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RESEARCH ARTICLE

# Metric and morphological analysis of pelvic scars in a historical sample from Lithuania: Associations with sex, age, body size and pelvic dimensions

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## Abstract

The theory behind the formation and manifestation of pelvic scars, sometimes called 'scars of parturition', and particularly their potential use in determining parity history has been a debated issue among anthropologists for nearly 50 years. To date, the association between parity and scar formation still remains unclear. The present study tests the effects of sex, age, body size and pelvic dimensions on the morphological and metric features of dorsal pits, pubic tubercle and preauricular sulcus. A total of 296 skeletons (167 males, 129 females) from historical samples in Lithuania were examined. Beyond assessing the above traits of these pelvic scars, we determined sex, age at death and pelvis dimensions. Moreover, we reconstructed body height and body mass. A marked sexual dimorphism was recorded. Scar formation was significantly more common among females. With increasing age, scar formation increased or remain unchanged. Pelvic dimensions, body height and body mass showed a weak association with pelvic scars. Sex seems to be independently associated with scar formation. Our results suggest that although sex plays a dominant role in scar formation, caution should be exercised in interpreting scars as being due solely to parity alone. The term 'scars of parturition' should be avoided.

KEYWORDS

dorsal pubic surface, body size, Lithuania, pelvic dimensions, pelvic scars, sulcus preauricularis

## 1 | INTRODUCTION

More than 50 years ago, Angel (1969) proposed that pregnancy leaves visible alterations on the female bony pelvis. Shortly thereafter, Stewart (1970) introduced the term 'scars of parturition' because it was believed that these traits of the bony pelvis might be used to assess the history of childbirth among female individuals (Angel, 1969; Stewart, 1970). Such pelvic scars occur on the pubic bone with the dorsal pubic pits and pubic tubercle on the ventral side, as well as on the ilium with the preauricular sulcus and interosseous groove. Especially the pubic bone with its imprints and extended tubercles has been of great interest as an indicator of pregnancy and childbirth (Snodgrass & Galloway, 2003).

During the subsequent 50 years, numerous studies have investigated these imprints and attempted to determine whether pregnancy is really a responsible factor for their development (Andersen, 1986; Cox & Scott, 1992; Kelley, 1979; Maass & Friedling, 2016; McArthur, Meyer, Jackson, Pitt, & Larrison, 2016). This strict association between the formation of typical traits on the bony pelvis and pregnancy as well as childbirth, however, is increasingly being discussed controversially. On the one hand, the physiological basis for the complex process of scar formation is not entirely understood. Generally, a strong association between hormonal changes during pregnancy and the separation of the pelvic joints during vaginal delivery are interpreted as the main triggers for the development of these pelvic scars (Cox & Mays, 2006; Houghton, 1975; Ullrich, 1987). On the other hand, an increasing number of studies indicate that pregnancy and vaginal childbirth are not the only factors behind such scars. Some studies showed that even men and nulliparous women can exhibit those bony imprints, suggesting that further influences must be involved. This calls for considering other factors when examining these bony imprints (Snodgrass & Galloway, 2003). Among others, age, body size, pelvic flexibility and pelvic dimensions have been postulated. This has led to an ongoing debate about the causes of pelvic scar formation and, in particular, whether it is justified to term these specific traits 'parturition scars'.

Unfortunately, only few historical skeletal samples contain information regarding parity, and the analyses of such samples have yielded conflicting results. Suchey, Wiseley, Green, and Noguchi (1979) analysed 486 skeletons of modern American females with known parity history and found a weak correlation between the number of pregnancies and the degree of pitting. Despite this association, severe pitting was found among nulliparous women as well. Those authors also reported an increase of scarring with age. Bergfelder and Herrmann (1980) examined 49 pairs of pubic bones from females with information about the number of births as well as miscarriages experienced. They found a significant association between the size of dorsal pubic pitting and the number of births but a less clear relationship between dorsal pubic pitting and pregnancy and childbirth. Moreover, pits were occasionally present in nulliparous women and, conversely, absent among multiparous women (Berfelder & Hermann 1980).

Cox and Scott (1992), who analysed female pelvis with definite information regarding their parity history from Spitalfields found a relationship between the extension of the pubic tubercle and parity status and between the degree of the extension of the tubercle and the number of offspring. Importantly, the authors noted that an extended tubercle is not conclusive evidence of pregnancy because nulliparous women and men also showed such an extension. Furthermore, no significant association was found between the dorsal pubic pits and the preauricular sulcus and parity. Consequently, Cox and Scott (1992) claimed that the theory behind the formation of the 'scars of parturition', which result from the traumata occurring during pregnancy and delivery, is unlikely to be correct.

Snodgrass and Galloway (2003) examined 148 modern female pairs of pubic bones with information about parity history, weight and age at death. They found no correlation between the extension of the pubic tubercle and the number of births but a strong relationship between the dorsal pubic pits and the number of births, particularly in younger individuals. In women over 50 years, pitting was associated with the body mass index (BMI) but not with the number of births. Thus, Snodgrass and Galloway (2003) concluded that alterations of the pubic area are probably caused by the interplay of several factors and not solely a consequence of parity. Their findings corroborated the view of Andersen (1986) and also suggested that pelvic instability might have an influence on pit development.

More recently, McArthur et al. (2016) examined 482 pelvic CT scans of females regarding their dorsal pubic surface. They found a significant relationship between the presence of dorsal pubic pitting and vaginal delivery. Furthermore, the authors demonstrated that more prominent dorsal pubic pits were related to a greater number of vaginal births. Accordingly, McArthur et al. (2016) suggest that pubic pits are indeed related to childbirth. Unfortunately, McArthur et al. (2016) examined exclusively females. Therefore, they focused on a biased sample and their results cannot be used to identify pelvic scars as exclusively female traits indicating childbirth. Based on the consideration that pelvic scars were found among females and males, but that age, body mass and pelvic dimensions might also be relevant, Maass and Friedling (2016) applied another approach: They analysed the impact of sex, age, body size and pelvic dimensions on the occurrence of pelvic scars. They reported a significant association between scaring and sex but suggested that weight-bearing and pelvic stability may be better explanations for scarring than parturition-related strain. McFadden and Oxenham (2018) tested in their recent meta-analytic study whether pelvic scars, in particular dorsal pits and preauricular groove, are potential predictors for sex and parity. Their results showed clearly that neither dorsal pits nor preauricular groove could be used as indicators of parity status. Dorsal pits showed only a weak association with sex. As a consequence, McFadden and Oxenham (2018) concluded that a causal relationship between pelvic scars and parity is more than questionable.

In the present study, we tested the following three hypotheses: (1) Pelvic scars are more frequent in females than males, but pelvic scars are not a sex specific trait. (2) Pelvic scars are associated with age, pelvic dimensions and body size in both sexes. (3) Pelvic scars are not useful as predictors of parity status. These hypotheses are tested using historical skeletal samples from Lithuania.

