.72
V0236	ID 000200	PM	MA	174	0			0	1		1	0	64.355	UN	UN	UN	UN
V0051	ID 000075	PM	MA	37	0	0	0	1	1	0	1	0	63.2	60.255	122.02	219.7	151.435
V0155	ID 000152	M	MA	111	0	0	0	1	1	1	1	0	66.18	53.975	124.16	227.96	158.085
V0134	ID 000133	M	MA	96	0			0			1	1	70.92	58.82	UN	UN	UN

V0043	ID 000070	PM	MA	30	0	0	0	1		0	1		69.825	50.61	124.48	215.1	UN
V0312	ID 000242	PM	MA	216	1	1	1	1	1	1	1	0	61.68	48.875	117.385	212.055	145.64
V0016	ID 000052	PF	EYA	11	1			1	1		1	0	58.315	48.925	UN	208.325	160.57
V0395	ID 002136	PF	MA	254	1	0	1	1	1	0	1	0	57.38	48.11	UN	189.32	153.57
V0119	ID000123	F	MA	65	1	0	0	1	1	0	1	0	56.6	42.405	98.19	194	156.9
V0385	ID 000319	PM	MA	249	1			1	1		1	0	81.08	89.46	UN	229.69	172
V0130	ID 000130	PM	MA	93	1			1	1				64.38	56.3	UN	UN	UN
V0137	ID 000136	M	MA	98		1	1	1	1	0	1	0	71.445	56.855	134.04	237.42	186.03
V0063	ID 000085	PM	EYA	48	1	0	1	1	1	0	1	1	53.755	50.32	111.49	206.405	155.48
V0171	ID 000162	PF	MA	125		0	1	1	1	1	1	1	73.325	51.43	134.06	UN	171.12
V0141	ID 000140	M	MA	100				1	1		1	1	68.21	54.75	UN	228.115	UN
V0177	ID 000166	M	MA	131	1	0	0	0	1	0	1	0	66.405	53.95	117.52	213.38	UN
V0035	ID 000063	PF	MA	23	1	1	1	1	1	1	1	0	64.58	45.945	122.73	187	142.3
V0351	ID 000296	PM	MA	231	1			1			1		70.595	59.025	UN	UN	UN
V0400	ID 002138	PF	MA	256	1	0	1	1			1	1	61.42	53.61	UN	216.9	UN

V0407	ID 002141	F	MA	256	1	0	1	1		0	1		65.735	54.075	126.61	UN	UN
V0287	ID 000228	PM	MA	201	1			1	1		1	1	57.08	54.29	UN	UN	157.62
V0167	ID 000160	M	MA	121	0			1			1	0	77.645	57.77	UN	UN	UN
V0247a	ID 000207	PM	MA	135	1	0	1	1	1	0	1		64.045	52.06	116.165	211.755	155.36
V0425	ID 000347	PF	MA	267	1	0	1	1			1		63.185	52.91	UN	203.61	UN
V0219	ID 000189	PF	MA	161	1	1		1			1		63.375	53.75	123.37	206.35	160.29
V0069	ID 000089	PF	MA	51	1			1	1		1	0	56.66	45.645	UN	UN	163.55
V0271	ID 000220	F	MA	189	1			1	1		1	0	62.02	48.775	UN	213.99	UN
V0250	ID 000208	PF	MA	168	1			1	1		1	1	59.37	45.79	UN	201.41	157.79
V0006	ID 000044	F	MA	3	1	1	1	1	1	0	1	0	60.72	49.065	155.55	211.67	166.94
V0172	ID 000275	PF	MA	126	1	1	1	1	1	0	1	0	59.35	48.985	121.96	197.315	160.375
V0073	ID 000090	PF	MA	52	1	1		1			1	1	60.165	43.43	UN	202.67	UN
V0315	ID 000245	PF	MA	217	1			1	1		1	0	57.62	51.165	UN	204.39	170.46
V0412	ID 000338	PF	EYA	220	0	0	0	1	1		1	0	57.825	48.935	UN	212.65	170.06
V0344	ID 000263	PF	EYA	221	1	0	0	1	1		1	0	56.81	50	UN	199.38	146.505