## 2 | MATERIAL AND METHODS

### 2.1 | Sample

Skeletal remains of 296 individuals (167 males and 129 females) from the University of Vilnius collection were examined. The majority, namely, 267 skeletal remains, belong to the collection of Alytus, which comprises the skeletal remains of 1,152 undisturbed graves excavated at the cemetery of Alytus between 1984 and 1986. The graves of this largest ever excavated cemetery in Lithuania date back to between the 14th to the 17th century (Svetikas, 2003). Additionally, the remains of 29 individuals of further Lithuanian archaeological collections (Mažeikiai, Ponkiškiai, Plinkaigalis, Mankūnai, Makrickai, Pupasodis, Obeliai, Alovė, Skovagaliai, Akalyčia, Paežeriai, Rokėnai, Norkūnai, Laičiai, Gaidžiai Molėtų, Tursučiai and Vilnius Cathedral) hosted by the Department of Anatomy, Histology, and Anthropology, University of Vilnius, were enrolled in the present analysis.

The relatively low number of individuals included in the analysis reflect the very strict selection criteria: Only skeletally mature individuals (≥20 years) with a relatively complete pelvis were included. Subadult individuals were excluded because among the majority of subadult skeletons, pelvic bones were incomplete. Furthermore, age determination is more reliable among adult skeletons. Individuals, whose sex was not possible to determine or who are indeterminant or in-between were excluded from the analysis. Skeletons showing any pathology affecting the areas of interest were excluded.

## 2.2 | Procedure of data collection

Data collection started with a pilot study at the Department of Evolutionary Anthropology at the University of Vienna in April 2018. Following the pilot study, the full data collection took place at the Department of Anatomy, Histology, and Anthropology, Faculty of Medicine, at the University of Vilnius, Lithuania, in May 2018.

## 2.3 | Sex and age at death estimation

Sex and age at death of the individuals were estimated by a combination of various standard techniques. Sex determination was carried out mainly based on the pelvic bones such as the Phenice (1969) method. The sciatic notch was classified according to Walker (2005). Furthermore, skull morphology was used for sex determination according to Walker in Buikstra and Ubelaker (1994). Age was determined using the pubic symphysis scoring system according to Suchey-Brooks symphysis scoring system (Brooks & Suchey, 1990) and the auricular surface of the ilium according to Lovejoy, Meindl, Pryzbeck, and Mensforth (1985). Additionally, the closure of cranial sutures was examined according to Lovejoy et al. (1985). Furthermore, mandibular and maxilliary attrition were analysed according to Lovejoy et al. (1985). For further analysis, rather than using the age group classification according to Buikstra and Ubelaker (1994) with its three adult age groups, we divided age at death into four categories to obtain narrower age ranges. The use of four adult age groups was designed to enhance the sensitivity in detecting possible relationships between age and pelvic scarring. The four age groups were young adults (20–30 years), middle-aged adults (30–40 years), old adults (40–50 years) and very old adults (>50 years). Sex and age group distributions are presented in Table 1.

**TABLE 1** Sex and age at death group of the sample

| | | Age group | | | | |
|---|---|---|---|---|---|---|
| | | Young adult | Middle adult | Old adult | Very old adult | Total |
| Sex | Male | 27 | 36 | 70 | 34 | 167 |
| | Female | 29 | 20 | 51 | 29 | 129 |
| Total | | 56 | 56 | 121 | 63 | 296 |

## 2.4 | Metric analysis of the pelvis and femur

In the first step, an osteometric analysis of the pelvis and the femur was carried out. In order to reduce the interobserver bias, all measurements were taken by one of the authors (E. Praxmarer) using a GPM calliper, an anthropometer and an osteometric board.

The following parameters were taken according to the methods described by Bräuer (1988): bicondylar lengths and maximum head diameter of the femur, pubic length and pubic symphysis length. In order to determine the dimensions of the whole pelvis, the pelvic girdle was rearticulated with the help of elastic bands and a 5-mm rubber insert at the pubic symphysis (see Figure 1). The insert functioned as the pubic symphysis to account for the absence of soft tissue. Several studies have confirmed an average thickness of the pubic symphysis of 5 mm (Garagiola, Tarver, Gibson, Rogers, & Wass, 1989; Schoellner, Szöke, & Siegburg, 2001; Sequeira, 1986). The following measurements of the articulated pelvic girdle were performed according to the descriptions of Dauber and Feneis (2008) and Bräuer (1988): intercristal distance, transverse diameter of the pelvic inlet, transverse diameter of the pelvic outlet, right and left anteroposterior inlet diameter, distance between ischial spines, the left and right oblique diameter, right and left anatomic conjugate, anterior upper spinal breadth and interobturatum breadth. All measurements represent important pelvic dimensions in obstetrics. In case of bilateral traits, the means of right and left dimensions were computed and used for further analyses.

## 2.5 | Analysis of the pelvic scars

To assess pelvic scars, we combined a morphological and a metric analysis. This combination provided accurate, reliable and sufficient information regarding the areas of interest. Again, all measurements and morphological classifications were taken by one person (E. Praxmarer). The morphological approach was based on observations of the areas of interest to determine the presence, absence, typology and severity of scarring. If possible, right and left side were analysed separately. Three areas were examined: the dorsal pubic surface, pubic tubercle and the sulcus preauricularis. Irrespective of age and sex, every individual was measured and observed in a uniform manner.

## 2.6 | Dorsal pubic surface

The maximum length, the length of the largest single pit and the width of the broadest pit were measured together with a classification of the dorsal pubic surface (i.e., whether it consists of single pits or a groove). An elongated cavity or fusing pits that were not separated by a ridge were considered as a groove (see Figure 1). In case of the single pubic pits, their number was noted. Finally, the pitted area was classified using the four categories according to McArthur et al. (2016): absent, faintly perceptible, present and prominent.

**FIGURE 1** Dorsal pubic surface with grooves of a 35 to 40 years old female

### 2.6.1 | Pubic tubercle

The maximum height of the pubic tubercle was measured from the base of the Ramus superior ossis pubis to the top of the pubic tubercle according to Snodgrass and Galloway (2003). Furthermore, the maximum diameter of the pubic tubercle was measured. Tubercle extensions were classified as absent, small, medium or large (Maas & Fielding 2016). The orientation of the tubercle was classified as cranial or ventral.

### 2.6.2 | Sulcus preauricularis

The maximum length and width of the preauricular sulcus were measured. The appearance of the sulcus was divided into four stages: broad-shallow, narrow-shallow, defined and complex. Furthermore, the five classification grades of Canty, Eliopoulos, and Borrini (2016) were applied:

- Grade 0: Absent preauricular sulcus;
- Grade 1: The sulcus is shallow and the floor has a consistent depth with no pits or grooves. The edges are usually undefined and the sulcus itself is faintly visible;
- Grade 2: The floor of the sulcus is slightly uneven and not completely smooth;
- Grade 3: The sulcus consists of more than one pit and its floor differs in depths. The edges of the sulcus are typically more defined;
- Grade 4: The floor of the sulcus is very inconsistent and has deep pits and grooves.

Additionally, the floor of the sulcus was overall classified either as being either pitted or smooth.

## 2.7 | Body size estimation

Body size was characterized by body height and body mass. Femoral head diameter (FH) was used to reconstruct body mass (BM) using the sex-specific formula of Ruff, Scott, and Liu (1991).

$$\text{Female BM} = (2.426\,\text{FH} - 35.1)0.90,$$

$$\text{Male BM} = (2.741\,\text{FH} - 54.9)0.90.$$

Femur length was used as an indicator of body height. Female body height was estimated according to Bach (1965) and male body height according to Breitinger (1937).

## 2.8 | Intraobserver error testing

The intraobserver error was tested using the statistical methods proposed by Bland & Altman (1986). During data collection, the second measurement was usually performed the day after the first measurement.

## 2.9 | Statistical analysis

Statistical analyses were carried out by using the SPSS for Windows Program Version 26. A Kolmogorov–Smirnov test (KS-test) was conducted to determine the distribution of the metric data. Sex differences were analysed using the Mann–Whitney *U* test. Differences between the age groups were tested using the nonparametric Kruskal–Wallis *H* test. A chi-squared and Fisher exact test were conducted to investigate the association of the scar manifestation with either sex or age of the individuals. Spearman correlations were computed to test the association patterns between the pelvic scars, pelvic measurements and body size estimates in both the female and male samples as well as in the age groups. Multiple regression analyses were performed to test the impact of sex, age, body size and pelvic dimensions on the appearance of pelvic scars. A $p$ value less than 0.05 was considered as significant.

# 3 | RESULTS

## 3.1 | Sex and age differences in femur and pelvic dimensions

Femur length as well as femur head diameters was significantly larger in males ($p < 0.001$). Most pelvic dimensions, however, were significantly larger in females. Males surpassed females significantly in the following pelvic parameters only: sacrum length ($p = 0.003$) and pubic symphysis height left and right ($p < 0.001$; Table 2).

Concerning age differences among females, no significant differences between the four age groups were recorded. Among males, in

**TABLE 2** Sex differences of femur and pelvic dimensions (in mm; Mann–Whitney *U* test)

| | Female | | | Male | | | Sign. |
|---|---|---|---|---|---|---|---|
| | *n* | *Mean* | *SD* | *n* | *Mean* | *SD* | *p* value |
| Femur length (mm) | 104 | 413.7 | 21.1 | 143 | 445.6 | 19.5 | <0.001 |
| Diameter femur head (mm) | 111 | 41.8 | 2.0 | 147 | 47.5 | 2.5 | <0.001 |
| Sacrum length (mm) | 78 | 108.6 | 10.7 | 110 | 113.5 | 11.8 | 0.003 |
| Sacrum breadth (mm) | 101 | 114.4 | 6.8 | 147 | 114.6 | 6.9 | 0.774 |
| Intercristal distance (mm) | 48 | 264.2 | 17.0 | 93 | 267.3 | 14.0 | 0.239 |
| Transverse diameter of the inlet (mm) | 54 | 132.4 | 7.6 | 101 | 126.4 | 7.7 | <0.001 |
| Transverse diameter of the outlet (mm) | 38 | 119.6 | 10.7 | 77 | 101.9 | 8.1 | <0.001 |
| Distance between the ischial spines (mm) | 7 | 109.6 | 9.3 | 22 | 88.6 | 6.7 | <0.001 |
| Oblique diameter (mm) | 55 | 128.6 | 5.9 | 101 | 122.1 | 6.1 | <0.001 |
| Anteriorposterior inlet dm (mm) | 43 | 104.6 | 9.5 | 86 | 100.7 | 6.7 | 0.030 |
| Anatomic conjugate (mm) | 38 | 113.7 | 9.2 | 82 | 111.3 | 74 | 0.245 |
| Anterior upper spinal breadth (mm) | 35 | 216.2 | 21.3 | 80 | 221.1 | 12.6 | 0.218 |
| Interobturatum breadth (mm) | 55 | 56.7 | 4.9 | 101 | 52.3 | 4.9 | <0.001 |
| Pubic length (mm) | 58 | 73.3 | 5.1 | 113 | 71.0 | 4.2 | 0.010 |
| Pubic symphysis height (mm) | 69 | 38.4 | 3.2 | 127 | 42.5 | 3.5 | <0.001 |

contrast, significant age group differences were determined for pubic symphysis height ($p$ = 0.014), pubic length ($p$ = 0.019), interobturatum breadth ($p$ = 0.043), distance between the ischial spines ($p$ = 0.030), transverse diameter of the inlet ($p$ = 0.037), intercristal distance ($p$ = 0.001), sacrum breadth ($p$ = 0.020) and the diameters of the femur ($p$ = 0.019). With increasing age, the pelvic or femur dimensions increased. Although the differences between age groups were significant, note the small number of individuals per age group. (Table 3).

## 3.2 | Sex differences in body height and body mass

Body height differed significantly ($p < 0.001$, $n$ = 271) between males ($\bar{x}$ = 167.7 cm, $SD$ = 3.3) and females ($\bar{x}$ = 160.8 cm, $SD$ = 2.7). This was also true of body mass, which differed significantly between the sexes ($p$ = 0.030, $n$ = 277). Males showed a larger body mass ($\bar{x}$ = 58.4 kg, $SD$ = 6.1) than females ($\bar{x}$ = 56.8 kg, $SD$ = 5.94).

## 3.3 | Sex differences in scarring

Although pelvic scars were recorded in both sexes, significant differences in the occurrence of dorsal pits, and in the appearance of the sulcus preauricularis, were observed between males and females. Females significantly more often showed dorsal pits and grooves ($p < 0.001$) and significantly more often present and prominent dorsal pits ($p < 0.001$). The sulcus preauricularis of females was significantly more often broad, defined and complex ($p < 0.001$). Furthermore, the floor of the sulcus preauricularis was significantly more often pitted ($p < 0.001$) and significantly more often showed grade 2 to 4 of the preauricular sulcus ($p < 0.001$; Table 4).

Concerning the metric traits of the pelvic scars, males and females differed significantly. Females surpassed males significantly in all dimensions with the exception of the maximal diameter of the pubic tubercle (Table 5).

## 3.4 | Age group differences in scarring

Among females, the morphological appearance of pelvic scars differed significantly (between the four age groups). With increasing age, the occurrence of pits and grooves increased significantly ($p$ = 0.048). Dorsal pits were significantly more often present or prominent among older females ($p$ = 0.001). Furthermore, a defined or complex preauricular sulcus was significantly more often recorded among older age groups ($p$ = 0.004), and the floor of the sulcus was significantly more often pitted among older age groups ($p$ = 0.031). Concerning the grade of the preauricular sulcus, grades 3 and 4 were more frequent among the higher age groups ($p$ = 0.009; Table 6). Among males, the occurrence of dorsal pits and their degree of manifestation decreased significantly with increasing age group. The dimensions of pubic tubercles, however, increased significantly with age (Table 6).