V0359	ID 000302	M	MA	23 6	70.41 5	UN	UN	UN	UN

Colibris code	ID.	Sex.	Age	Anterior Height Sacrum	Anterior Breadth Sacrum	TDS1.	APS1
V0032	ID 000061	M	MA	UN	UN	UN	UN
V0052	ID 002069	PF	MA	117.36	111.08	42.19	27.94
V0108	ID 000118	M	MA	UN	119.73	53.11	40.03
V0138	ID 000137	PM	MA	114.63	109.41	47.31	29.73
V0303	ID 000582	PF	EYA	115.6	115.06	54.2	32.57
V0327	ID 000253	PM	MA	106.74	109.09	48.48	31.21
V0360	ID 000303	PM	MA	99.69	114.07	51.56	30.34
V0409	ID 000335	PM	MA	105.115	119.025	47.27	33.655
V0009	ID 000046	PF	MA	UN	UN	47.32	31.76
V0174	ID 000164	PM	EYA	105.16	120.33	45.41	25.86
V0236	ID 000200	PM	MA	105.1	110.84	43.41	31.4
V0051	ID 000075	PM	MA	113.18	122.66	50.83	32.52
V0134	ID 000133	M	MA	138.56	123.31	59.12	40.84
V0043	ID 000070	PM	MA	UN	UN	UN	UN
V0312	ID 000242	PM	MA	UN	109.76	53.15	32.22
V0395	ID 002136	PF	MA	91.09	UN	41.84	29.84
V0119	ID 000123	F	MA	115.8	113.2	49.01	27.46
V0385	ID 000319	PM	MA	132.35	118.13	61.29	35.28
V0130	ID 000130	PM	MA	105.53	123.48	UN	UN
V0137	ID 000136	M	MA	UN	120.75	55.29	42.18
V0063	ID 000085	PM	EYA	122.56	115.9	50.04	31.89
V0171	ID 000162	PF	MA	124.13	122.01	44.04	29.5
V0141	ID 000140	M	MA	112.51	119	50.75	UN

V0177	ID 000166	M	MA	103.32	118.47	56.5	UN
V0035	ID 000063	PF	MA	117.99	117.44	UN	UN
V0409	ID 000335	PM	MA	105.115	119.025	47.27	33.655
V0351	ID 000296	PM	MA	UN	UN	55.69	38.67
V0400	ID 002138	PF	MA	UN	132.34	56.1	35.73
V0407	ID 002141	F	MA	UN	114.62	47.48	37.66
V0287	ID 000228	PF	MA	101.46	116.8	51.43	35.78
V0167	ID 000160	M	MA	UN	121.26	48.25	33.83
V0247a	ID 000207	PM	MA	UN	UN	UN	UN
V0425	ID 000347	PF	MA	UN	UN	UN	UN
V0219	ID 000189	PF	MA	UN	UN	UN	UN
V0069	ID 000089	PF	MA	UN	113.54	39.27	28.98
V0271	ID 000220	F	MA	101.2	UN	49.49	30.46
V0250	ID 000208	PF	MA	UN	117.67	42.4	30.80
V0006	ID 000044	F	MA	129.94	130.72	41.24	33.79
V0172	ID 000275	PF	MA	UN	118.41	41.51	25.89
V0073	ID 000090	PF	MA	UN	109.08	45.94	27.56
V0315	ID 000245	PF	MA	128.04	127.8	52.01	32.36
V0412	ID 000338	PF	EYA	UN	122.42	50.27	32.02
V0344	ID 000263	PF	EYA	94.01	107.17	47.65	30.58
V0359	ID 000302	M	MA	UN	UN	53.03	32.86