Age differences in metric scars dimensions are presented in Table 7. Although no significant association between age group and dimensions of scars could be proved among males, females showed a significant increase of length of preauricular sulcus with age ($p$ = 0.040).

## 3.5 | Scarring and body size

Among male skeletons, body height correlated significantly ($\underline{r}$ = 229; $p$ = 0.018, $n$ = 85) with tubercle width (diameter) only. Among females,

**TABLE 3** Age differences of femur and pelvic dimensions according to sex (Kruskall–Wallis tests)

| | Females | | | | | | | | Males | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Femur and pelvic dimensions (in mm) | Young | | Middle | | Old | | Very old | | Young | | Middle | | Old | | Very old | |
| *N* | 29 | | 20 | | 51 | | 29 | | 27 | | 36 | | 70 | | 34 | |
| | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* |
| Femur length | 414.2 | 18.9 | 411.4 | 18.4 | 412.1 | 20.9 | 418.1 | 25.9 | 438.2 | 19.9 | 446.4 | 18.2 | 445.7 | 20.7 | 448.1 | 16.8 |
| Diameter femur head | 41.2 | 2.2 | 41.8 | 1.4 | 41.9 | 2.2 | 42.3 | 2.1 | 46.0 | 2.5 | 47.5 | 2.5 | 47.6 | 2.5 | 48.1 | 2.4 |
| Sacrum length | 106.1 | 12.5 | 107.3 | 12.3 | 110.7 | 8.7 | 109.1 | 10.2 | 110.1 | 11.1 | 112.3 | 12.5 | 116.3 | 10.8 | 110.9 | 13.1 |
| Sacrum breadth | 111.0 | 8.1 | 115.4 | 6.1 | 115.5 | 6.6 | 115.5 | 5.1 | 111.2 | 6.5 | 114.2 | 5.6 | 114.8 | 7.5 | 117.1 | 6.1 |
| Intercristal distance | 253.9 | 16.1 | 263.9 | 8.2 | 267.9 | 17.7 | 271.6 | 17.3 | 261.7 | 10.8 | 260.5 | 12.4 | 267.0 | 13.1 | 267.9 | 12.6 |
| Transverse inlet diameter | 130.5 | 6.8 | 130.1 | 6.9 | 133.1 | 7.3 | 135.0 | 9.2 | 123.1 | 6.0 | 124.1 | 8.1 | 126.9 | 6.9 | 129.6 | 8.3 |
| Transverse outlet diameter | 124.9 | 12.3 | 114.5 | 8.6 | 119.1 | 8.8 | 113.8 | 11,2 | 101.6 | 5.7 | 102.6 | 9.6 | 102.0 | 8.1 | 101.4 | 8.2 |
| Ischial spines distance | 115.8 | 6.0 | 100.0 | - | 106.8 | 11.5 | 115.0 | - | 86.9 | 7.6 | 87.8 | 4.7 | 92.2 | 7.2 | 85.3 | 5.6 |
| Oblique diameter | 127.2 | 6.1 | 127.2 | 3.5 | 128.9 | 5.9 | 130.6 | 6.2 | 120.4 | 6.8 | 121.7 | 5.6 | 122.5 | 6.1 | 122.9 | 6.4 |
| Anteriorposterior inlet dm | 104.4 | 10.2 | 104.1 | 11.0 | 105.5 | 9.7 | 103.7 | 8.0 | 101.6 | 6.2 | 99.1 | 6.9 | 100.4 | 7.7 | 101.3 | 5.7 |
| Anatomic conjugate | 113.3 | 9.2 | 110.9 | 11.0 | 115.1 | 10.2 | 114.5 | 8.1 | 112.1 | 7.3 | 109.4 | 6.8 | 111.3 | 8.7 | 112.1 | 5.7 |
| Anterior upper spinal breadth | 205.6 | 30.2 | 218.6 | 10.6 | 223.5 | 13.8 | 221.1 | 11.6 | 221.2 | 15.0 | 216.8 | 12.5 | 220.9 | 12.8 | 227.9 | 8.5 |
| Interobturatum breadth | 55.4 | 5.7 | 56.0 | 4.5 | 58.3 | 4.8 | 55.6 | 4.4 | 49.3 | 3.7 | 51.3 | 5.7 | 52.9 | 4.4 | 53.8 | 5.1 |
| Pubic length | 73.5 | 4.6 | 76.4 | 3.7 | 75.6 | 4.5 | 76.9 | 4.1 | 71.1 | 4.2 | 73.2 | 4.0 | 73.9 | 4.4 | 74.5 | 3.7 |
| Pubic symphysis height | 37.5 | 4.1 | 38.9 | 3.6 | 38.6 | 2.3 | 38.5 | 3.3 | 41.1 | 2.4 | 41.8 | 3.9 | 43.0 | 3.8 | 43.6 | 3.9 |

**TABLE 4** Sex differences in the metrics of pregnancy scars (in mm; Mann–Whitney *U* test)

| | Female | | | Male | | | Sign. |
|---|---|---|---|---|---|---|---|
| | *n* | *Mean* | *SD* | *n* | *Mean* | *SD* | *p* value |
| Length of dorsal pubic pits | 29 | 5.2 | 1.3 | 33 | 4.5 | 1.4 | 0.031 |
| Width of dorsal pubic pits | 29 | 4.9 | 1.3 | 33 | 3.0 | 1.1 | <0.001 |
| Pubic tubercle height | 46 | 4.6 | 1.5 | 42 | 3.9 | 1.1 | 0.025 |
| Maximal diameter of pubic tubercle | 46 | 6.3 | 1.9 | 42 | 8.3 | 2.8 | 0.001 |
| Length of preauricular sulcus | 121 | 24.8 | 6.6 | 126 | 17.1 | 6.2 | <0.001 |
| Width of preauricular sulcus | 121 | 6.9 | 2.6 | 126 | 4.2 | 1.6 | <0.001 |

**TABLE 5** Sex differences in the appearance of scaring (chi-square)

| | Female | | Male | | Sign. |
|---|---|---|---|---|---|
| | *n* | % | *n* | % | *p* value |
| **Occurrence of dorsal pits** | | | | | |
| Absent | 19 | 19.0 | 109 | 75.7 | <0.001 |
| One single pit | 10 | 10.0 | 25 | 17.4 | |
| Two and more pits | 19 | 19.0 | 8 | 5.6 | |
| Groove | 52 | 52.0 | 2 | 1.3 | |
| **Manifestation of the dorsal pits** | | | | | |
| Absent | 19 | 19.0 | 109 | 75.7 | |
| Fairly perceptible | 16 | 16.2 | 29 | 20.1 | <0.001 |
| Present | 37 | 37.4 | 6 | 4.2 | |
| Prominent | 27 | 27.4 | 0 | 0.0 | |
| **Pubic tubercle appearance** | | | | | |
| Absent | 8 | 14.9 | 42 | 50.0 | 0.035 |
| Small | 6 | 11.1 | 18 | 21.4 | |
| Medium | 34 | 62.9 | 18 | 21.4 | |
| Large | 6 | 11.1 | 6 | 7.2 | |
| **Preauricular sulcus** | | | | | |
| Absent | 4 | 3.2 | 35 | 21.7 | <0.001 |
| Broad-shallow | 31 | 24.8 | 25 | 15.5 | |
| Narrow shallow | 24 | 19.2 | 101 | 62.8 | |
| Defined | 41 | 32.8 | 0 | 0.0 | |
| Complex | 25 | 20 | 0 | 0.0 | |
| **Floor of the preauricular sulcus** | | | | | |
| Pitted | 94 | 77.7 | 19 | 15.1 | <0.001 |
| Smooth | 27 | 22.3 | 107 | 84.9 | |
| **Grade of preauricular sulcus** | | | | | |
| Absent | 4 | 3.2 | 35 | 21.7 | |
| Grade 1 | 19 | 15.2 | 104 | 64.6 | <0.001 |
| Grade 2 | 29 | 23.2 | 22 | 13.7 | |
| Grade 3 | 44 | 35.2 | 0 | 0.0 | |
| Grade 4 | 29 | 23.2 | 0 | 0.0 | |

body height correlated significantly negatively with pit length ($r$ = −0.27; $p$ = 0.032; $n$ = 48). Body mass and the pelvic scars were not significantly associated within the male sample. In the female sample, significant but weak negative associations were recorded between body mass and tubercle height ($r$ = −0.32, $p$ = 0.012, $n$ = 50), sulcus preauricularis length ($r$ = −0.29, $p$ = 0.001, $n$ = 115) and sulcus preauricularis width ($r$ = −0.27, $p$ = 0.002, $n$ = 110).

### 3.6 | Scarring and pelvic dimensions

Among females, a significantly positive relationship was recorded between tubercle height and anterior upper spinal breadth ($r$ = 0.49, $p$ = 0.024, $n$ = 21) and between tubercle diameter and pubic length ($r$ = 0.31, $p$ = 0.032, $n$ = 49). Sulcus width correlated negatively with pubic length ($r$ = −0.24, $p$ = 0.026, $n$ = 84).

Among males, tubercle height correlated significantly positively with pubic length ($r$ = 0.21, $p$ = 0.028, $n$ = 90) and *distantia intercristalis* ($r$ = 0.28; $p$ = 0.013; $n$ = 63). Tubercle width correlated significantly with pubic length ($r$ = 0.26, $p$ = 0.005, $n$ = 96) and anterior-posterior diameter of the inlet ($r$ = 0.25, $p$ = 0.027, $n$ = 62).

### 3.7 | Multiple regression analyses

In the last step, multiple regression analyses were performed to test the independent associations between pelvic scars and sex, age group, body size and selected pelvic dimensions. Sex was significantly associated with morphological and metric parameters of dorsal pubic pits and with morphological and metric traits of the preauricular sulcus (Table 8). Pubic pit breadth and the manifestation of dorsal pubic pits were significantly positively associated with pubic length. Tubercle height and width showed no significant association with sex, age, body size or pelvic dimensions.

## 4 | DISCUSSION

The existence of the so-called scars of parturition has been critically discussed for nearly 50 years (Holt, 1978; Stewart, 1970; Suchey et al., 1979). Initially interpreted as visible signs of pregnancy and vaginal deliveries on the female pelvic bones (Angel, 1969), dorsal pits, pubic tubercles, interosseous groves and the preauricular sulcus are found not only in females with a history of vaginal deliveries but also

**TABLE 6** Age differences in the absolute and relative appearance of scaring among females and males (*n*, %)

| | Females | | | | Males | | | |
|---|---|---|---|---|---|---|---|---|
| Parturition scars | Young | Middle | Old | Very old | Young | Middle | Old | Very old |
| Occurrence of dorsal pits | | | | | | | | |
| Absent | (8) 4.8% | (2) 15.4% | (9) 23.7% | (0) 0.0% | (16) 61.5% | (19) 63.2% | (46) 80.7% | (25) 88.2% |
| One single pit | (5) 21.7% | (2) 15.4% | (1) 2.6% | (1) 4.0% | (7) 26.9% | (92) 30.0% | (9) 15.8% | (0) 0.0% |
| Two and more pits | (4) 17.4% | (3) 23.0% | (6) 15.8% | (6) 24.0% | (3) 11.6% | (1) 3.3% | (2) 3.5% | (2) 7.2% |
| Groove | (6) 26.1% | (6) 46.2% | (22) 57.9% | (18) 72.0% | (0) 0.0% | (1) 3.3% | (0) 0.0% | (1)3.6% |
| Manifestation of the dorsal pits | | | | | | | | |
| Absent | (8) 34.8% | (2) 15.4% | (9) 23.7% | (0) 0.0% | (16) 61.5% | (19) 63.3% | (46) 80.7% | (25) 89.3% |
| Fairly perceptible | (7) 30.4% | (1)7.7% | (6) 15.8% | (1) 4.2% | (4) 34.6% | (7) 23.3% | (10) 17.5% | (3) 10.7% |
| Present | (6) 26.1% | (9) 69.2% | (12) 31.6% | (10) 41.7% | (1) 3.9% | (4) 13.4% | (1) 1.8% | (0) 0.0% |
| Prominent | (2) 8.7% | (1) 7.7% | (11) 28.9% | (13) 54.1% | (0) 0.0% | (0) 0.0% | (0) 0.0% | (0)0.0% |
| Pubic tubercle category | | | | | | | | |
| Absent | (5)41.7% | (1) 20.0% | (0) 0.0% | (2) 22.2% | (11) 68.8% | (8) 47.1% | (15) 34.1% | (7) 33.3% |
| Small | (3) 25.0% | 20.0% | (1)9.1% | (0)0.0% | (2) 12.5% | (1) 5.8% | (13) 29.5% | (18)9.5% |
| Medium | (4) 33.3% | 20.0% | (9) 81.8% | (4) 44.5% | (3) 18.7% | (7) 41.2% | (15) 34.1% | (33) 38.1% |
| Large | 0.0% | 40.0% | (1) 9.1% | (3) 33.3% | (0) 0.0% | (1) 5.9% | (1) 2.3% | (4)19.1% |
| Preauricular sulcus | | | | | | | | |
| Absent | (3) 10.7% | (1) 5.3% | (0)0.0% | (0) 0.0% | (6) 25.0% | (6) 17.6% | (16) 23.5% | (5) 15.6% |
| Broad-shallow | (8) 28.6% | (6)31.6% | (9)18.4% | (8) 28.6% | (4) 16.7% | (5) 14.8% | (11) 16.2% | (5) 15.6% |
| Narrow shallow | (11) 39.3% | (4)21.1% | (6) 12.2% | (3) 10.7% | (14) 58.3% | (23) 67.6% | (41) 60.3% | (22) 68.8% |
| Defined | (4) 14.3% | (5)26.3% | (24) 49.0% | (8) 28.6% | (0) 0.0% | (0) 0.0% | (0) 0.0% | (0) 0.0% |
| Complex | (2) 7.1% | (3)15.7% | (10) 20.4% | (9) 32.1% | (0) 0.0% | (0) 0.0% | (0) 0.0% | (0) 0.0% |
| Floor of the preauricular sulcus | | | | | | | | |
| Pitted | (14) 56.0% | (14)77.8% | (42) 85.7% | (23) 82.1% | (2) 11.1% | (4) 14.3% | (9) 17.3% | (4)14.8% |
| Smooth | (11) 44.0% | (4) 22.2% | (7) 14.3% | (5) 17.9% | (16) 88.9% | (24) 85.7% | (43) 82.7% | (23) 85.2% |
| Grade of preauricular sulcus | | | | | | | | |
| Absent | (3) 10.8% | (1) 5.2% | (0) 0.0% | (0) 0.0% | (6) 25.0% | (6)17.6% | (16) 23.5% | (5) 15.6% |
| Grade 1 | (9) 32.1% | (4)21.1% | (3) 6.1% | (3) 10.7% | (15) 62.5% | (23) 67.7% | (42) 61.8% | (23) 71.9% |
| Grade 2 | (9) 32.1% | (3)15.8% | (11) 22.4% | (6) 21.4% | (3) 12.5% | (5) 14.7% | (10) 14.7% | (4) 12.5% |
| Grade 3 | (5) 17.9% | (8)42.1% | (21)42.9% | (10) 35.8% | (0) 0.0% | (0) 0.0% | (0) 0.0% | (0) 0.0% |
| Grade 4 | (2) 7.1% | (3)15.8% | (14) 28.6% | (9) 32.1% | (0) 0.0% | (0) 0.0% | (0) 0.0% | (0)0.0% |

**TABLE 7** Age differences of pregnancy scars dimensions (Kruskall–Wallis tests)

| | Females | | | | | | | | Males | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scars dimensions (in mm) | Young | | Middle | | Old | | Very old | | Young | | Middle | | Old | | Very old | |
| | x | *SD* | x | *SD* | x | *SD* | x | *SD* | x | *SD* | x | *SD* | x | *SD* | x | *SD* |
| Length of dorsal pubic pits | 5.1 | 1.8 | 6.0 | 0.9 | 5.1 | 1.7 | 5.0 | 0.7 | 4.2 | 1.3 | 4.6 | 1.8 | 4.6 | 1.3 | 4.5 | 0.1 |
| Width of dorsal pubic pits | 4.5 | 1.5 | 4.7 | 1.1 | 4.9 | 1.4 | 5.3 | 1.2 | 3.0 | 0.6 | 3.1 | 0.8 | 3.0 | 0.8 | 3.0 | 0.1 |
| Pubic tubercle height | 3.6 | 0.9 | 5.1 | 1.7 | 4.5 | 1.1 | 5.6 | 1.8 | 3.4 | 0.4 | 4.3 | 1.0 | 3.6 | 0.9 | 4.6 | 1.1 |
| Max. diameter of pubic tubercle | 6.2 | 2.1 | 5.9 | 1.5 | 6.2 | 1.8 | 6.8 | 2.8 | 8.0 | 2.3 | 8.3 | 2.5 | 7.8 | 2.2 | 9.8 | 3.8 |
| Length of preauricular sulcus | 20.9 | 4.9 | 23.6 | 5.5 | 26.6 | 6.8 | 26.0 | 7.0 | 16.3 | 5.9 | 16.9 | 5.8 | 17.8 | 6.7 | 16.2 | 6.0 |
| Width of preauricular sulcus | 5.6 | 2.5 | 6.9 | 2.6 | 7.4 | 2.6 | 7.3 | 2.5 | 4.3 | 1.3 | 4.3 | 1.8 | 4.2 | 1.5 | 4.3 | 1.7 |

**TABLE 8** Associations between scarring and sex, age, body size and pelvic dimensions (multiple regression analyses)

| Variable | $R^2$ | Coeff | Sign. | 95% CI | $R^2$ | Coeff | Sign. | 95% CI | $R^2$ | Coeff | Sign. | 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pubic pit length | | | | Pubic pit diameter | | | | Pubic pit manifestation | | | |
| Sex | 0.42 | 0.20 | 0.001 | 0.09 to 0.31 | 0.51 | 0.36 | **0.001** | 0.22 to 0.49 | 0.55 | 1.50 | **0.001** | 0.90 to 2.10 |
| Age group | | −0.02 | 0.172 | −0.06 to 0.01 | | 0.02 | 0.412 | −0.02 to 0.06 | | 0.11 | 0.246 | −0.07 to 0.28 |
| Body mass | | −0.01 | 0.264 | −0.01 to 0.01 | | −0.01 | 0.329 | −0.01 to 0.01 | | −0.01 | 0.328 | −0.04 to 0.02 |
| Body height | | −0.01 | 0.869 | −0.01 to 0.01 | | 0.01 | 0.165 | −0.01 to 0.03 | | 0.03 | 0.379 | −0.04 to 0.11 |
| *Distantia intercristalis* | | −0.02 | 0.632 | −0.03 to 0.05 | | 0.01 | 0.855 | −0.04 to 0.04 | | 0.03 | 0.717 | −0.14 to 0.20 |
| Anterior–posterior dm Inlet | | 0.09 | 0.054 | −0.08 to 0.18 | | 0.03 | 0.310 | −0.03 to 0.08 | | 0.13 | 0.301 | −0.12 to 0.37 |
| Anterior-upper spinal breadth | | −0.02 | 0.574 | −0.08 to 0.04 | | −0.03 | 0.235 | −0.07 to 0.02 | | −0.16 | 0.090 | −0.34 to 0.03 |
| Pubic length | | 0.06 | 0.505 | −0.12 to 0.24 | | 0.11 | **0.047** | 0.01 to 0.21 | | 0.49 | **0.034** | 0.04 to 0.94 |
| | Tubercle height | | | | Tubercle diameter | | | | Preauricular sulcus grade | | | |
| Sex | 0.37 | 0.08 | 0.474 | 0.14 to 0.29 | 0.25 | −0.09 | 0.703 | −0.53 to 0.36 | 0.46 | 1.65 | **0.001** | 0.97 to 2.34 |
| Age group | | 0.05 | 0.099 | −0.01 to 0.12 | | 0.09 | 0.168 | 0.04 to 0.23 | | 0.14 | 0.182 | −0.07 to 0.36 |
| Body mass | | 0.01 | 0.775 | −0.01 to 0.01 | | −`0.01 | 0.963 | −0.02 to 0.02 | | −0.02 | 0.266 | −0.05 to 0.02 |
| Body height | | 0.01 | 0.854 | −0.02 – 0.03 | | −0.01 | 0.998 | −0.06 to 0.06 | | 0.03 | 0.413 | −0.05 to 0.13 |
| *Distantia intercristalis* | | 0.01 | 0.940 | −0.06 to 0.06 | | 0.05 | 0.389 | −0.07 to 0.18 | | 0.01 | 0.917 | −0.19 to 0.21 |
| Anterior–posterior dm Inlet | | −0.03 | 0.589 | −0.12 to 0.07 | | 0.04 | 0.658 | −0.15 to 0.24 | | 0.14 | 0.288 | −0.13 to 0.43 |
| Anterior-upper spinal breadth | | −0.02 | 0.565 | −0.08 to 0.44 | | −0.04 | 0.506 | −0.17 to 0.09 | | −0.17 | 0.119 | −0.38 to 0.05 |
| Pubic length | | 0.10 | 0.181 | −0.05 to 0.25 | | 0.19 | 0.242 | −0.13 to 0.51 | | −0.25 | 0.352 | −0.77 to 0.28 |
| | Preauricular sulcus length | | | | Preauricular sulcus width | | | | Preauricular sulcus appearance | | | |
| Sex | 0.31 | 1.49 | **0.001** | 0.72 to2.26 | 0.44 | 0.32 | **0.002** | 0.13 to 0.52 | 0.45 | 1.12 | **0.005** | 0.34 to 1.89 |
| Age group | | 0.21 | 0.078 | −0.02 to 0.45 | | 0.04 | 0.229 | −0.02 to 0.09 | | 0.13 | 0.278 | −0.11 to 0.37 |
| Body mass | | −0.02 | 0.326 | −0.06 to 0.02 | | −0.01 | 0.378 | −0.01 to 0.01 | | −0.02 | 0.273 | −0.06 to 0.02 |
| Body height | | 0.07 | 0.179 | −0.03 to 0.17 | | 0.02 | 0.204 | −0.01 to 0.04 | | 0.07 | 0.165 | −0.03 to 0.16 |
| *Distantia intercristalis* | | 0.05 | 0.664 | −0.18 to 0.28 | | 0.03 | 0.337 | −0.03 to 0.09 | | −0.03 | 0.785 | −0.26 to 0.19 |
| Anterior–posterior dm Inlet | | 0.12 | 0.447 | −0.19 to 0.43 | | 0.04 | 0.310 | −0.04 to 0.12 | | 0.19 | 0.224 | −0.12 to 0.50 |
| Anterior-upper spinal breadth | | −0.17 | 0.153 | −0.41 to 0.07 | | −0.04 | 0.199 | −0.10 to 0.02 | | −0.17 | 0.154 | −0.41 to 0.07 |
| Pubic length | | −0.22 | 0.449 | −0.79 to 0.36 | | −0.03 | 0.735 | −0.18 to 0.12 | | −0.23 | 0.433 | −0.82 to 0.35 |

among nulliparous women, who never experienced pregnancy, and even among males (Maass & Friedling, 2016). According to the meta-analysis of McFadden and Oxenham (2018), neither dorsal pits nor the sulcus preauricularis are indicators of parity. On the other hand, dorsal pits are moderately associated with female sex.

Initially, the occurrence of these characteristic traits on Os pubis and Os Ilium was interpreted as the result of pregnancy-induced stress effects on the bony pelvis. From a physiological viewpoint, hormonal changes during pregnancy induce changes in the bony structure of the pelvis. There is an increased release of relaxin during pregnancy, which induces relaxation of the pelvic ligaments and pelvic joints (Borg-Stein & Dugan, 2007). Other pregnancy-related changes such as weight gain and lumbar hyperlordosis during late pregnancy lead to increased stretching of the ligaments. This results in cysts and knots of fibrocartilage and haemorrhages as well as oedema on its attachment sites as well as larger muscle insertions (Angel, 1969; Bergfelder & Herrmann, 1980; Borg-Stein & Dugan, 2007; Cox & Mays, 2006; Houghton, 1975). During the birth process, the pelvic ligaments are heavily stretched and may tear. To counteract these stresses and strains, cortical reorganization and active osteoclastic resorption occur on the attachment sites of the ligaments and lead to pits or even grooves on the bone, commonly called pelvic scars (Houghton, 1975; Ullrich, 1987). After labour, the pelvic ligaments slowly return to their normal condition within a few weeks. However, the reorganization and repair processes of the previous active bone resorption areas are slow, and it takes years for the scars to become shallower until they potentially disappear completely (Houghton, 1975).

An increasing number of researchers have come to question that pregnancy and childbirth lead to pelvic scars. According to Andersen (1986), pelvic flexibility might be responsible for the formation of the pelvic imprints. Snodgrass and Galloway (2003) suggested that body size plays another important role in pelvic scarring. Cox and Scott (1992), Spring, Lovejoy, Bender, and Duerr (1989) and Tague (1988) reported that pregnancy and parturition do not cause such scar formation. Tague (1988) suggested that oestrogen might contribute to pelvic scarring because oestrogen has a direct effect on the bone, which induces resorption processes by stimulating the production of osteoclastic enzymes (Tague, 1988). Bergfelder and Herrmann (1980) added that pelvic constitution might also play a role. McFadden and Oxenham (2018) interpreted the weak association between pelvic scars and parity as a side effect of the relationship between pelvic scars and sex.

Despite this criticism, several studies found a significant relationship between parity history and manifestations of pelvic scars. According to Stewart (1970), traumata associated with vaginal deliveries may be responsible. With increasing age, those imprints are eliminated by remodelling process (Stewart, 1970). Houghton (1975) emphasized that the preauricular sulcus represents an indicator of parity and supported Stewart's interpretation that increasing age obscures scar manifestations. Furthermore, Houghton (1975) mentioned that improved prenatal care and reduced physical activity during a pregnancy diminish pelvic scarring. Suchey et al. (1979) determined that the number of full-term pregnancies and age are the most important predictors of pitting. Finally, McArthur et al. (2016) showed that dorsal pubic pitting is related to childbirth; however, McArthur analysed female probands only and therefore a biased sample.

Clearly, pelvic scars are also found among persons who never experienced pregnancy and childbirth, such as males or nulliparous women. Nonetheless, pelvic scars are more highly prevalent among females. Furthermore, age, body size and pelvis dimensions were mentioned as being associated with pelvic scars (Maass & Friedling, 2016).

The present study tests the association patterns between dorsal pits, pubic tubercle and the sulcus preauricularis, and sex, age, body size and pelvic dimensions based on a historical sample from Lithuania. In detail, we hypothesized that pelvic scars are more frequent in females than males, but pelvic scars are not a sex-specific trait, that pelvic scars are associated with age, pelvic dimensions and body size in both sexes and that pelvic scars are not useful as predictors of parity status. One limitation of the present study is the lack of information regarding the parity history of the women involved. This limitation prevents determining the full relationship between pregnancy, childbirth and the formation and manifestation of the pelvic scars. Nonetheless, we believe that there is a high likelihood that most women got pregnant and gave birth in former times. Another uncertainty represents the age at which females became pregnant for the first time. These considerations about parturition and delivery make it difficult to definitively interpret pelvic scarring as a sign of pregnancy. Importantly, however, we were able to study sexual dimorphism of the bony imprints in detail.

We could verify the first hypothesis because we found a significant effect of sex on the formation of pelvic scaring. Although pelvic scarring was present in both sexes, the degree and frequency were significantly higher in women than in men. The morphological analysis yielded a significant sexual dimorphism in the occurrence and manifestation of dorsal pits, pubic tubercle appearance and the appearance of the preauricular sulcus. Furthermore, dorsal pubic pits and the preauricular sulcus were significantly larger among females. Nevertheless, 19% of the females in the present sample showed no dorsal pits, 3.2% no preauricular sulcus. According to Angel (1969), Houghton (1974) and Kelley (1979), females without any pelvic scars were nulliparous. Because we have no information regarding parity history in our sample, we are unable to corroborate this interpretation. Regarding pubic tubercle dimensions, males surpassed females significantly. Our findings regarding sexual dimorphism are similar to those of McFadden and Oxenham (2018) and also to those of Maas and Friedling (2016), who also found significantly more severe scaring at the dorsal pubic surface and the preauricular sulcus in females but larger pubic tubercles in males.

The fact that scarring was also present among males suggests that pregnancy and childbirth cannot be the only factors causing pelvic scars. Angel (1969) interpreted scars among males as results of trauma or diseases. As mentioned above, scars are seen as the results of mechanic strains that act on the ligaments attached to these sides.

Consequently, the same stress factors seem to affect the bony pelvis in both sexes. On the one hand, the weight-bearing function of the bony pelvis might result in the development of scars at the bony pelvis, on the other hand activities involving trunk flexion or carrying heavy loads may increase the stress on muscles and ligaments. In case of the pubic tubercle, the musculus rectus abdominis plays a central role. The larger dimensions of the pubic tubercle can be explained by the larger strain on this muscle, for example caused by a heavier work load (Ruff, 1987; Maass & Friedling, 2016).

One proposal was that pelvic architecture in general might have contributed to scar formation and manifestation. Accordingly, females have more developed scars due to their more flexible pelvic girdle. Females have a broader pelvis but at the same time smaller articular surfaces of the pelvis and thus a more flexible pelvic architecture. This flexibility requires more ligamentous stabilization, which results in increased pelvic scarring, whereas men exhibit less scarring due to their more tightly articulated pelvis architecture (Andersen, 1986; Snodgrass & Galloway, 2003). Pelvic dimensions determine how obstetrically efficient the bony pelvis is. If the pelvic scars are related to pregnancy and childbirth, one would expect that delivery in smaller pelvis is associated with greater ligamentous stress, thus leading to more severe scarring than wider pelvis.

We could also verify our second hypothesis, because pelvic scars showed significant associations with age, few pelvic dimensions and body size. In the present study, we tested the association patterns between pelvis dimensions and metric traits of the scars. The anterior upper spinal breadth and the pubic bone length were the only two pelvic dimensions that were positively associated with pelvic scarring among females. Because the anterior upper spinal breadth is part of the false pelvis and, therefore, not relevant in obstetrics, its relationship with tubercle height is probably less affected by childbirth than by biomechanics or the stability of the pelvic girdle. In the case of the pubic bone, general anatomy might help explain the relationship with the diameter of the pubic tubercle, whereby longer pubic bones accompany thicker tubercles. Snodgrass and Galloway (2003) showed that females with longer pubic bones also tend to have an extended pubic tubercle, whereas those with smaller pubic bones were associated with no extension. Among males in the present study, tubercle height correlated significantly positively with pubic length and *distantia intercristalis*, whereas tubercle width correlated significantly positively with pubic length and the anterior–posterior diameter of the inlet.

Age is a frequently discussed factor influencing the manifestation of pelvic scars. The present study revealed that, with advancing age, the incidence and manifestation of pelvic scarring either increased or remained unchanged. These findings agree with those of Suchey et al. (1979), who reported more severe dorsal pitting among older than younger individuals. At the same time, the results of the present study are in contrast to those of several other authors who proposed that pelvic scars recede over the course of time after the last child was born (Bergfelder & Herrmann, 1980; Kelley, 1979). Snodgrass and Galloway (2003) found a strong relationship between age and pitting and suggested that the hormonal change at the end of childbearing years has a direct effect on pelvis stability or leads to bone loss in the pubic joint. The present study defines old age as 40 to 50 years, very old age as exceeding 50 years. Because we lack information regarding parity in general and age at last childbirth in particular, we are not able to say that last childbirth or pregnancy dated back many years among old or very old females in our sample. It may be assumed that in a population of natural fertility, as in this historical sample from Lithuania, women gave birth up to the end of their reproductive phase (ca. 40–50 years). Therefore, the effects of age, which are based on the increasing distance to the last pregnancy, might not be observable in the present sample.

Finally, we investigated the effects of body size on the development of scarring. Body mass is considered as another potential influencing factor, but its impact has been rarely tested. The underlying idea is that the physical conditions of pregnant women and overweight individuals have certain similarities. During pregnancy, the circumference of the anterior abdomen increases particularly in the last months of pregnancy, which is also associated with an increased weight gain. As a consequence, the ligaments and muscles of the pelvis become increasingly stretched and strained, ultimately leading to the formation of the pelvic scars on the pelvis. The same principle can be applied to overweight people, who also tend to have an increased abdominal circumference, which affects the pelvic ligaments and muscles and the bony pelvis itself. One of the few studies testing this relationship was that of Snodgrass and Galloway (2003). They found a positive association between dorsal pubic pitting and individuals over 50 years with a higher BMI. A similar association was found by Holt (1978), where four women who had not given birth but were obese exhibited medium to severe scarring. In testing the association patterns between body mass as well as body height and pelvic scars here, males showed a significant positive correlation between body height and tubercle width. This might reflect allometry. Body weight however, was not significantly associated with scaring among males. Among females, body height correlated negatively with pit length, and body mass correlated significantly negatively with tubercle height and the dimensions of the preauricular sulcus.

The present study found several significant associations of pelvic scars with sex, age, body size and pelvic dimensions. The multivariate analysis showed that, nearly exclusively, sex has a significant independent effect on scar formation. Nevertheless, our third hypothesis could be verified, because we found no evidence that pelvic scars might be used as indicators of parity in skeletal samples, because pelvic scars occurred in both sexes.

## 5 | CONCLUSION

Sex has a marked effect on scar formation, although scars are found in both sexes. Scars are significantly more frequent among females, but this observation is insufficient no legitimatize interpreting scars on the bony pelvis as a clear indicator of pregnancy. Although most females in former times experienced pregnancies and childbirths, we generally lack information regarding parity history. This was also true of the present sample. Considering scar formation among males, however, we can clearly state that scars at the bony pelvis are not exclusively caused by pregnancy or childbirth. None of the imprints are an indisputable indicator of pregnancy and childbirth. Consequently, the term 'scars of parturition' should be avoided.

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